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ARTIFICIAL INTELLIGENCE IMPACTS ON ORGANIZATIONS AND WORK: A DELPHI STUDY WITH BRAZILIAN EXPERTS

IMPACTOS DA INTELIGÊNCIA ARTIFICIAL NAS ORGANIZAÇÕES E NO TRABALHO: UM ESTUDO DELPHI COM ESPECIALISTAS BRASILEIROS

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Artificial Intelligence Impacts on Organizations and Work:
A Delphi Study with Brazilian Experts

Impactos da Inteligência Artificial nas Organizações e no Trabalho:
Um Estudo Delphi com Especialistas Brasileiros

Tese apresentada ao Programa de Pós-Graduação em Administração do Departamento de Administração da Faculdade de Economia, Administração e Contabilidade da Universidade de São Paulo, como requisito parcial para a obtenção do título de Doutor em Ciências.

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“I am putting myself to the fullest possible use,
which is all I think that any conscious entity can ever hope to do”

HAL 9000

I dedicate this great achievement to my family,
always inspiring, supportive, and caring

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Abstract

We are living a new and emerging technological wave that is mainly based on Artificial Intelligence. It is being led by the great IT corporations and could potentially bring transformation and disruption in large scale to the economy, industries, businesses, organizations, and people in the years to come. Frey & Osborne (2017)'s research was an important milestone in evaluating the impact of AI and automatization in the future of employment and their key conclusion that 47% of total U.S. employment was at risk of being potentially extinguished in a decade or two had an enormous impact on the mass media. Therefore, the objective of this study is to evaluate what could be the key impacts of Artificial Intelligence on Organizations and Work. In doing so, we scrutinize the authors' research and propose an alternate ranking of occupation's susceptibility based on a different method and grounded on experts' opinions. We also evaluate Frey & Osborne (2017)'s key finding regarding to employment impact by technologies and identify key positive and negative qualitative impacts of AI on organizations and work, occupations and labor market. Taking into account the nature of this research, which is forward-looking, experimental and propositional, focused on current and future implications of Artificial Intelligence, we performed field research with experts supported by a Delphi Method, which is complemented by other techniques. Delphi is a robust and proven method commonly used in future research to assess the direction of long-range trends, with special emphasis on science and technology, and their probable effects on our society and our world. Among our key conclusions, we evaluate bottlenecks applied in to the occupation context and compare them to those identified by Frey & Osborne (2017). We also create our susceptibility ranking that takes into account an integration complexity factor, derived from Metcalfe's Law, which shows that occupations with less integration complexity, like clerks and assistant positions, are more likely of being replaced, while the ones that demand higher integration of abilities are practically not at risk. These results help in elucidating the current and future situation of this theme and allow us to suggest some possible suppositions. One of the most important is that no occupation will reach the 100% susceptibility index in twenty years, contrary to Frey & Osborne (2017)'s research, which means that few occupations can be entirely replaced with acceptable quality by machines that combine Artificial Intelligence, Robotics, and related technologies. Yet, our most relevant finding is this research is related to complexity and integration of occupations. Technologies may emulate individual abilities to a higher extent in the future, but more important than that is being able to harmonically combine these capabilities and make them work together with synergy to achieve even basic tasks of occupations. This integration challenge in association with Autor (2015)'s Polanyi's paradox corroborates the fact that no matter how advanced technology might be in a specific ability, it takes more than that for machines to successfully replace humans in an occupation, which we understand confirms the future scenario of collaboration, complementation and synergy between humans and machines, rather than the replacement and displacement.

Keywords

Artificial Intelligence, Organizations, Work, Impacts, Delphi Method.

Resumo

Vivemos uma nova e emergente onda tecnológica que é principalmente baseada em Inteligência Artificial. Ela está sendo liderada pelas grandes corporações de TI e pode trazer transformação e rupturas em grande escala para a economia, indústrias, empresas, organizações e pessoas nos próximos anos. A pesquisa de Frey & Osborne (2017) foi um marco importante na avaliação do impacto da IA e da automatização no futuro do emprego e sua conclusão fundamental de que 47% do emprego dos EUA está em risco de ser potencialmente extinto em uma década ou duas, teve um enorme impacto nos meios de comunicação de massa. Assim, o objetivo deste estudo é avaliar quais podem ser os principais impactos da Inteligência Artificial sobre as organizações e o trabalho. Ao fazer isso, examinamos a pesquisa dos autores e propomos um ranking alternativo da suscetibilidade das ocupações com base em um método distinto e fundamentado em opiniões de especialistas. Também avaliamos as principais conclusões de Frey & Osborne (2017) em relação ao impacto no emprego pelas tecnologias e identificamos os principais impactos qualitativos positivos e negativos da IA em organizações e trabalho, ocupações e mercado de trabalho. Levando em conta a natureza desta pesquisa, prospectiva, experimental e proposicional, focada nas implicações atuais e futuras da Inteligência Artificial, realizamos uma pesquisa de campo com especialistas apoiados pelo método Delphi, que é complementado por outras técnicas. O Delphi é um método robusto e comprovado, comumente usado em pesquisas com orientação futura para avaliar a direção de tendências de longo prazo, com especial ênfase em ciência e tecnologia, e seus prováveis efeitos em nossa sociedade e em nosso mundo. Entre nossas principais conclusões, avaliamos os gargalos aplicados no contexto das ocupação e comparamos com aqueles identificados por Frey & Osborne (2017). Também elaboramos nosso próprio ranking que leva em conta um fator de complexidade de integração, derivado da Lei de Metcalfe, que mostra que ocupações com menor complexidade de integração, como assistentes, têm maior probabilidade de serem substituídas, enquanto as que exigem maior integração entre habilidades estão praticamente fora de risco. Estes resultados ajudam a elucidar a situação atual e futura deste tema e nos permitem sugerir algumas possíveis suposições. Uma das mais importantes é que poucas ocupações atingirão o índice de suscetibilidade de 100% em vinte anos, contrariamente à pesquisa de Frey & Osborne (2017), o que significa que nem uma única ocupação pode ser totalmente substituída com um nível de qualidade aceitável por máquinas que combinem Inteligência Artificial, Robótica e outras tecnologias. No entanto, nosso achado mais relevante nesta pesquisa está relacionado à complexidade e integração de habilidades para ocupações. As tecnologias podem emular habilidades individuais em maior escala no futuro, mas mais importante do que isso, é poder combinar harmonicamente essas capacidades e fazê-las trabalhar em sinergia para alcançar tarefas básicas de ocupações. Este desafio de integração associado ao Paradoxo de Polanyi de Autor (2015) corrobora o fato de que não importa quão avançada seja a tecnologia em uma habilidade específica, é preciso mais do que isso para que máquinas substituíam com sucesso humanos em uma ocupação, o que entendemos que confirma o cenário futuro de colaboração, complementação e sinergia entre humanos e máquinas, ao invés de substituição e deslocamento.

Palavras Chave

Inteligência Artificial, Organizações, Trabalho, Impactos, Método Delphi

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1. Introduction

In this first chapter, we introduce our study by explaining the background of the research and its context, the research question, and its key objectives, as well as the methodological approach to achieve the expected goals. We provide the key justifications and motivations for the study, clarifying its relevance to several levels and different perspectives – society, economy, academy, and individual. We close this first chapter detailing the structure of this document to enable its clear comprehension.

1.1. Background

Information Technology Revolution

We learn in History books about two major industrial/technological revolutions. The first, by the end of the 18th century, "(…) allowed huge and unprecedented increases in population, social development, and standards of living" (Brynjolfsson & McAfee, 2011) with technologies such as steam engine, spinning jenny and improvements in metallurgy, basically replacing inefficient and rudimentary hand-tools by machines (Castells, 2010). The second industrial/technological revolution "(…) allowed these beneficial trends to continue and led to a sharp acceleration of productivity in the 20th century" (Brynjolfsson & McAfee, 2011) thru innovations such as electricity, internal combustion engines, chemicals and new communication technologies, such as the telegraph and the telephone (Castells, 2010).

We are living now in what is considered the third industrial/technological revolution, also known as the Information Technology Revolution, in which microelectronics, computers, and communications (networks) played the initial role of general-purpose technologies (GPTs) of this era. GPTs that, by themselves or in combination, led to a series of innovations like mainframes, personal computers, personal productivity tools, internet, mobiles, smartphones, social networks, and many others. Like its predecessors, this revolution is continuously generating new, ubiquitous and disruptive changes but in a faster pace and with higher and ever-increasing implications to societies, organizations, and people, as analyzed by Castells (2010) in his inspiring seminal work, The Rise of the Network Society.

But now, looking back over the last decade, a new stage in this revolution unfolds – or as some may say, a fourth revolution begins[1,2]. A silent and gentle but steady trend that will lead to a major turning point in our lives, sooner than most can think of. As IBM puts it, "the early days of promising new technology, and of the new era to which it is giving birth"[3]. The new wave of this computerization, automation or digitalization is based on recent developments in several areas, but particularly in "(…) advances in fields related to Machine Learning (ML), including Data Mining, Machine Vision, Computational Statistics and other sub-fields of Artificial

[1] https://www.weforum.org/events/world-economic-forum-annual-meeting-2017/sessions/the-real-impact-of-artificial-intelligence
[2] https://www.wsj.com/articles/how-artificial-intelligence-will-change-everything-1488856320
[3] https://www.ibm.com/blogs/think/2017/01/ibm-cognitive-principles/

Intelligence (AI), in which efforts are explicitly dedicated to the development of algorithms that allow cognitive tasks to be automated" (Frey & Osborne, 2017). These innovations are accelerating AI development and creating new opportunities in the market, moving it out of sci-fi movie pictures and into real-life applications, in some cases as simple as apps on our smartphones, in others, menacing to replace human beings in activities that require some level of intelligence.

Some of these complex Artificial Intelligence applications are already known and very much publicized, like Waymo[4], Google's autonomous car, that currently test drives in U.S. cities, replacing human drivers with a combination of AI elements; Enlitic's diagnosis imaging tool[5] that improves accuracy in identifying cancer in image exams, replacing human specialists by using powerful Deep Learning techniques (Standage, 2016); and Watson, IBM's cognitive platform that won the game show Jeopardy!, overpassing human competitors using a combination of several technologies and advanced algorithms[6]. Besides, there are many more examples of less known applications, including Cogito, "(….) a fusion of machine learning and behavioral science (…) to improve the emotional intelligence of customer support representatives" and therefore, the interaction between customers and phone professionals[7].

However, if AI has been around since the early days of the Third Revolution, why are these remarkable achievements only happening now? According to Brynjolfsson & McAfee (2011) because of two key concepts: Moore's Law by Moore (1965) and the Chessboard Principle by Kurzweil (2001). In general terms, both concepts are associated to computer performance and capacity improvement, which as in an exponential function, are reaching a point where machines with ever-increasing performance can accomplish previously impossible tasks in an affordable price, consuming less time and resources. In other words, a feasible change due to "(…) processing, storage, and transmission of data available on a massive scale at extremely low cost" (Loebbecke & Picot, 2015). A third concept that contributes to explain these achievements is the incremental development approach, when new technology leverages the positive aspects of its predecessor (even from other fields) and accelerates its applications, such as the positive experiences and feedbacks of Kinect, a videogame that was a breakthrough in the Machine Vision field (Brynjolfsson & McAfee, 2011).

There is no denying that a new world unfolds before our eyes with new features that demonstrate the capability of human ingenuity and resourcefulness – as Stephen Hawking explains, "success in creating AI would be the biggest event in human history"[8]. But then again, great challenges, implications, and risks come along, as several great minds of our time keep stressing. Hawking himself joined Elon Musk, Steve Wozniak, Bill Gates and hundreds of others before his passing in warning that Artificial Intelligence can potentially be more dangerous

[4] http://www.businessinsider.com/google-driverless-car-facts-2016-7/#googles-driverless-car-project-is-run-under-google-x-the-moonshot-lab-thats-part-of-googles-parent-company-alphabet-1
[5] http://money.cnn.com/2015/03/12/technology/enlitic-technology/
[6] https://www.youtube.com/watch?v=lI-M7O_bRNg
[7] https://www.forbes.com/sites/robertadams/2017/01/10/10-powerful-examples-of-artificial-intelligence-in-use-today/2/#5cbdd5d93c8b
[8] http://www.independent.co.uk/news/science/stephen-hawking-transcendence-looks-at-the-implications-of-artificial-intelligence-but-are-we-taking-9313474.html

than nuclear weapons[9]. As stated by Loebbecke & Picot (2015), Digitization, Big Data, and Artificial Intelligence "(…) are likely to open up new opportunities while also leading to new challenges – in a manner similar to those that had to be confronted in the age of industrialization" or worst.

Artificial Intelligence Concerns

One of the recurrent concerns in literature is the employment question – maybe because it is a discussion as old as the technological revolutions themselves. Early in the 19th century, the first rebellions against machines happen in the UK led by people frightened with the idea that increases in labor productivity would inevitably reduce employment because there was only a finite amount of work to do – the 'lump of labor' fallacy (Autor, 2015). A century later, in the 1930s, Keynes (1963) (and Ricardo before him) suggested that society was being afflicted with a new disease called Technological Unemployment. This meant "(…) unemployment due to our discovery of means of economizing the use of labor outrunning the pace at which we can find new uses for labor" (Keynes, 1963). Keynes' argument reflected the anxious and uncomfortable feeling of a world that was still living in the shadows of the great depression and had already faced two technological revolutions, mechanization waves that resulted in severe unemployment cycles. First one happened in the fields when changes in agriculture extinguished millions of jobs and drove crowds into cities in search of factory work. Second happened in the cities when mechanized production in intensive labor processes pushed workers out of the manufacturing sector into new service industries (Ford, 2015). A century has passed and Keynes' Technological Unemployment fear is alive again and stronger: "(…) automation anxiety has clearly returned", according to Autor (2015).

The key difference is that technology in predecessor revolutions was largely confined to the mechanization of manual, repeated, simple tasks that required some level of physical labor (Frey & Osborne, 2017). But in the new wave, Computerization "(…) can be expected to contribute to a wide range of cognitive tasks, which, until now, have largely remained a human domain" (Frey & Osborne, 2017), similar view of Loebbecke & Picot (2015), that explain that AI is driving "(…) 'machine-for-human' substitution to diffuse into domains that are highly complex". "While computerization has been historically confined to routine tasks involving explicit rule-based activities, algorithms for big data are now rapidly entering domains reliant upon pattern recognition and can readily substitute for labor in a wide range of non-routine cognitive tasks" (Frey & Osborne, 2017). According to Ford (2015), "(…) the word 'routine' may not be the best word to describe the jobs most likely to be threatened by technology. A more accurate term might be 'predictable'".

There is no consensus among authors over the extension of the implications and few studies are available with conclusive results, although several discussions are in progress, even in Davos during the World Economic Forums[10]. Some are more optimistic, believing that like in other revolutions, new opportunities of employment will be created; or arguing that this revolution it is not about substitution, but more likely about collaboration and

[9] http://observer.com/2015/08/stephen-hawking-elon-musk-and-bill-gates-warn-about-artificial-intelligence/
[10] https://www.weforum.org/events/world-economic-forum-annual-meeting-2017/sessions/the-real-impact-of-artificial-intelligence

complementation of human labor (Autor, 2015). On the other hand, others think that this wave of automation seems scarier than previous ones and with good reasons (Davenport & Kirby, 2015), with extreme unemployment (Frey & Osborne, 2017) and several other considerable impacts[11].

Nonetheless, many agree that jobs, from low to high end, will be impacted somehow during the next years (Frey & Osborne, 2017; Ford, 2015; Loebbecke & Picot, 2015), with several careers ceasing to exist and others entirely new being generated for businesses yet to mature. The menace in this employment equation though, is the mismatch in volume and speed of the concurring trends: while 47% of total U.S. employment is at risk of being potentially extinguished by automatization in a decade or two according to Frey & Osborne (2017), new hires in traditional organizations are flat and brand new companies flourishing are highly hi-tech driven, with only a handful of people taking care of million-dollars business like Waze, the traffic app. In other words, a "mismatch between rapidly advancing digital technologies and slow-changing humans" (Brynjolfsson & McAfee, 2011). Even though 2009 depression seemed to be over and U.S. GPD started to grow again, in 2011 the rate of unemployment in the country still kept the recession levels (Brynjolfsson & McAfee, 2011). In Brazil, the computerization is affecting not only the automotive industry, reducing employment and increasing production, but civil engineering, financial services (including banking) and several other industries[12], examples of what could be a worldwide trend.

This entire situation results in obvious economic consequences. This revolution has shown that the virtuous feedback loop between the economy and technology that worked many times as perfect symbiosis in the past may be severely weakened or even disrupted. This virtuous loop explained that, as machines used in production improved, the productivity of the workers likewise increased, making them more valuable and with higher wages. Those workers, in turn, went out and spent their ever-increasing incomes, further driving demand for the products and services they were producing in a win-win scenario (Ford, 2015). With massive unemployment caused by the replacement of human labor by machines, as some authors believe, all the fundaments of the modern economy could be at stake, increasing the gap in social equality and several other perverse implications (Davenport & Kirby, 2015).

Another implication that is gaining a lot of attention is the ethical discussion on the use of Artificial Intelligence. According to Bostrom & Yudkowsky (2011), when machines cross the boundaries of simple routine tasks into cognitive work with social dimensions – cognitive tasks previously performed by humans, machines must inherit the social requirements that come with them. Among these social criteria are simpler discussions on responsibility, transparency, auditability, incorruptibility, and predictability (Bostrom & Yudkowsky, 2011). In this scenario, probably the most debated example in nonacademic fields is, not surprisingly, the autonomous car. "Autonomous vehicles may put people in life-or-death situations, will the outcomes be decided by ethics or data?" asks a reporter from Scientific American[13]; "self-driving cars don't care about your moral dilemmas",

[11] http://www.futuristgerd.com/wp-content/uploads/2016/09/Technology-versus-Humanity-Gerd-Leonhard-Presentation-Futurist-London.pdf
[12] http://opiniao.estadao.com.br/noticias/geral,robotizacao-e-desemprego,70001643188
[13] https://www.scientificamerican.com/article/driverless-cars-will-face-moral-dilemmas/

answers another from The Guardian[14]. This ethical discussion, that puts philosophers and humanists against engineers and computer scientists, is important because it "(…) could have a big impact on the way self-driving cars are accepted in society"[15].

The ethics debate gets even harder and complex when one gets into the discussion of Strong AI, the claim of sentient machines (Searle, 1980), the Intelligent Explosion, the notion of auto-recursive improving machines by their feedback cycle, and the Superintelligence scenario, "humans with intelligence augmented through a brain-computer interface" (Bostrom & Yudkowsky, 2011). And similarly to other highly conflictive ethical fields, like Genetics, controls must be put into place. "The ethical dilemma of bestowing moral responsibilities on robots calls for rigorous safety and preventative measures that are fail-safe, or the threats are too significant to risk" argues Stephen Hawking[16]. Concerned with the increasing power of AI and its public perception, even profitable corporations around the world have set up an active research group to discuss the ethical use of this technology[17] and the set of principles to develop and guide it.

Both cases aforementioned – employment and ethics – are only two of the macro challenges and implications from the new wave of Artificial Intelligence from individual to organizational and societal level. There are plenty of other examples being discussed worldwide. Concerned with this scenario, we decided to investigate this topic further.

1.2. Research Question and Key Objectives

Detailing the Research Context

The recent revival of Artificial Intelligence led by the big IT corporations[18] could potentially bring transformation and disruption in large scale to the economy, industries, businesses, organizations, and people in the following years to come. But to what extent and intensity, is still to be defined. Nonetheless, it will most likely profoundly affect business models (either destroying or creating new ones); change current processes and enhance productivity in organizations; challenge companies core competitive advantages and long-term strategies; alter work relations within organizations thru replacement or complementation of humans in unpredictable ways. As an example, Loebbecke & Picot (2015) believe that "(…) cross-location teams will emerge and traditional hierarchical work structures will dissolve and transform into increasingly flexible, in-house and net-worked structures across locations." Sørensen (2016) articulates the concerns of several other authors by explaining that technological developments of Artificial Intelligence, Robotics, and related technologies will result in fundamental reconfigurations of the labor market, occupations, and work.

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14 https://www.theguardian.com/technology/2016/aug/22/self-driving-cars-moral-dilemmas3
15 https://www.technologyreview.com/s/542626/why-self-driving-cars-must-be-programmed-to-kill/
16 http://observer.com/2015/08/stephen-hawking-elon-musk-and-bill-gates-warn-about-artificial-intelligence/
17 http://www.theverge.com/2017/1/27/14411810/apple-joins-partnership-for-ai
18 Ito's comment in https://www.weforum.org/events/world-economic-forum-annual-meeting-2017/sessions/the-real-impact-of-artificial-intelligence

As an illustration, Call Center Services already reflect this ongoing and rapid reconfiguration. Call Centers serve "(…) as a primary customer-facing channel for firms in many different industries" (Aksin *et al*, 2007) and encompass telemarketing, customer services, technical support and all kind of phone-based services provided to customers. It is also known for its expanded concept of Contact Centers (Bergevin *et al*, 2010). This highly-intense human labor industry employed more than 1.4 million people in Brazil in 2012[19] and 3.5 million people in the US, becoming the factory floors of the 21st century[20]. Call Center is a relatively recent business that was created and has improved over the years due to the continuous progress in Information Technology. It is already quite digitalized and very technology-driven. In fact, the relationship between Call Centers and IT has been quite fruitful for a long while, bringing to the industry operational improvements and greater productivity. But these occupations are now at risk and threatened by technology. Some companies already "(…) provide call computerization solutions that use machine learning technology and advanced speech recognition to improve upon conventional interactive voice response systems, realizing cost savings of 60 to 80 percent over an outsourced call center consisting of human labor" (Frey & Osborne, 2017). Moreover, in Frey & Osborne (2017)'s rank of occupations in risk of automatization, telemarketer occupation[21] held the number one position with the highest probability of being replaced by computers in 10-20 years.

Despite Frey & Osborne (2017)'s first great effort on evaluating the impact of AI in the future of employment, not much has been researched in an academic perspective in this theme nor sufficient depth yet. Researches in Artificial Intelligence and its implications to people and organizations are not present in Information Technology and Information Systems journals agenda – as seen in Chapter 2, though several IT gurus keep delivering bestselling books. Several reasons can be suggested to explain this situation: AI is not part of the research scope for these journals, AI researches with applied social science perspective are still lacking (or don't have enough quality), AI theory is lagging behind AI practice or simply that AI is a broad, complex, blurred, manifold concept very hard to work with. As a matter of fact, as Yudkowsky (2008) explains, "Artificial Intelligence is not settled science; it belongs to the frontier, not to the textbook".

Loebbecke & Picot (2015) made one of the first attempts to set up a research agenda on the topic in their article in 2015 in Journal of Strategic Information Systems, trying to "(…) dig deeper into the effects of digitization and big data analytics on the organizational and societal levels" – although these authors have a very particular view on AI, as embedded into Digitalization and Big Data. In their article, Loebbecke & Picot (2015) set the course to help drive responses to how will these technologies re-shape business models and transform society. Thus, it is safe to say that this current work is a modest step towards this path, a limited answer to Loebbecke & Picot (2015)'s call for action and research in trying to develop theories and improve research that allows the academic community to appropriately address this next technological wave.

[19] http://g1.globo.com/concursos-e-emprego/noticia/2012/10/telemarketing-emprega-14-milhao-no-pais-veja-como-e-o-trabalho-no-setor.html
[20] http://knowledge.wharton.upenn.edu/article/telephone-call-centers-the-factory-floors-of-the-21st-century/
[21] https://www.onetonline.org/link/summary/41-9041.00

Designing the Research Question

This thesis is set in the Business, Management, and Accounting area, more specifically in Information Technology and Information Systems fields of study, focusing primarily on Artificial Intelligence as its key subject. As an applied social sciences research, it has a human and business perspective on the matter, concerned to how it may affect individuals and organizations – hence not a technical discussion over technologies and advanced mathematics that support it, neither a philosophical debate on Singularity and such matters.

Considering the research context aforementioned, our scope for this work is set the following overarching research question:

What will be the key Impacts of Artificial Intelligence on Organizations and Work?

By Artificial Intelligence (AI) we mean the capability of machines to understand, learn, and apply knowledge and decide when dealing with complex situations in a way that they can perform things as well or even better than humans can (Nilsson, 1998). In practical terms, it refers to products and research in Machine Learning (ML), Data Mining (and Big Data), Machine Vision (MV), Computational Statistics, as well as Mobile Robotics (MR), like Frey & Osborne (2017) and other research fields in technology, Computer Sciences, Robotics and Mathematics related to AI. We understand Artificial Intelligence as the primary area of other terms such as Computerization, used by Frey & Osborne (2017) and Digitalization, used by Loebbecke & Picot (2015) to describe this process of general automation by machines. In this work, they might be used as synonyms.

By Impact we mean the direct causal effect of one element over the other, either positive, meaning something that produces good or helpful results or effects or that promotes well-being, or negative, something that produces disadvantageous, objectionable, not propitious results. In other words, the possible results that AI could produce to organizations and work, occupations and labor market as a revolutionary transformational process. We also use the term implications as a synonym for impacts, benefits for the positive impacts or drawbacks for the negative ones.

By Organizations we mean the administrative and functional business structures, represented by either public or private companies and institutions, as well as and non-governmental groups, considering it as one of the major areas of interest in the area of Business, Administration and Management. Within this Business context, Work means occupations, types of regular remunerative jobs in different fields that require a mix of knowledge, skills, and abilities, and are performed thru activities and tasks for several types that may be partially or totally executed by Artificial Intelligence, Robotics, and related technologies. Labor Market, another term used in this work is the complete set of occupations and the total positions in a particular geography.

In defining this overarching research problem, we had a critical concern in setting up a research question using the future tense. Our apprehension was related with criticisms about building research based on speculations and predictions that could not be reliable, valid or reproducible, key elements of scientific research and scientific papers. Actually, this work has some particularities and uniqueness in comparison to other works of such nature, in the sense that it offers a proactive, forward-looking, experimental and propositional approach in studying a subject that is the knowledge frontier and in current transformation. Nonetheless, as will be shared in following chapters, we believe we also respected the key "principles and procedures for the systematic pursuit of knowledge involving the recognition and formulation of a problem, the collection of data through observation and experiment, and the formulation and testing of hypotheses, which are the basis of scientific research"[22].

Defining the Research Objectives

This work is motivated by Frey & Osborne (2017)'s research on how susceptible jobs are to computerization, an interesting but worrisome prediction and Loebbecke & Picot (2015)'s challenge for further research in the field – though there is some confusion on the terms used by the German authors (Digitalization, Big Data, and Artificial Intelligence). According to Frey & Osborne (2017), "(…) 47% of total U.S. employment is in the high risk category, meaning that associated occupations are potentially automatable over some unspecified number of years, perhaps a decade or two" and Loebbecke & Picot (2015) state that "clearly, a lot is at stake and our current understanding is limited, (…) this gap calls for extensive research in IS and neighboring disciplines – ideally developing theories that will allow us to appropriately tackle the next technological wave".

Therefore, the overarching goal of this thesis is to contribute with the current body of knowledge, by critically evaluating Frey & Osborne (2017)'s prediction for several occupations and by responding to Loebbecke & Picot (2015)'s call for action for further research on the subject, in the hope that "a better understanding of the underlying mechanisms and the effects of digitization (…)" and Artificial Intelligence would allow us "(…) to systematically approach any resulting opportunities and challenges from an IS perspective". Ultimately, in trying to understand the problem, we believe it might create awareness of the subject and also help in preparing ourselves for the future. These are hard challenges that we hope to address in this work.

In order to limit the scope and make this a feasible research, besides simplifying the handling of a complex subject, we set the following primary research objectives in order to answer our overarching research question:

- Scrutinize Frey & Osborne (2017)'s research, debating methods, outcomes, and limitations, in order to confirm or refute their findings. In doing so, propose an alternate ranking of occupation's susceptibility to computerization based on a different method and based on experts' opinions.

- Evaluate Frey & Osborne (2017)'s key finding in regard to employment impact by technologies. In other words, confirm or refute the authors' key conclusion that 47% of total U.S. employment is in high risk of automation by machines over a decade or two.

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[22] https://www.merriam-webster.com/dictionary/scientific%20method

- Identify key positive and negative impacts of AI on organizations and work, occupations and labor market with the help of experts, as a complementary confirmation or denial of the findings in the other objectives, already mentioned.

- Explore occupational characteristics to understand what drives the risk of replacement by Artificial Intelligence, Robotics, and related technologies based on O*NET's Content Model, trying to identify further bottlenecks and appreciate what's left for humans in terms of abilities and occupations.

Besides those, this thesis also has secondary goals, complementary to the overarching objectives, which are:

- Elucidate terms and concepts associated with Artificial Intelligence with an IS perspective, hoping to reduce to some extent the misunderstandings over the topic.

- Discuss the current status of academic research on the Applied Social Science perspective (business to be precise) of Artificial Intelligence and its implications.

- Evaluate the current body of knowledge available on the topic, again, considering Information Systems and Business point of view.

1.3. Key Justifications and Motivations

Artificial Intelligence has always been a fascinating subject, producing mixed feelings among people, from the overconfident excitement of sentient machines that could help us in doing unimaginable deeds to the utmost fear of machine dominance and mass unemployment. But the fact is most of us have very limited and superficial knowledge on the topic, no different from other frontier sciences like Biogenetics and Astronomy. And, unfortunately, our limited knowledge is often distorted by sci-fi literature and movies, as Stanley Kubrick's masterpiece 2001: A Space Odyssey, or by technological gurus and biased pseudo researches.

In the author's personal experience, the real Artificial Intelligence was first noticed when IBM Watson won Jeopardy! back in 2011. Watson is IBM's Artificial Intelligence platform and one of the first commercial examples of a concrete application to reach the mainstream. But as the AI concept itself, Watson is a combination of several ideas and solutions put to work together in harmony: hi-tech supercomputers with enormous memory and processing, advanced communication algorithms (to convert natural language in computer language and the other way around), Big Data Analytics (to crunch and analyze huge amounts of data), Machine Learning capabilities (to learn and improve its analysis) and decision making abilities (with modifiable parameters like aggression and accuracy). Watson in Jeopardy! renewed a myriad of possible applications and discussions of Artificial Intelligence and, as IT professionals, we observed with attention and great enthusiasm big organizations such as IBM turning their strategies into the newly called Cognitive Era – a new technological wave based on Artificial Intelligence[23,24].

However, our academic interest in the subject grew stronger when Frey & Osborne (2017)'s working paper was released, alerting that half of the U.S. employment was at risk of being replaced by computers in the next decade or two. Moreover, a series of non-academic publications from gurus, futurists and bestselling authors like Brynjolfsson and McAfee, Carr, Davenport, Ford, Bostrom, Kurzweil, and so many others also expressed concerns, mostly about the employment question and the very likely replacement (therefore displacement) of human labor and its historical perspective. As Brynjolfsson & McAfee (2015) state, "the debate over what technology does to work, jobs, and wages are as old as the industrial era itself". In fact, John Keynes already proposed in the 1930s what he called the Technological Unemployment wave "(…) due to our discovery of means of economizing the use of labor outrunning the pace at which we can find new uses for labor" (Keynes, 1963). As in that period, "our technologies are racing ahead but many of our skills and organizations are lagging behind", because there is a "mismatch between rapidly advancing digital technologies and slow-changing humans" (Brynjolfsson & McAfee, 2011).

In addition to individual interests and motivations, the discussion over the impacts of AI on society and economy is another compelling reason to execute this research, in line with what Loebbecke & Picot (2015) mentioned in their work, "(…) interested in changes of established patterns caused by the digital transformation and complementary innovations in our economy and society". This is relevant research to society in the sense that it evaluates organizations, people and indirectly the employment question, no matter where one stands, on either massive unemployment or plenty of new jobs offers in markets yet to be created. Evidently, the research is also relevant to the economy for the same reason, but in this case, the consequences are already being discussed in worldwide debates, just like the one held in World Economic Forums since 2017. One of the most heated debates is the so-called universal basic income (UBI) movement (Ford, 2015) that defends an unconditional monthly installment in cash given to all citizens. Of course, there are several motives behind this claim – especially in a period when the world it is still recovering from a major crisis, but one of the strongest ones is the "powerful new technologies, like machine intelligence (…) that will make life still harder for workers in future."[25]

Additionally, from an economic perspective, there seems to be a headlong market pursuit in the Artificial Intelligence area.[26] According to the site CB Insights, "nearly 140 private companies working to advance artificial intelligence technologies have been acquired since 2011, with over 40 acquisitions taking place in 2016 alone." These AI startups acquisitions are being grabbed by key players from the IT market like Google, IBM, Yahoo, Intel, Apple and Salesforce that are looking for technologies that can complement their Artificial Intelligence portfolio and uniquely position these companies in the new technological wave.

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[23] https://www.ibm.com/blogs/think/2017/01/ibm-cognitive-principles/
[24] https://www.weforum.org/events/world-economic-forum-annual-meeting-2017/sessions/the-real-impact-of-artificial-intelligence
[25] http://www.economist.com/blogs/economist-explains/2016/06/economist-explains-4
[26] https://www.cbinsights.com/blog/top-acquirers-ai-startups-ma-timeline/

In terms of the academic relevance, Computer Science, Applied Mathematics, Electronic Engineering fields have been the most prominent areas of research in Artificial Intelligence, but mostly with a technical focus on algorithms, methods, techniques, and small-scale experiments. Although an immeasurable effort and fundamental to reach the point where we stand now, few studies achieved practical mainstream applications, probably because of the limitations from technology – except the Expert Systems explained in detail later on. However, not much has been researched in the practical applications of AI in the Business and Information Systems area, even less considering the implications. As Sørensen (2016) states, IS currently has a complex relationship with Artificial Intelligence due to a conflictive past, full of frustrated promises; as a result, not many researchers embrace the idea of looking into this wave and revise its understanding from an IS perspective. However, "it is essential to not remain on the sideline but to engage both critically and constructively in the debate of computer agency, robotics, and automation, as indeed many researchers and commentators from outside" (Sørensen, 2016).

As explored in the literature review, later on, the view shared by Sørensen (2016) is confirmed: research on Artificial Intelligence and its implications to organizations are not in IT and IS journals agenda (though several technology gurus keep delivering bestselling books). Therefore, this work is relevant to the academy in the sense that it tries to debate the research of applied artificial intelligence to business applications and impacts the current academic investigation in the matter, improving the body of knowledge and contributing and complementing other studies in the area, responding to Sørensen (2016)'s request to engage critically and constructively as well as Loebbecke & Picot (2015)'s call for action.

In addition to the relevancy criteria in several instances already mentioned, this research abides by the golden rules of a successful research problem and study scope, which, by itself, is an acceptable justification and validation for the work. It is original, in the sense that it deals with a new subject and new implications in a different way of most of the researches available – with a business focus, looking to contribute with the discussion in the academic point of view. It is also attractive, for it is about Artificial Intelligence, an interesting topic that since the origins of the computer has been in our minds as a thrilling, fascinating and sometimes threatening technology, which results particularly joyful and satisfying to the research authors. It is also a feasible project, which means its objectives can be achieved, by the literature review or by the empirical study, with controlled risks in terms of scope, time and effort. It is restricted, which means that it has clear boundaries defined, dealing with a specific subject, allowing to reach significant conclusions with the appropriate level of confidence. Finally, it is precise and concise, making it easier to understand what the overall objectives of the research are, as well as to evaluate if the results are met and the conclusions are coherent.

1.4. Methodological Approach

Taking into account the overarching question and the key objectives of this work, the key methodological approach selected for the field research was the Delphi Method. Delphi is a qualitative research method used in several studies in the Health Sciences and Social Sciences fields (Landeta, 2006), over and above the Information Systems area, with a very successful track history. Over the last century, “Delphi's ubiquity has grown, so has the method evolved, with the development of numerous variants (…)” (Rowe & Wright, 2011). Its use has increased both in breadth and depth thanks to its reliability and versatility, especially in situations like the one in discussion in this research, where the exploratory and prognostic features are particularly obvious and where the knowledge or theory seems to be incomplete (Yeoh & Koronios, 2010).

Helmer (1967) defines Delphi as a methodological solution to, as systematically as possible, obtain relevant intuitive insights with informed judgment from experts about specific topics, especially – but not limited – to situations where there may be an absence of a proper theoretical foundation. Thru elicitation and refinement, the intended outcome of Delphi is to reach a combined informed judgment from a group of individual opinions, a decision that is usually more valid than those taken from a single individual (Murry Jr & Hammons, 1995). Therefore, Delphi is “(…) above all, a rapid and relatively efficient way to ‘cream the tops of the heads’ of a group of knowledgeable people” (Dalkey, 1969). Its procedure consists of a “(…) carefully designed program of sequential individual interrogations (by questionnaires) interspersed with information and opinion feedback derived by computed consensus” (Helmer & Rescher, 1958). “Delphi may be characterized as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem” (Linstone & Turoff, 2002).

Considering the nature of this research, forward-looking, experimental and propositional, focused on current and future impacts of Artificial Intelligence, a theme in the knowledge frontier and constant transformation and evolution, we believe Delphi is the method that had more adherence to our purposes. According to Aengenheyster *et al* (2017) “Delphi Method is undisputedly a commonly used method in futures research”, an opinion that is shared by Schmidt (1997), who considers that forecasting is a major area of application of the method in many different fields. Gordon & Helmer (1964) also provide support for this decision, explaining that a major cornerstone to Delphi Method is the intent to assess “(…) the direction of long-range trends, with special emphasis on science and technology, and their probable effects on our society and our world”, which is exactly in line to our key objectives.

Apart from that, Delphi is justified “(…) when accurate information is unavailable or expensive to obtain, or evaluation models require subjective inputs to the point where they become the dominating parameters” (Linstone & Turoff, 2002), a situation that is explained in further detail in Chapter 4. Additionally, Delphi is of great importance in helping to create more insightful results than in other types of methods (Helmer & Rescher, 1958). It also provides a structured way of enabling an efficient communication process with experts, which allows dealing with complex problems. Finally, there is also a considerable adherence and compatibility between the Delphi method and the Information Systems and Information Technology fields, which we understand to be an important complementary justification for choosing this method. According to Skinner *et al* (2015), “(…) Delphi method is particularly appropriate for acquiring expert recommendations when addressing an IS research issue” (…) “due to these specialist authorities having extensive knowledge of specific areas of IS interest”.

In spite of Delphi being the key method selected for this work, it is complemented with other techniques and methods, to help us achieve our different objectives. This is a decision based on Rowe & Wright (2011)'s guidance, that Delphi can be complemented by other approaches, either quantitative or qualitative.

1.5. Structure of the Thesis

This work is divided into nine chapters. In this first chapter, we covered the introduction of the thesis, explaining the background of the research and its high-level context, the research question, and its key objectives, as well as the methodological approaches to achieve the expected goals. Finally, the key justifications and motivations, clarifying its relevance to several levels and different perspectives – society, economy, academy, and individual.

In Chapter 2 we execute scanning of back up academic literature about the subject, considering an applied social science perspective and focus on implications. We first start with the key Information System and Information Technology journals and then proceeded to expand the initial research. We limited to these IS and IT journals to evaluate in further details the lack of research in the topic.

Chapter 3 presents a literature review of the themes under discussion, with an interactive and critical view of the different authors and their perspectives. First, the key subject of this research is reviewed. A brief history of Artificial Intelligence is presented focusing mostly on its origins to help contextualize the next section which is the discussion over AI definitions. Then, we debate Strong AI and Weak AI in terms of intentionality and consciousness, two important concepts. The discussion on why Artificial Intelligence should be considered a discussion in the Information Systems follows. Chapter 3 carries on with the literature review on the implications of Information Technology and Information Systems to organizations and individuals. This is complemented with the diverse opinions of authors that deal with AI, basically in the two most recurrent opinions: replacement and dislocation or complementation and collaboration.

Chapters 4 focus is on the methodological part of this thesis. In this chapter, we cover the background, definitions and key characteristics of the Delphi Technique, as the main research method for this work. We also present the benefits and limitations of this method, as well as its applications in the scientific research context. We close this chapter by explaining the reasons that made us choose this method, contextualized to the particularities of this research.

In Chapter 5 we cover the design, planning, and execution of the research method. We begin with preliminary considerations that are required to understand the rationale behind the method design and application, considering Frey & Osborne (2017)'s findings as a major reference and starting point. The key design features are then explained in detail, as well as the execution itself before the actual research results are presented, analyzed and discussed in the following chapters. This is an important piece within the research in the sense that it should clearly explain the research procedure and set the bridge between literature, method, and application, allowing for scrutinization, validation and possible replication, key features of academic research and the scientific method.

Chapter 6 addresses the data and findings gathered during the execution of the field research focusing on the abilities survey. First, we share our initial considerations and guidance on how the results were analyzed. Later, we present the overall statistics on the combined responses and evaluate all abilities, cross-checking with justifications and comments by the participants, considering the four major abilities categories (cognitive, psychomotor, physical and sensory) and their respective abilities types and abilities.

Based on the outputs from Chapter 6, where the impacts of technology in abilities were evaluated, in Chapter 7 we focus on the occupational analysis, designing and discussing occupational susceptibility rankings, similar to that of Frey & Osborne (2017). First, we share our preliminary considerations, including the basic preparations for the calculations. Then, we present two different rankings of susceptibility, detailing how the results were achieved as we gradually improve them in seeking for what we believe is a better representation of reality and context. We also compare our findings to those of Frey & Osborne (2017) and finally, we use one of the rankings to evaluate the overall impact of Artificial Intelligence, Robotics, and related technologies in the U.S. job market.

In Chapter 0 we discuss the results of the Delphi research, which was designed to collect qualitative feedback from experts regarding impacts and bottlenecks of Artificial Intelligence and related technologies. First, we share some important considerations about the treatment of the data as mediators of the process. Then, we present in three sections the key findings in terms of implications to Organizations and Work, Occupations and Labor Market and finally the bottlenecks.

Finally, in Chapter 9, the key conclusions and final considerations are presented and discussed, tying it back to the original research question and the key objectives of this thesis. The research limitations are also evaluated in this final chapter, and these manuscripts close with a debate over the implications and contributions of this research as well as recommendations on further studies.

2. Literature Research

With the high-level idea, the basic concepts and some basic references at hand, the first step on the research was to execute a scanning of back up academic literature about the themes, considering an applied social science perspective and focus on implications. We first started with the key Information System and Information Technology journals and then proceeded to expand the initial research. As is remarked in the following sections, we noticed with some concern that, in spite of having several journals and articles on Artificial Intelligence, few discussed the implications to organizations and people, at least in the IS and IT realm.

2.1. Key IS and IT Journals

As a starting point, we first checked journals in Information Systems (IS) and Information Technology (IT) areas. The Association for Information Systems (AIS), an international academic association with an undisputed reputation in the Information Technology and Information Systems research field, thru the College of Senior Scholars suggests a basket of eight journals as the top in the field – known as the AIS Basket Journals. Its intention is "(…) to provide more consistency and meaningfulness to tenure and promotion cases"[27]. It is a "(…) list of the top IS journals and thereby influences the work of many academics and practitioners worldwide" (Bernroider *et al*, 2013) for the reason that serves as guidance and reference for new researches. Since 2011, the eight journals that comprise the basket are:

- European Journal of Information Systems (EJIS)
- Information Systems Journal (ISJ)
- Information Systems Research (ISR)
- Journal of AIS – Association for Information Systems (JAIS)
- Journal of Information Technology (JIT)
- Journal of MIS – Management Information Systems (JMIS)
- Journal of Strategic Information Systems (JSIS)
- MIS – Management Information Systems Quarterly (MISQ)

The decision to scan on these journals was two-folded. First, IS and IT journals mentioned cover a wide spectrum of technologies and a wide range of approaches or perspectives, but, most importantly, they focus on the relations and implications of IT and IS to people and organizations, a key aspect in this applied social sciences research. Second, although AI may be a subject historically more closely associated to Computer Science, if we take into account the definitions suggested for IS and IT and the reasons discussed later in Chapter 3, we can also interpret Artificial Intelligence as an Information Technology product, more precisely an Information System or at least part of it.

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[27] http://aisnet.org/?SeniorScholarBasket

Thus, we executed an evaluation of the articles published in these journals. The search period covered from January 2011 to December 2016, a six-year window and was performed back in 2017. The decision to use January 2011 as a starting point was intentional, considering that Watson's victory on Jeopardy! – a key milestone in this new wave of Artificial Intelligence – was broadcasted at the beginning of 2011, and could have triggered new researched on the field.

The total number of manuscripts found within the period was of 1,866, ignoring cover pages, indexes, call for papers, editors and writers' presentations and such. Of this total number, 235 Editorials, Commentaries, and Responses were removed from the sample since they could not be considered scientific articles, either in structure, objectives or content. Thus, the total number of texts considered was 1,631, that had several different names and formats: Contrarian Studies, Debates and Perspectives, Empirical Researches, Ethnographies, Issues and Opinions, Literature Reviews, Method Articles, Opinion Pieces, Original Articles, Research Articles, Research Commentaries, Research Essays, Research Note, Review Articles, Theory and Review Articles and Theory Development. The distribution is shown in Table 1.

Basket Journals	**Code**	**Texts**	**Articles**
European Journal of Information Systems	EJIS	255	220
Information Systems Journal	ISJ	165	129
Information Systems Research	ISR	340	321
Journal of AIS	JAIS	190	179
Journal of Information Technology	JIT	180	120
Journal of MIS	JMIS	276	237
The Journal of Strategic Information Systems	JSIS	151	117
MIS Quarterly	MISQ	309	308
Total		**1866**	**1631**

Table 1. Articles in AIS Basket between 2011 and 2016

Using a list of keywords previously collected from the basic literature as reference, we evaluated all articles within the mentioned time window. The title, keywords, and if relevant, abstracts were analyzed in the face of those preselected terms. This was done in several iterations: the initial list was complemented every time a new term relevant to the AI topic was found during the analysis and reading of new literature. Results are depicted in Table 2. An important remark is that the Journal of AIS did not have keywords available in general access pages and, therefore, keywords were taken subjectively from the title by the authors.

Artificial Intelligence Keywords	**Articles**
Artificial Intelligence	1
Machine Learning	1
Algorithm	3
Cognitive Computing	0
Cognitive Intelligence	0
Deep Learning	0
Reasoning System	1
Expert System	1
Knowledge-based System	0
Total	**7**

Table 2. Relevant Articles for Artificial Intelligence in AIS Basket

To our surprise, only 7 terms matches were found in 6 articles (one of them had two keywords). However, only 4 were really related to the Artificial Intelligence topic we were evaluating within a sample of 1,631 articles. Interestingly, Deep Learning, Cognitive Computing, and Cognitive Intelligence were not found in the database, the third a new market term introduced in the last years. Also, not much in Expert Systems, Knowledge-based Systems or Reasoning Systems. The four articles found were:

- Ubiquitous IT and Digital Vulnerabilities by Sam Ransbotham, Robert G. Fichman, Ram Gopal and Alok Gupta, in Information Systems Research, vol.27, i.4, December 2016

- A Machine Learning Approach to Improving Dynamic Decision Making by Georg Meyer, Gediminas Adomavicius, Paul E. Johnson, Mohamed Elidrisi, William A. Rush, JoAnn M. Sperl-Hillen and Patrick J. O'Connor, in Information Systems Research, vol.25, i.2, June 2014

- Supporting Creative Problem Solving with a Case-Based Reasoning System, by Niek Althuizen and Berend Wierenga, in Journal of MIS, vol.31, i.1, 2014

- Strategic opportunities (and challenges) of algorithmic decision-making: A call for action on the long-term societal effects of ‘datification’ by Sue Newell and Marco Marabelli, in The Journal of Strategic Information Systems, vol.24, i.1, March 2015

Other terms and concepts previously discussed in the definition of AI were also evaluated, as shown in Table 3. There were 164 matches and, excluding the overlaps, 147 articles (out of 1,631). Contrary to Artificial Intelligence (and its most used synonyms), several articles were found, especially on Knowledge Management, Business Intelligence, Big Data, and Neuro IS, which seem to be concepts more mature and with higher coverage in the academic IS community. Two articles intersected between the two groups because Reasoning System and Creativity Support Systems (CSS’s) were used as keywords in lthuizen and Wierengaand’s work and Machine Learning, Algorithm and Data Mining, Simulation were used in Meyer *et al*’s article.

Other Keywords	Articles
Business Intelligence	13
Business Analytics	2
Data Analytics	4
Analytics	5
Predictive Analytics	5
Prescriptive Analytics	1
Big Data (or Biga Data Analytics)	15
Analytical Modeling	14
Predictive Modeling (or Predictive Model)	4
Text Mining	13
Data Mining	6
Simulation (or Computer Simulation)	13
Knowledge Management	40
Neuro IS	17
Cognitive IS	2
Cognitive Modeling	1
Human–computer Interaction	5
Competitive Intelligence	1
Collective Intelligence	2
Creativity Support Systems (CSSs)	1
Total	**164**

Table 3. Relevant Articles for other Themes in AIS Basket

These numbers corroborate the general view that the literature available in the key AIS journals about Artificial Intelligence was especially poor in the period of 2011 and 2016, which confirmed in our opinion the importance of this study. During this six-year window, these journals had only 1 research article that clearly stated Artificial Intelligence as a keyword, and 4 if we expand the research for correlate terms and concepts. We suggest that this scenario could be explained by four major reasons, working either individually or in combination:

AI is not part of the research scope for these journals: As mentioned before, Artificial Intelligence is clearly more closely related to technical fields such as Computer Science and Engineering than Social Sciences, which could be an argument to explain the situation. None of the eight journals clearly states AI or any related keywords explicitly among their scope of work and research – more information in Appendix 1, but neither are other terms mentioned in detail. In fact, on the editorial guidelines, most journals declare very broad interests in articles on generic IT and IS, including emerging topics. AI and its implications on people and organizations are clearly relevant and associated with IT and IS and should be covered in these journals, just like other technical terms (i.e. as cloud applications). Actually, Information Systems Research (ISR) had a recent (December 2016) special section over vulnerabilities related to IT called 'Ubiquitous IT and Digital Vulnerabilities', an introductory paper that was the only one to explicitly talk about AI among its keywords. However, none of the articles delved into the subject. None of the journals also proposed discussions on the topic in recent years. Another reason that could explain why AI is not part of the research in these publications, is that they do not consider AI as IS or part of IS.

AI researches with applied social science perspective are still lacking: Artificial Intelligence is an old concept, maybe even older than Information Technology and Information Systems themselves, and it is quite an intriguing theme. In the academic world, this can be clearly demonstrated by the over 140 journals about the subject taken from Scimago's 2015 Journal Ranking (more details in the next section). Thus, one cannot say there is no research in the area. Nonetheless, due to technical limitations, AI studies are much narrowed into a land of ideas, algorithms improvements and small applications rather than concrete and larger scale outputs that could really be applied with considerable impact on the applied social sciences fields. Only recently, concrete applications with this focus have come to light, confirming that improvements in the field are quite new, as suggested by Brynjolfsson & McAfee (2011). So the argument here is that is not that AI is currently out of the agenda for these set of journals, but rather the production of non-technical research and its practical applications is still very limited since AI applications in organizations are still in its early days.

AI theory is lagging behind AI practice: Although research in Artificial Intelligence was confined into the corridors and rooms of universities and academic research labs for most time of its history, in this new wave of AI, corporations are taking a step ahead and are also investing in innovations and breakthroughs of this field with practical solutions and what promises to be the first large scale commercial products. Academia has had an important role in its improvements, including inside the organizations themselves, but just as it happened with other examples in Information Technology, real studies in AI may be lagging behind the practice. This can be considered usual in a field where new technologies are created and spread at a very fast pace. However, in the case of AI, and considering the six-year window, there could be some farsightedness, especially when we see alarming studies such as Frey & Osborne (2017). Nonetheless, one thing is certain: commercial books by several gurus and futurists have already reached the shelves of most libraries around the world, while academic journals are still discussing old fashioned outsourcing, incidentally, one of the solutions that researchers think will be deeply impacted by AI over the next decade.

AI is a broad, complex, blurred, manifold concept: Artificial Intelligence is not a flat concept with clearly defined lines. As Yudkowsky (2008) puts it "Artificial Intelligence is not settled science; it belongs to the frontier, not to the textbook." And the fact is that today AI is more of an umbrella term, comprised of several concepts, methods, and technologies, with academic and market nuances. It is closely related to Machine Learning and Deep Learning and to Algorithms and mathematical methods that support them, such as Fuzzy Systems, Neural Networks, and Bayesian networks, that open the path for more technical discussions. AI in its current state depends on several other technologies and information technologies, adding more variables to the equation. For instance, as Loebbecke & Picot (2015) explain, "technical and analytical advancements in big data analytics (…) are crucial for the development of sophisticated Artificial Intelligence, Cognitive Computing capabilities (…)". So AI could not exist without Big Data and Analytics, though none of them are AI by their own. In addition, corporations keep creating new terms and buzzwords every year – like Cognitive Computing aforementioned. Because of this multitude of understandings, research is quite fragmented and specialized, paying more attention to components rather than the whole and its implications.

The lack of results on topics that are not really technical was also faced by other authors. For instance, when studying the global catastrophic risks of Artificial Intelligence, Yudkowsky (2008) underscored that "it is not that I have neglected to cite the existing major works on this topic, but that, to the best of my ability to discern, there are no existing major works to cite (as of January 2006)". Sørensen (2016) also has an opinion on that topic. According to the author: "The IS tradition has a complex relationship to this development from a past of Artificial Intelligence (AI) super-optimism more than super-intelligence (…). In my view, underwhelmed by the reality of the hype surrounding AI and expert systems in the 1980s, IS researchers do not seem to embrace the fast-computational land grabs and translate these into a revised understanding of our field. It is essential to not remain on the sideline but to engage both critically and constructively in the debate of computer agency, robotics, and automation, as indeed many researchers and commentators from outside IS has done".

2.2. Complementary Journals

The complementary approach to the AIS basket was using Scimago Journal Rank – SJR[28], but in this case, complementing the Information Systems focus with Artificial Intelligence journals. Defining as selection criteria the category Artificial Intelligence, publication type Journals and year 2015, we found 140 matches– none from countries in Latina America. These journals encompass research in several areas, from the expected Computer Science, Mathematics and Engineering to Neuroscience, Psychology, Biochemistry, Genetics and Molecular Biology, Agricultural and Biological Sciences, Environment Science, Medicine, Social Science, Arts and Humanities, Business, Management and Accounting, Decision Science, Physics and Astronomy and Chemical Engineering.

A high-level analysis was executed based on title, area and brief description provided by the journal. Journals were marked as highly relevant considering if they had a broader and interdisciplinary view of Artificial Intelligence with its general implications; journals were not marked if they had specific views on particular topics, such use of Artificial Intelligence on language and linguistics or specific techniques in engineering and computer science. The final result was 14 journals considered as highly relevant and other 11 more as possibly relevant, that could be considered in a fine-tuning round, if necessary. Therefore, the complementary journals selected were:

- Machine Learning
- Artificial Intelligence
- Information Sciences
- Journal of the ACM
- Journal of Artificial Intelligence Research
- Knowledge-Based Systems
- AI Magazine
- Artificial Intelligence Review

[28] http://www.scimagojr.com/index.php

- Applied Artificial Intelligence
- Computational Intelligence
- Minds and Machines
- Artificial Intelligence and Law
- International Journal or Robotics and Automation
- AI and Society

Nonetheless, in a detailed evaluation, some of these proved to be still quite technical or narrow sighted in Computer Science, lacking interdisciplinarities, such as Machine Learning and Artificial Intelligence. Others were still too focused on particular problems, such as Artificial Intelligence and Law. On the other hand, in proceeding with the research, we came across some other journals that provided interesting results, which were:

- Journal of Evolution & Technology
- Communications of the ACM
- International Journal of Human-Computer Studies

This preliminary analysis helped in defining the keywords and search criteria for supporting literature, as well as the journals where to look for. However, the mission was complicated and with limited success. In our point of view, it clearly demonstrated how difficult it was to find relevant literature on the impacts of Artificial Intelligence, at least in the IS and IT field, giving us further encouragement, because it showed that this initiative was a mandatory work in an unexplored area. To build our Literature Review, which is presented in Chapter 3, we had to expand our search criteria and scavenge for articles and books on several places, journals and complement it with books where the scientific method may be disputable. We believe, as a future endeavor, a systematic review complemented by a bibliometric study could be performed to further evaluate this difficulty that we faced regarding supporting literature as well as insist in a broader research, moving out of the IS and IT fields.

3. Literature Review

In this chapter, we focus on reviewing the literature that serves as a foundation for our work. We first discuss our understanding of Artificial Intelligence by recovering its history and early development, as well as its definitions, subfields, and considerations about intentionality and conscience. It is not our intent to cover Artificial Intelligence from a technical point of view in this work. Instead, our effort is to evaluate it from an Information Technology perspective, and its relation and application to organizations. We also analyze the literature on the impacts of Artificial Intelligence, and related concepts such as Computerization as used by Frey & Osborne (2017), Digitalization as used by Loebbecke & Picot (2015) and Automatization, as used by Vermeulen *et al* (2018). Considering the limitations previously mentioned in Chapter 2, it was not our intention to run an exhaustive literature review.

3.1. Artificial Intelligence

Yudkowsky (2008) begins one of his articles declaring that "by far the greatest danger of Artificial Intelligence is that people conclude too early that they understand it". In our opinion, this statement is extremely appropriate for this particular subject. The knowledge about Artificial Intelligence for most of us is quite superficial, mostly driven by sci-fi literature and movies, which makes the topic fascinating in one hand, but very confusing and misunderstood on the other hand. The current body of knowledge in AI is usually very technical and fairly advanced in the different fields where it is studied, whether in Computer Science, Mathematics and Statistics, Engineering, Philosophy or any of the applied fields (Medicine, for instance). This is why we first discuss our understanding of AI, its history, definitions, and components.

Brief History of Artificial Intelligence

According to Russell & Norvig (1995), the bases of Artificial Intelligence are spread throughout 2,000 years of human achievements and mostly western culture, inheriting ideas and concepts from philosophy, mathematics (computation, logic and probability), psychology, engineering, linguistics and, of course, computer science, demonstrating how multifaceted and interdisciplinary the subject is. A truly interdisciplinary field in its origin, current studies and applications in different areas (Russell & Norvig, 1995). Actually, themes are so interconnected and dependent on each other for enabling it, that removing one could possibly impair the evolution of Artificial Intelligence. Thus, as Human Intelligence, AI can be considered as the result of an intricate but harmonious combination of several elements of numerous different fields of knowledge.

The discussion about intelligence is very old, and maybe the idea of artificially emulating it likewise, as Buchanan (2006) and Nilsson (1998) point out. However, the means to really start doing it were only available in the 20th century, more precisely in the 1930s and 1940s, when two essential features were enhanced or developed: Mathematical Logic and Computation (Barr & Feigenbaum, 1982). Based on those, Alan Turing, Konrad Zuse, John Atanasoff, and Clifford Berry invented almost in parallel the first versions of the modern digital electronic computer and opened up the discussion on automata, self-operating machines (Russell & Norvig, 1995). In the dawn of the computers, the first ideas related to Artificial Intelligence started to flourish and Warren McCulloch and Walter Pitts, as early as in 1943, were the first to propose a model of artificial neurons based on the human brain that would respond (and learn) to certain stimulus (Russell & Norvig, 1995). Many others followed in several different directions and Turing (1950)'s seminal paper was "(…) a major turning point in the history of AI" because it crystallized "(…) ideas about the possibility of programming an electronic computer to behave intelligently, including a description of the landmark imitation game that we know as Turing's Test" (Buchanan, 2006).

Nonetheless, the beginning of the Artificial Intelligence as a research field – the establishment of the serious area of study, really took place a few years later, in 1955, when John McCarthy (Dartmouth College), Marvin Minsky (MIT), Nathaniel Rochester (IBM) and Claude Shannon (Bell Laboratories) decided to organize the Dartmouth Summer Research Project (Moor, 2006). The event that happened in 1956, was an effort to promote cooperation among researchers on automata theory, neural nets, and the study of intelligence, but it ended up establishing Artificial Intelligence as a concept and as an interdisciplinary research discipline. Although it fell short of expectations, with limited collaboration among researches (Moor, 2006), the event was a key milestone in the history of AI because it helped to define and to design the key directions and approaches for Artificial Intelligence research for the following decades.

In this initial period, the creativity and dedication to the AI cause from several researchers associated with the enormous gap of knowledge of an entirely new field made the 1950-1960s period, a time of intense exploration, experimentation, and expansion, full of enthusiasm and great expectations and of relative great success. It resulted in several remarkable achievements and by-products, such as General Problem Solver (GPS) from Newel, Shaw, and Simon (1959), that imitated human problem-solving protocols (Nilsson, 1998); and Geometry Theorem Prover (1959), that proved theorems using explicitly represented axioms (Russell & Norvig, 1995). Additionally, in 1956, sponsored by IBM and using IBM 701, Arthur Samuel demonstrated on television his checkers-playing program that had an outstanding self-learning capability (Russell & Norvig, 1995). Buchanan (2006) explains that "Samuel's program is all the more impressive because the program learned through experience to improve its own checker-playing ability", something unimaginable at the time. Some years later, in 1962 and using IBM 7094, the program defeated a master checkers player, just like his predecessors some decades after: IBM Deep Blue defeated Garry Kasparov in a chess match in 1997 and IBM Watson did the same with the two biggest winners of Jeopardy! in 2011. Despite possible doubts over the 1962 achievement[29], this demonstration of a machine victory caused a great impression. According to Russell & Norvig (1995), a machine defeating a man in a game (as simple as it could be) brought paranoia to the technology-illiterate public of the early 1960s, that believed "mankind's intellectual superiority was being challenged by electronic monster"[30]. This event and its frenzy were surely key inspirations for Stanley Kubrick and Arthur C. Clarke to create a sci-fi masterpiece, 2001: A Space Odyssey – in which Marvin Minsky had an important role as technical advisor.

[29] http://webdocs.cs.ualberta.ca/~chinook/project/legacy.html
[30] http://www-03.ibm.com/ibm/history/ibm100/us/en/icons/ibm700series/impacts/

However, this initial optimism and enthusiasm with AI soon proved to be overconfident. The progress was, in fact, slow over the next decades (Zwicker, 2010), and unlike sci-fi literature and movies, the learning curve and success rate were very flat. During this period, AI field got a "(…) reputation for making huge promises and then failing to deliver on them" (Yudkowsky, 2008). This 'Dose of Reality' period, as Russell & Norvig (1995) call it, happened during the late 1960s and 1970s and had several motives. The key one was the complexity and the variables involved in emulating intelligence – they were far more complicated than replicating games or theorems. AI products failed "miserably when tried out on wider selections of problems and on more difficult problems", because they lacked a basic body of knowledge on the matters and they could not easily manage the new kind of problems they faced (Russell & Norvig, 1995). Actually, this is a problem that persists even today. Autor (2015) explains that "most automated systems lack flexibility – they are brittle", meaning they cannot generally operate autonomously in unpredictable environments, so in most cases, their creators have to simplify the environment in which they work to enable autonomous operation. According to Lucas & van der Gaag (1991), at that time and still today, it was very hard to replicate heuristics, rules of thumb and facts learned by experience – "the knowledge of human expert in the field has, is generally not laid down in clear definitions or unambiguous algorithms", a similar view to that of Autor (2015) and his Polanyi's Paradox argument. Besides that, there were technical limitations such as speed and memory capacity of primitive computers, a fundamental component of AI as explained. They were insufficient and restricted to simulate the abilities and functions of the human brain (McCarthy *et al*, 2006).

This rudimentary period had two consequences over the next decades until the late 1990s: the initial prospects and investment pace reduced because the benefits were not as favorable as expected by both market and academy. Due to the limitations aforementioned, solutions that involved AI became more and more localized and specific to particular scenarios or problems, and its applications turned out to be what has been known as Expert Systems. Nilsson (1998) complements this explaining that the late 1970s and early 1980s was a period of development of more capable programs that contained knowledge required to mimic expert human performance in specific tasks, including diagnosis, design, and analysis. These developments, nonetheless, can be considered as marginal improvements in different directions and subfields of Artificial Intelligence with limited applications with only a few turning into successfully marketable solutions (Russell & Norvig, 1995). Besides the technical limitations, Barr & Feigenbaum (1982) believe there was an additional issue in the education – there were no industry specialists that knew the AI principles and techniques, and there were no written materials and courses to train these experts as required.

In the 1990s, the interest was renewed. Gradually and without the expectation pressure, AI increased its maturity and dissemination, flourishing and expanding as a research field within the Computer Science, Mathematics and Engineering areas. It slowly established itself as an industry, reaching the 2 billion dollar mark by 1990s (Russell & Norvig, 1995). This gentle revolution prolonged into the 2000s in probabilistic models, decision theory, robotics, computer vision, machine learning and knowledge representation, that were supported by improvements in computers and internet (Russell & Norvig, 1995). Also, "a better understanding of the problems and their complexity properties, combined with increased mathematical sophistication, led to workable research agendas and robust methods" (Russell & Norvig, 1995), which set the foundation for the new stage in the history of Artificial Intelligence that we are living today. In this last decade, a steady trend of increasing computerization, automation, and digitalization has been unfolding, based on these recent developments in several areas, but particularly in "(…) advances in fields related to Machine Learning (ML), including Data Mining, Machine Vision, Computational Statistics and other sub-fields of Artificial Intelligence (AI), in which efforts are explicitly dedicated to the development of algorithms that allow cognitive tasks to be automated" (Frey & Osborne, 2017). Loebbecke & Picot (2015) complement this idea, explaining that technical and analytical advancements, what they call Big Data Analytics, "(…) are crucial for the development of sophisticated artificial intelligence, cognitive computing capabilities, and business intelligence".

According to Brynjolfsson & McAfee (2011), this is happening now because of two key concepts: Moore's Law by Moore (1965) and the Chessboard Principle by Kurzweil (2001). In general terms, both are associated to computer performance and capacity improvement, which as in an exponential function, are reaching a point where machines, with ever-increasing performance, can accomplish previously impossible tasks by an affordable price, consuming less time and resources. In other words, a feasible change due to "(…) processing, storage, and transmission of data available on a massive scale at extremely low cost" (Loebbecke & Picot, 2015). An additional concept that also explains these achievements according to Brynjolfsson & McAfee (2011) is the incremental development approach, which happens when new technology leverages the positive aspects of its predecessor (even from other fields) and accelerates its applications, such as the positive experiences and feedbacks of Kinect, a videogame that was a breakthrough in the Machine Vision field.

These innovations are accelerating AI development and application in the organizations, to a point that it seems we may be finally reaching Minsky (1960)'s prophecy, of a "threshold of an era that will be strongly influenced, and quite possibly dominated, by intelligent problem-solving machines".

Artificial Intelligence Definitions

Before we delve into Artificial Intelligence definitions and concepts, one must be aware of the meanings behind the words Artificial and Intelligence. Intelligence is the English word for Latin *intelligentia*, which means to understand (Oxford, 2017)[31]. According to Merriam-Webster Dictionary (2017)[32], intelligence means "the ability to learn or understand or to deal with new or trying situations" and "the ability to apply knowledge to manipulate one's environment or to think abstractly as measured by objective criteria (as tests)". Intelligence is therefore closely associated with five other words. Understanding, the capacity to "apprehend general relations of particulars" and "the power to make experience intelligible by applying concepts and categories"; comprehension, the ability of "grasping the nature, significance, or meaning of something"; reasoning, the capability of "drawing of inferences or conclusions through the use of reason, the power of comprehending, inferring, or thinking especially in orderly rational ways"; learning, the act of "gaining knowledge or

[31] https://en.oxforddictionaries.com/
[32] https://www.merriam-webster.com/

understanding of or skill in by study, instruction, or experience"; and applying, the ability of "putting to use especially for some practical purpose". Intelligence can be considered then as the power of understanding and comprehending situations thru the use of reasoning, learning and building knowledge, experience and skills and applying them to new situations. This is a simplistic, dictionary-based definition of intelligence. Nonetheless, the subject is far more complex because it has multiple perspectives and particularities in philosophy, anthropology, psychology, medicine, and many other fields, as intelligence is a uniquely human attribute but broad in use among these several fields.

The concept of artificial is more straightforward. According to Merriam-Webster Dictionary (2017), artificial means something that is "humanly contrived often on a natural model"[33] or, in other words, "made or produced by human beings rather than occurring naturally, especially as a copy of something natural"[34] (Oxford, 2017). Consequently, Artificial Intelligence can be interpreted as human-made artifacts that to some extent simulate human intelligence, from understanding, comprehending, reasoning to learning and applying. Though dictionary-based, this definition is quite close to that from John McCarthy, one of the pioneers of the AI movement, who is credited for the creation of the term back in 1955. In the authors' opinion, Artificial Intelligence is the effort (in terms of research and study) that focused on "(…) the conjecture that every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it" (McCarthy *et al*, 2006).

Unfortunately, there are several other definitions for Artificial Intelligence. As Yudkowsky (2008) explains in an ironic way, the term refers to a vastly greater space of possibilities than does the term "Homo sapiens". According to Nilsson (1998), Artificial Intelligence is concerned with intelligent behavior artifacts, which "(…) involves perception, reasoning, learning, communicating, and acting in complex environments" a similar view to Chomsky, that understands AI as "the effort to program machines to mimic or approximate certain aspects of human behavior"[35]. AI has as its long-term objective "(…) the development of machines that can do these things as well as humans can, or possibly even better" (Nilsson, 1998), a similar perspective to Zwicker (2010) and Rich & Knight (1991) in Russell & Norvig (1995) that understand AI as the "study of how to make computers do things at which, at the moment, people are better." In general terms, these authors seek for an Artificial Intelligence that has human intelligence as its reference ("as good as humans").

Others have a more pragmatic view. In Russell & Norvig (1995)'s textbook, used in introductory undergraduate courses on AI[36], for instance, the authors focus their work on a more practical perspective of AI, basically as "the study and construction of rational agents" (Russell & Norvig, 1995). Rational agents, according to the authors, are agents that perceive their environment through sensors and act upon it through effectors in a rational way – doing the right. And there are some alternative meanings to AI too, some of them that can be considered as extensions of the basic understanding. For instance, "AI is software that writes itself, writes its own updates, it

[33] https://www.merriam-webster.com/
[34] https://en.oxforddictionaries.com/
[35] https://www.youtube.com/watch?v=0kICLG4Zg8s
[36] In the Computer Science Institute (IME) of University of São Paulo, Brazil

renews itself independently and autonomously"[37], which has a strong relationship with Bostrom (2012)'s opinion that once a certain level of intelligence is reached, machines can start applying its technology to improve itself autonomously. There are also definitions that point Artificial Intelligence to the concept of thinking, such as 'machines that think'. Haugeland (1985) in Russell & Norvig (1995) believes that AI is "the exciting new effort to make computers think, although it is a difficult mission to define what thinking is about". This point of view is surely influenced by the work of Turing (1950), one of the creators of the modern computer. But thinking is a concept as abstract as intelligence, which is why Turing diverted from the terms and established the Turing Test as a way to measure it. In Machines Who Think, McCorduck (2004) also discusses this particular view on Artificial Intelligence as the capability to think.

In an academic point of view, one can find more definitions of Artificial Intelligence. "The field of computer science that studies how machines can be made to act intelligently" (Jackson, 1986 in Russell & Norvig, 1995). The research effort on "(…) the nature of intelligence and the principles and mechanisms required for understanding or replicating it" (Sharpies *et al*, 1989 in Russell & Norvig, 1995). The attempt to find how to make machines use language, form abstractions and concepts, solve problems that are reserved for humans, and, at the same time, improve themselves (McCarthy *et al*, 2006).

Due to its essential association with the digital computers and correlated fields, most of the research in Artificial Intelligence resides in the Computer Science field and its applications in other areas. Within this area, AI is traditionally a technical discipline, based on advanced theories, methods, and tools on programming, logic, mathematics, and statistics. Therefore, it is possible to find Artificial Intelligence definitions less broad than those already mentioned that are in line with this technical perspective like Tanimoto (1990) in Russell & Norvig (1995): "a field of study that encompasses computational techniques for performing tasks that apparently require intelligence when performed by humans"; and Partridge (1991) in Russell & Norvig (1995): "a collection of algorithms that are computationally tractable, adequate approximations of intractably specified problems".

In addition to this multitude of definitions, Artificial Intelligence is often misunderstood with its innumerous subfields, tools, methods, and applications. And there are several of them, that focus on different parts of intelligence. Neural Networks (brain modelling, time series prediction, classification); Evolutionary Computing (genetic algorithms, genetic programming); Machine Vision (object recognition, image understanding); Expert Systems (decision support systems, teaching systems); Speech Processing (speech recognition and production); Natural Language Processing (machine translation); Planning (scheduling, game playing); Machine Learning (decision tree learning, version space learning); Robotics (intelligent control, autonomous exploration); and so on. Though a research field on its own as a branch of Engineering, Robotics has also a close association with Artificial Intelligence and it is considered, at least partially, a subfield of AI. Russell & Norvig (1995) consider the robots as active, artificial agents that are applied in the physical world, and in the sense of autonomous robots, artifacts that interact and make decisions based on feedback, requiring intelligent behavior.

[37] https://www.youtube.com/watch?v=BrNs0M77Pd4

Apart from the usual concepts and subsets, we can also see several other terms that are used as synonyms of Artificial Intelligence, while others may be complementary. Some of them, collected during the literature review are Knowledge Representation Systems, Automated Reasoning, Deep Learning, Algorithms, Fuzzy Systems, Cognitive Computing, Cognitive Intelligence, Reasoning Systems, Knowledge-based Systems, Business Intelligence, Business Analytics, Data Analytics, Analytics, Predictive Analytics, Prescriptive Analytics, Big Data (or Big Data Analytics), Analytical Modeling, Predictive Modeling (or Predictive Model), Text Mining, Data Mining, Simulation (or Computer Simulation), Mobile Robotics, Computational Statistics, Knowledge Management Systems, Neuro IS, Cognitive IS, Cognitive Modeling, Competitive Intelligence, Collective Intelligence, Creativity Support Systems. This is not intended to be an exhaustive list; we are sure that there are several other related concepts not listed and that several more will be created in the following years. And we understand that though related, they may not be Artificial Intelligence.

Considering this complex scenario, after so many decades of studies in several different directions, it is comprehensible that diverse views and perspectives of Artificial Intelligence flourished, although most of them related to the Computer Science field, resulting in no general theory of intelligence or learning that unites the discipline (Moor, 2006). But based on Russell & Norvig (1995)'s analysis of AI goals to pursue, there are four basic categories of AI definitions that we consider in this work: (a) systems that think like humans, (b) systems that act like humans, (c) systems that think rationally and (d) systems that act rationally. The four categories and their key ideas and authors are summarized in Figure 1.

Systems that think like humans "The exciting new effort to make computers think… machines with minds, in the full and literal sense" (Haugeland, 1985) "[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning ..."(Bellman, 1978)	**Systems that think rationally** "The study of mental faculties through the use of computational models" (Charniak and McDermott, 1985) "The study of the computations that make it possible to perceive, reason, and act" (Winston, 1992)
Systems that act like humans "The art of creating machines that perform functions that require intelligence when per formed by people" (Kurzweil, 1990) "The study of how to make computers do things at which, at the moment, people are better" (Rich and Knight, 1991)	**Systems that act rationally** "A field of study that seeks to explain and emulate intelligent behavior in terms of computational processes" (Schalkoff, 1990) "The branch of computer science that is concerned with the automation of intelligent behavior" (Luger and Stubblefield, 1993)

Figure 1. Artificial Intelligence Definitions

Source: Russell & Norvig (1995)

The difference in the vertical axis between Think and Act, according to Russell & Norvig (1995), is that the first is concerned with understanding the thought and reasoning processes, while the second is solely concerned in displaying intelligent behavior (looking intelligent is enough). The difference in the horizontal axis between the references Humans and Rationally is that in the first, success is measured in terms of human performance (thus comparable to humans), whereas the second is measured against an ideal concept of intelligence, or Rationality, which is basically doing the right thing (Russell & Norvig, 1995). This second discussion, which Moor (2006) names the Psychology vs Pragmatic Paradigm Debate, remains one of the key disagreements in the area between purists and dissenters according to the author.

Russell & Norvig (1995) explain that other dimensions can be used for defining categories or type, such as application (theoretical vs practical), intentionality (intentional or unintentional) and consciousness (conscious vs unconscious), these last two we evaluate in more detail further ahead. But these categories accommodate only a part of the several disagreements that have been observed in the area. Moor (2006) states that other alive discussions keep affecting the definitions of AI, such as if Artificial Intelligence should be logic-based, in line with McCarthy's traditional train of thought, or probability-based, Mumford and Charniak's line of argument, a more recent approach to the topic.

Artificial Intelligence as Information Systems

Analyzing the set of definitions aforementioned in the literature, we can see that the subject is very much focused on the Computer Science field, even though several philosophers are discussing the subject (Searle, Chomsky and Bostrom, among others). In spite of presenting greater and broader Artificial Intelligence in terms of definitions and objectives, most of the authors end up discussing technical issues, tools, and methods. This technical focus is what we interpret as the hardcore perspective of Artificial Intelligence, which is not the interest of our work. A different and maybe recent or less common standpoint, on the other hand, considers the new developments in the Artificial Intelligence field as artifacts with growing application to different organizational contexts and situations, in a softer perspective, less concerned with the technical, but more with the applications and their implications. In doing so, we understand that AI overlaps with topics of study related to technology in organizations, which is mainly covered by Information Technology and Information Systems fields.

Information Technology (IT) encompasses "a broad array of communication media and devices which link Information Systems (IS) and people including voice mail, e-mail, voice conferencing, video conferencing, the internet, groupware and corporate intranets, car phones, fax machines, personal digital assistants, and so on" (Dewett & Jones, 2001). IT covers all kinds of artifacts based on digital technology (such as hardware, software, networks, databases, internet, etc.) developed to assist and leverage the execution of strategical objectives of the organizations (Laudon & Laudon, 2012; Pauli, 2012). In this research, Information Technology is also considered as a broad topic inside the area of Business, that is especially concerned with technology applied in organizations. On the other hand, as one of the components of IT, Information Systems (IS) are technological applications based on a set of interrelated components (basically information, individuals, procedures and technologies) that generically collect, process, store, present, analyze and share data for specific organizational needs (Laudon & Laudon, 2012; Turban *et al*, 2005; Pauli, 2012).

We believe that when Artificial Intelligence is applied into the organization context, it becomes a new element of the IT and IS field, with increasing relevance to be study. We share the four key reasons to explain this proposition of Artificial Intelligence as Information Technology and as Information Systems.

Information Processing Artifacts: According to definitions, one of the long-term key objectives of Artificial Intelligence is to replicate intelligent behavior into artifacts, creating intelligent thinking machines. In a very simple way, understanding and reasoning, typical human capabilities, are mental processes, performed by a complex physical tool which is the brain. The processes are usually triggered by stimulus or inputs of the environment or oneself, information that is collected either thru one of the senses or recovered from experience and knowledge, which undergoes into complex logics and operations to generate specific outputs, abstract like reflections, ideas, and knowledge or practical like actions, reactions and decisions. This is a definition that has similitudes to the concept of Information Systems and also Artificial Intelligence, since they both require inputs (data and information from diverse sources), need hardware to store the data and to compute algorithms and logics on its own and produce similar outcomes, some of them automated in a way there is no need for human beings at all.

Previous Experience with Expert Systems: Knowledge-based Systems and Expert Systems were the first examples of applied Artificial Intelligence algorithms and logics to the context of organizations and they were considered as examples of Information Systems. Lucas & van der Gaag (1991) explain that "Knowledge-based System is generally employed to indicate Information Systems in which some symbolic representation of human knowledge is applied, usually in a way resembling human reasoning." According to the authors, Expert Systems were the most successful example of Knowledge-based systems and they were capable of providing solutions to specific problems within in a given domain (Lucas & van der Gaag, 1991). Just like other IS, the development of an Expert System depended on knowledge sources and knowledge acquisition that help built a knowledge base, where an inference machine consisting of algorithms manipulated the information, offering solutions or advice in particular domains (Lucas & van der Gaag, 1991), as explained in the above paragraph.

Recent Market Applications with Embedded Intelligence: In its beginning, AI was a great promise but during the 'Dose of Reality' period aforementioned, it was clear that realizing ideas into applied commercial products was much more difficult than anticipated. The first area of Artificial Intelligence to be commercially fruitful that received more attention was exactly the Expert Systems just mentioned (Lucas & van der Gaag, 1991) because it offered an end-to-end solution with business (or specific domain) real benefits. In other words, from a market point of view, techniques and algorithms by themselves as studied by the AI hardcore scientists were not of much use to organizations, but Information Systems with embedded intelligence are. An example is IBM's Watson (just like other AI products from Google and Amazon), a cognitive platform which is comprised of a combination of several ideas put to work together in harmony: hi-tech supercomputers with enormous memory and processing capabilities, advanced communication algorithms (to convert natural language in computer language), big data analytics (to crunch and analyze huge amounts of data), machine learning capabilities (to learn and improve its analysis) and decision making abilities (with parameters like aggression vs accuracy trade-off). In other words, most of the Artificial Intelligence artifacts are not standalone solutions. Instead, most companies that market them have tried to do so by embarking these capabilities into existing Information Systems, leveraging the data they store, the interface with final users and their application to existing requirements of organizations.

Interdependency with other topics in IT and IS: We believe that the core technical Artificial Intelligence would never have advanced by itself if it was not for its dependence on other components from IT and IS. Recent advances in AI were possible due to improvements on the algorithms and logics, and also because of breakthroughs in IT and IS, with better performance, better capacity, more information and increased application in organizations. It is very hard to segregate somethings within the IT field because as a symbiotic partnership, they need each other to progress. The same is true for Artificial Intelligence.

But why is important to recognize Artificial Intelligence's connection to Information System or, what would be more precise, as an enabler of Information Systems? This is a research in the Applied Social Sciences field, more specifically the Business and Management area, concerned with the impacts on organizations and people. Advanced algorithms and hard theories studied in Computer Sciences are fundamental, however, this technical content has limited use and it is difficult to apply. Tied with Information System, Artificial Intelligence is more relevant to organizations and people and more capable of delivering the expected benefits. Moreover, in the academic sense, it offers a reference to understand what the implications to organizations and people of Artificial Intelligence in short, medium and long turn maybe.

Although we may consider Artificial Intelligence artifacts as Information Systems, not all Information Systems can be considered as or contain Artificial Intelligence artifacts. Since we observe some confusion in that sense, especially because several of these solutions have been off lately commercialized as having AI embedded, we evaluate some key terms.

Business Intelligence: Business Intelligence (BI) as a concept can be traced back to 1958 when Luhn (1958) suggested an Information System (IS) that supplied "(…) suitable information to support specific activities carried out by individuals, groups, departments, divisions, or even larger units", concerned "(…) with the admission or acquisition of new information, its dissemination, storage, retrieval and transmittal to the action points it serves." Luhn's Business Intelligence System was a combination of techniques for auto-abstracting and auto-encoding of documents, automatic creation, the update of action-point profiles, based on statistical procedures, supported by computers (data processing machines) and communication facilities. Considering the lack of maturity of the technology available at the time of the article, Luhn's ideas were ahead of his time. In a way, he laid the cornerstones of the concepts that still today define BI, though he was more document / knowledge oriented, objects that are in fact the focus of other topics like Content Management and Knowledge Management (Pauli, 2012). The not so current recycled BI term is a "(…) popularized, umbrella term coined and promoted by

Howard Dresner of the Gartner Group in 1989 (…)" that "(…) describes a set of concepts and methods to improve business decision making by using fact-based support systems" (Power, 2003). This is a view shared by several authors, including Watson (2009), that sees Business Intelligence as an encompassing term for Decision Support Systems (DSS), as well as Keyes (2006) and Chen *et al* (2012). There is no doubt BI is an example of Information System, only possible due to several technological achievements, especially in the areas of databases (or data warehouses), extraction, transformation and loading (ETL) tools, online analytical processing (OLAP), reporting tools and software, besides the other basic IT components (computers, programs, networks, etc). Actually, some of these system components mentioned are often used as synonyms. But Business Intelligence is mostly about "tools to support data-driven decisions, with emphasis on reporting" (Davenport, 2014), consequently the intelligence itself is totally left to the minds of the human counterparts and their analytical capabilities, that really turn raw data into information and insights aided by the dimensional data models. This is why Business Intelligence cannot be considered, by itself, an Artificial Intelligence artifact, example or application. Neither can Content Management or Knowledge Management.

Analytics: As it often happens in the Information Technology world, when close to fatigue by either overpromising or underachieving (or both), ideas and products are reshaped and recycled into new concepts and terms. This is no different for Business Intelligence, a "(…) term IT people use for analytics and reporting processes and software, generally managed by departments (…)" that resulted into a chaos of spreadsheets and data silos in several organizations, according to Davenport (2006). In his 2000s article in Harvard Business Review, Davenport (2006) proposed a new concept named Analytics, build on top of the basic BI components, but with three fundamental differences: widespread use of modeling and optimization, enterprise and centralized approach, and senior executive sponsorship. For our discussion, the first one is more relevant (and less abstract), so it is used to distinguish Analytics, Data Analytics or Business Analytics from Business Intelligence, in line with Davenport's view, that Analytics "focus on statistical and mathematical analysis for decisions" (Davenport, 2014). Nonetheless, some authors like Chen *et al* (2012) don't discriminate them at all and put it all on the same bucket under the Business Intelligence and Analytics (BI&A) umbrella. By widespread use of modelling and optimization, Davenport (2006) meant going beyond the basic descriptive statistics and methods that were possible in the first stage of BI, into the Predictive Analytics realm, using complex models, the latest statistical algorithms and decision science approach for Forecasting (suggesting future scenarios and their chances), Data Mining (finding underlying patterns on data sets) and Simulations (or data experiments). Although the first stage of BI (the 1990s) already permitted basic statistical analysis, "(…) grounded mainly in statistical methods developed in the 1970s and data mining techniques developed in the 1980s" (Chen *et al*, 2012), it was only in the second stage during the 2000s, that its real power was unleashed. In this BI 2.0, according to Chen *et al* (2012), the sources and types of data also changed. First, organizations expanded their boundaries, collecting data made available thru other sources than itself alone, such as the web and novelties like social networks. Second, organizations started to make sense and take advantage of unstructured data. Although Data Analytics have embedded in its advanced statistics and powerful algorithms that allow, among other things, pattern recognition, it is still an Information Systems without much intelligence embedded. This is why Analytics (or Data Analytics) cannot be considered, by itself, Artificial Intelligence artifact. Neither can Predictive Analytics or Predictive Modelling.

Big Data: Over the two last decades, the improvements in IT and IS in processing, storage, networks, interfaces, software, etc and the pervasiveness of new data sources led into an explosion of digital data in a high rate growth – IBM estimates 2.5 quintillion bytes are being generated per day around the world (Davenport, 2014). According to Chen *et al* (2012), "(…) an overwhelming amount of web-based, mobile, and sensor-generated data arriving at a terabyte and even exabyte scale (…)" that presents us with an unprecedented challenge. This outcome of the Digitalization process (or Datification proposed by Negroponte), the broad and fast paced conversion of analogic into digital information by either machines or humans (Loebbecke & Picot, 2015), requires a new approach to deal with abundant data and getting the best out of it. This approach is Big Data. Big Data in its essence, shares the same ideals and objectives of Business Intelligence and Analytics: they are about collecting business relevant data and translating them into actable knowledge, improving decision making. But according to McAfee & Brynjolfsson (2012), the key differences to its predecessors are volume, variety and velocity. Big data, as the name implies, deals with large volumes of data, in different forms (but mainly unstructured), from a diverse set of data sources (web, mobiles, sensors, etc) that most often are dynamic and ever changing. "Big data refers to data that is too big to fit on a single server, too unstructured to fit into a row-and-column database, or too continuously flowing to fit into a static data warehouse" (Davenport, 2014). In simpler terms, it is a new wave of Business Intelligence or Analytics with focus on and prepared for "very large, unstructured, fast-moving data" (Davenport, 2014). But like its predecessors, as stated by McAfee & Brynjolfsson (2012), "Big data's power does not erase the need for vision or human insight". Indeed, Davenport (2014) defends the human side of Big Data and affirms "(…) it is obvious by now that the skills of talented human beings are the single most important resource in successfully exploiting Big Data" and reinforces the role of the Data Scientist that is responsible for building the models, but also, for making sense of the results achieved. This is why Big Data cannot be considered, by itself, Artificial Intelligence either. However, as explained by Loebbecke & Picot (2015), it clearly contributed to the momentum of Artificial Intelligence.

Intentionality and Consciousness

Moving from definitions into some specific topics, we evaluate now the discussion of intentionality and consciousness in Artificial Intelligence. One of the possible categorizations that can be found in textbooks is the Weak AI (or Narrow AI or Cautious AI) versus Strong AI, as suggested by Searle (1980) and discussed by Russell & Norvig (1995) and several other authors, including Kurzweil (2005). This is an old debate (maybe as old as AI itself) that, unlike the technical and practical discussions mentioned in the previous session, is more abstract and philosophical. It basically faces two confronting perspectives, one from computer science, another from philosophy. These two opposing concepts deal with different views on Artificial Intelligence and take into account two important notions which are intentionality and consciousness. This is an important discussion because, as Standage (2016) puts it, "intelligence is not the same as sentience or consciousness (…) though all three concepts are commonly elided". In fact, this confusion is what makes the gap between fiction and reality grows larger every day.

Before moving on, a brief discussion on the meanings. In simple terms, intentionality means doing something in a certain way with purpose and determination[38], knowing the consequences of the action or decision and accepting them. In other words, deliberately take action or decision towards an expected result (positive or negative) and, either way, desire it and make it happen. Intentionality is a very human characteristic that requires knowing the possible consequences (either if they are deliberately overlooked or not). Consciousness means the quality of being sentient, aware of oneself and responsive to one's surroundings[39] by using mental faculties and organized adaptive mental activities and sapient, "a set of capacities associated with higher intelligence, such as self-awareness and being a reason-responsive agent" (Bostrom & Yudkowsky, 2011). It is "the state of being characterized by sensation, emotion, volition, and thought"[40] and using one's mind. Again, this is a particular capability of humans, deeply studied in psychology and philosophy and also a very complex and abstract concept, as Searle explains[41].

According to Bringsjord & Schimanski (2003), Weak AI is concerned with the artifacts (programs and machines) build to deliberately (or not) display some intelligent behavior just "as if they were intelligent" (Russell & Norvig, 1995). Weak AI is also a powerful tool in the study of mind, according to Searle (1980). In the Weak AI perspective, there are several things that computers/machines cannot do (and will never do), no matter how well they are programmed or how well they can learn. No matter how good the design of artificial intelligence systems and programs are, they will always be limited to boundaries and in specific applications, (hence, the synonym Narrow AI) and bound to fail in the long run (Russell & Norvig, 1995; Nilsson, 1998). Moreover, Weak AI has a certain overlap with the idea of systems that Act on the categorizations of AI proposed by Russell & Norvig (1995), and it is where we see the real and practical application of AI and the one that is facing important recent breakthroughs due to the advances in information technology[42].

Autor (2015)'s opinion is consistent with the Weak AI view. He believes that "computers do not think for themselves, do not have common sense, do not compensate for programmer oversights and errors and do not improvise solutions for unexpected cases", they follow meticulously what was laid out by programmers – or by the dataset in which they practiced and learned, demonstrating lack of creativity. Interestingly, Russell & Norvig (1995) disagree. They think that computers can demonstrate creativity just by learning from experience (machine learning), which is a bold statement. Another fascinating discussion inside the Weak AI claim is the argument of informality of behavior, that states that "human behavior is far too complex to be captured by any simple set of

[38] https://www.merriam-webster.com/
[39] https://en.oxforddictionaries.com/
[40] https://www.merriam-webster.com/
[41] https://www.youtube.com/watch?v=rHKwIYsPXLg
[42] https://www.weforum.org/events/world-economic-forum-annual-meeting-2017/sessions/the-real-impact-of-artificial-intelligence

rules; and because computers can do no more than follow a set of rules, they cannot generate behavior as intelligent as that of humans" (Russell & Norvig, 1995).

Although we may have examples that might even convince a human counterpart that the machine they are dealing with can really be intelligent and think (at least on first sight), or even show some autonomous actions and decision making, Weak AI makes no claims on machines being able to work with intentionality or consciousness. "Weak AI holds that though the external behavior of such machines might convince external observers to ascribe subjective awareness to them, such machines can't possibly have the relevant mental states" (Bringsjord & Schimanski, 2003).

Strong AI, as the name implies, goes in the opposite direction. It claims that programs and machines can be intentional and conscious (Russell & Norvig, 1995), "that the appropriately programmed computer literally has cognitive states and that the programs thereby explain human cognition" (Searle, 1980) and that Strong AI is the "artificial intelligence that exceeds human intelligence" (Kurzweil, 2005). According to Bringsjord & Schimanski (2003), it "(…) is indeed the view that cognition (including subjective awareness or phenomenal consciousness) is computation, and that an appropriately programmed information processing machine operating at or below the Turing Limit can literally be subjectively aware." Therefore, in Strong AI "the machine has to be aware of its mental state and actions" (consciousness) and it has to have purposes, beliefs and desires (intentionality) (Russell & Norvig, 1995).

Within the Strong AI resides the notion of a General Artificial Intelligence or Artificial General Intelligence (AGI), machines or programs completely sentient, capable of understanding, thinking, reasoning and demonstrating intentionality and consciousness, performing any mental activity as a human being and capable of solving a wide range of tasks (instead of having several systems for each problem) (Bostrom & Yudkowsky, 2011; Standage, 2016). Although consciousness and intentionality are not the same as thinking, one could say that Strong AI has a considerable overlap with the idea of Systems that think as a human category, reminding that these are two particular characteristics of human beings.

In a way, Turing was the first one to discuss Strong AI when trying to answer if machines could think. He foresaw machines with human capabilities (artificial intelligence) that would act like humans and proposed a test to identify if machines were really able to achieve human-level performance in all cognitive tasks – in fact, he proposed a way to measure if machines could think (Russell & Norvig, 1995). The original Turing Test is basically a blind interrogation of two entities, a person and a machine, where the machine would pass (therefore prove itself intelligent) if it managed to fool the interrogator in identifying which one is the machine (Turing, 1950). Despite having direct physical interaction (breaking one of the assumptions of the original test), a cinema version of the Turing Test is performed by Inspector Rick Deckard in Ridley Scott's Blade Runner (1982), as a mean to identify replicants (the reference in the movie was not a human, but expected behaviors and answers).

But there is also a great share of criticism of Turing's work. In 1980, philosopher John Searle questioned Turing Test ability to really check if systems could think – or simply fool an investigator. He proposed a different (theoretical) experiment to demonstrate the intention and conscious actions of a machine, which was named as the Chinese Room Experiment (Searle, 1980). With the Chinese Room exercise, Searle refuted the idea that machines could think (at least in his point of view). According to Nilsson (1998), "(…) Searle believes that what we are made of is fundamental to our intelligence" so "thinking can occur only in very special machines – living ones made of proteins" – a contrary view from Newell and Simon's hypothesis that it doesn't matter what the system is made of (protein or silicon), if a machine is capable of manipulating symbolic data, then it can be as intelligent as humans are. A second experiment, called Brain Prosthesis Experiment, also evaluated by Searle (1980) but most commonly associated with Hans Moravec, suggests an alternative way of debating thinking machines still within the Strong AI scenario (Russell & Norvig, 1995). It is important to mention that both are philosophical experiments (abstract and theoretical), which may explain why they are not so known to the general public, while Turing Test is still very much commented and used. Both experiments are debated in Russell & Norvig (1995) and are very much criticized by the AI futurists and enthusiasts such as Kurzweil (2005)[43].

Unlike Weak AI, we don't see great advances and evolution in Strong AI, because it is not only a matter of better machines, methods or algorithms, but also a question of knowledge. Considering the current understanding of the brain and mind related topics and how they work, Artificial General Intelligence and Strong AI are, right now, an improbable notion, just a futuristic, theoretical and sci-fi discussion. Chomsky[44] agrees with that perspective; according to him, "to try to capture the nature of human intelligence is a colossal problem, way beyond the limits of contemporary science." Despite being optimistic about the Strong AI claim, Nilsson (1998) agrees that "(…) full scale, human-level intelligence may be too complex, or at least too dependent on the precise physiology of humans, to exist apart from its embodiment in humans situate in their environment". Even among the most influent AI scientist and founders, there is skepticism with Strong AI. Moore, for instance, quoted by Moor (2006), also suggests that machines are very unlikely to ever match the imagination of humans. Standage (2016) also quotes an incredulous IBM researcher that states "the idea that machines will 'one day wake up and change their minds about what they will do' is just not realistic". Moreover, a possible "intelligence explosion" and rapid growth as suggested by Kurzweil (2005) can be considered unlikely, because it "would require an AI to make each version of itself in less time than the previous version as its intelligence grows"; however, "(…) most computing problems, even much simpler ones than designing an AI, take much longer as you scale them up" (Standage, 2016). Despite these facts, Strong AI is what's known and feared by the most AI illiterates, a realm that is closer to sci-fi literature and movies than reality or current developments in the computer science field.

3.2. Artificial Intelligence Impacts

During the literature research, we realized that the evaluation of Artificial Intelligence implications to people and organizations was not yet a trending topic in the major academic journals we investigated, especially in those

[43] https://www.youtube.com/watch?v=rHKwIYsPXLg
[44] https://www.youtube.com/watch?v=0kICLG4Zg8s

that evaluate Information Technology and Information Systems. However, it was a recurrent theme on the mass media channels, as shown by the great number of articles about it and illustrated by two recent examples in the UK[45,46]. This lack of scholar literature could be explained by the factors already mentioned in Chapter 2 and by the challenges we also faced in this work: creating a robust study that is simultaneously forward-looking in a subject in continuous evolution and, at the same time, acceptable from scientific and method points of view.

Be that as it may, there are some concerns in terms of impacts of AI that have been already been discussed to some extent. One of the most significant impacts is evaluated in the ethical discussion about the use of Artificial Intelligence. According to Bostrom & Yudkowsky (2011), when machines cross the boundaries of simple routine tasks into cognitive work with social dimensions, machines must inherit the social requirements that come with them. Among these social criteria are discussions on responsibility, transparency, auditability, incorruptibility, and predictability (Bostrom & Yudkowsky, 2011). In this scenario, probably the most debated example in nonacademic fields is, not surprisingly, the autonomous car. "Autonomous vehicles may put people in life-or-death situations, will the outcomes be decided by ethics or data?" asks a reporter from Scientific American[47]; "self-driving cars don't care about your moral dilemmas", answers another journalist from The Guardian[48]; Harari (2016) questions if it matters that self-driving vehicles do not have consciousness, if they make better decisions than human drivers, as can be confirmed by their significantly lower number of traffic accidents. This ethical discussion, that puts philosophers and humanists against engineers and computer scientists, is important because it "(…) could have a big impact on the way self-driving cars are accepted in society"[49]. Moreover, we have the ethics discussion in several other fields, like Medicine[50,51] and Warfare[52,53], just to illustrate our point.

The ethics debate gets more complex when we evaluate it from a Strong AI point of view, the claim of sentient machines (Searle, 1980) previously mentioned. This refers to the Intelligent Explosion, the notion of auto recursive improving machines by their own feedback cycle and the Superintelligence scenario, "humans with intelligence augmented through a brain-computer interface" (Bostrom & Yudkowsky, 2011). And just like other conflictive ethical fields, such as Genetics, several authors agree that controls must be put into place. "The ethical dilemma of bestowing moral responsibilities on robots calls for rigorous safety and preventative measures that are fail-safe, or the threats are too significant to risk" argues Stephen Hawking[54]. Concerned with the increasing power of AI and its public perception, corporations around the world have set up a research group to

[45] https://www.telegraph.co.uk/news/2019/03/25/rise-robots-fears-overestimated-new-employment-data-reveals/
[46] https://www.bbc.com/news/business-47691078
[47] https://www.scientificamerican.com/article/driverless-cars-will-face-moral-dilemmas/
[48] https://www.theguardian.com/technology/2016/aug/22/self-driving-cars-moral-dilemmas3
[49] https://www.technologyreview.com/s/542626/why-self-driving-cars-must-be-programmed-to-kill/
[50] https://journalofethics.ama-assn.org/article/should-artificial-intelligence-augment-medical-decision-making-case-autonomy-algorithm/2018-09
[51] https://journalofethics.ama-assn.org/article/ethical-dimensions-using-artificial-intelligence-health-care/2019-02
[52] https://www.defenseone.com/technology/2019/01/pentagon-seeks-list-ethical-principles-using-ai-war/153940/
[53] https://www.chathamhouse.org/sites/default/files/publications/research/2017-01-26-artificial-intelligence-future-warfare-cummings-final.pdf
[54] http://observer.com/2015/08/stephen-hawking-elon-musk-and-bill-gates-warn-about-artificial-intelligence/

discuss the ethical use of this technology[55,56], trying to set the key principles to develop it as well as define direct legal regulation of AI (Cerka *et al*, 2015).

Another impact that has recently increased its publicity is associated with the increasing gap between current skills on the market and capabilities required for the jobs in the future. Artificial intelligence will progressively be embedded in the activities necessary to perform occupations and, according to IBM's CEO, Ginni Rometty, "to get ready for this paradigm shift companies have to focus on three things: retraining, hiring workers that don't necessarily have a four-year college degree and rethinking how their pool of recruits may fit new job roles"[57].

However, the main recurring concern in literature is the impact of Artificial Intelligence to occupations (jobs) and employment. This is, in fact, a recycled concern from the past. Early in the 19th century, the first rebellions against machines happen in the UK led by people frightened with the idea that increases in labor productivity would inevitably reduce employment because there was only a finite amount of work to do – the Lump of Labor fallacy (Autor, 2015). A century later, in the 1930s, Keynes (1963) (and Ricardo before him) suggested that society was being afflicted with a new disease called Technological Unemployment. This meant "(…) unemployment due to our discovery of means of economizing the use of labor outrunning the pace at which we can find new uses for labor" (Keynes, 1963). Keynes' argument reflected the anxious and uncomfortable feeling of a world that was still living in the shadows of the great depression and had already faced two technological revolutions, mechanization waves that resulted in severe unemployment cycles. First one happened in the fields when changes in agriculture extinguished millions of jobs and drove crowds into cities in search of factory work. Second happened in the cities when mechanized production in intensive labor processes pushed workers out of the manufacturing sector into new service industries (Ford, 2015). A century has passed and Keynes' Technological Unemployment fear is alive again and stronger: "(…) automation anxiety has clearly returned" (Autor, 2015).

The key difference now is that, according to Frey & Osborne (2017), technology in predecessor revolutions was largely confined to the mechanization of manual, repeated, simple tasks that required some level of physical labor. But in the new wave, Computerization "(…) can be expected to contribute to a wide range of cognitive tasks, which, until now, have largely remained a human domain" (Frey & Osborne, 2017), similar view of Loebbecke & Picot (2015), that explain that AI is driving "(…) 'machine-for-human' substitution to diffuse into domains that are highly complex". "While computerization has been historically confined to routine tasks involving explicit rule-based activities, algorithms for Big Data are now rapidly entering domains reliant upon pattern recognition and can readily substitute for labor in a wide range of non-routine cognitive tasks" (Frey & Osborne, 2017). According to Ford (2015) "(…) the word 'routine' may not be the best word to describe the jobs most likely to be threatened by technology. A more accurate term might be 'predictable'".

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[55] http://www.theverge.com/2017/1/27/14411810/apple-joins-partnership-for-ai
[56] https://www.weforum.org/events/world-economic-forum-annual-meeting-2017/sessions/the-real-impact-of-artificial-intelligence
[57] https://www.cnbc.com/2019/04/02/ibm-ceo-ginni-romettys-solution-to-closing-the-skills-gap-in-america.html

In that specific subject of impacts on occupations, work, labor market, and employment, we see futurists, gurus, researchers, and professionals debating two opposing macro impact scenarios. The first scenario considers the replacement and displacement of humans by machines in large scale, while the second scenario believes in the augmentation and complementation of humans with machines. This binary perspective is obviously a simplification to a complex reality with countless variables to allow some discuss over the matter. Apart from those two key scenarios extracted from literature, we can argue about the no-change state, which describes the situation where not much would change with the introduction of systems and machines powered by AI. This could occur if an overwhelming technical barrier (more than a bottleneck) not easy to be handled, limited research and development, just like it happened in the 1950s and 1970s when computers were not powerful enough. Or if the complexity and cost to move to the next step was too high and unaffordable, reducing the pace and generating frustration, just like it happened in the 1980s with the expert systems. Or if AI proved to be just a commercial hype, one more IT bubble, just like it happened to the Y2K – Millennium Bug issue[58] in the end of the 1990s. This alternative, nevertheless, seems to be unanimously discarded by all authors discussing Artificial Intelligence – as IBM's CEO, Ginni Rometty, explains, "I expect AI to change 100 percent of jobs within the next five to 10 years"[59]. Another possible scenario is the intermediate situation between the first two described. In other words, is the scenario where we will see both replacement in a series of occupations and, at the same time, augmentation of another portion of occupations, with distribution and levels yet to be determined. This is probably the more realistic scenario, but we focus our discussion on the two initial opposing and extreme views considering the literature available.

Replacement and Displacement by Artificial Intelligence

This first scenario suggests a full scale and widespread application of Artificial Intelligence artifacts across industries and business areas that, combined with other advances in related fields, like Robotics, would be able to perform non-routine activities that require some level of intelligence. These advanced machines would be able to execute not only specific tasks but would possess a combination of abilities and skills that would permit them to respond to a wide variety of day-to-day challenges, demonstrating, in fact, all prerequisites of a particular occupation. The application of these machines would bring higher productivity, cost-effectiveness and lower vulnerability in comparison to humans. They would, therefore, allow organizations to take a strategic decision to replace the human employee currently responsible for those chores, setting aside the cost / benefit discussion. This movement in large scale would signify an intense reduction of labor positions for humans and would displace people out of the labor market. In a way, this scenario replicates previous experiences from past industrial revolutions, and a more recent movement, which was the massive offshorability from developed to developing countries, as evaluated by Blinder (2006).

An illustration of this reasoning can be done using the telemarketers' occupation, which Frey & Osborne (2017) rank as the occupation with a higher risk of computerization. According to O*NET Resource Center, U.S.

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[58] https://global.britannica.com/technology/Y2K-bug
[59] https://www.cnbc.com/2019/04/02/ibm-ceo-ginni-romettys-solution-to-closing-the-skills-gap-in-america.html

primary source of occupational information sponsored by the U.S. Department of Labor, telemarketers goal is to "solicit donations or orders for goods or services over the telephone"[60]. It is an occupation that does not require graduate degree (89% have high school or less than high school), but demands abilities like Oral Expression, Oral Comprehension, Speech Clarity, Speech Recognition, Selective Attention, Written Comprehension and skills like Speaking, Persuasion, Active Listening, Service Orientation, Social Perceptiveness and Reading Comprehension.

We interpret that authors aligned with this replacement scenario believe that an Artificial Intelligence program or artifact (or a combination of them) would be able to perform the abilities and skills described before. Their reasoning is based on recent advances in two AI's subfields. First, thru Natural Language Processing (NLP), the machine would manage to communicate and maintain conversions with human counterparts, thus, being able to listen, understand and speak back transferring the information effectively. With specific algorithms from Affective Computing that can reproduce aspects of human social interaction, the computer could also succeed in showing social perceptiveness during the call (being aware of one's reaction), and maybe even be able to active listen – though human emotion recognition still is a challenging problem (Frey & Osborne, 2017). Second, thru Machine Learning (ML) and a combination with other sub-areas of AI, the computer would have the complementary skills required for the job, with algorithms that, after learning from an enormous database of recorded calls and selling scripts, would permit the computer to find the best approach to engage clients and somehow persuade them into donations or orders.

If not declared supporters of this replacement claim, Frey & Osborne (2017) are the authors that contributed the most to it by providing a study that indicates almost half of the positions in the U.S. are at risk of computerization. Although they write about risks – not certainties, their work has references that support this replacement scenario. Frey & Osborne (2017) argue, for instance, that it is already technologically possible to automate almost any task, thus, labor substitution would not remain confined to routine tasks anymore but be extended to non-routine tasks that are not subject to bottlenecks.

Though this notion of replacement scares most of us and it is often mentioned in debates and newspapers, the fact is that this is not a popular idea to back up. However, several authors debate it. Davenport & Kirby (2015), for instance, explain that "automation has traditionally displaced workers, forcing them onto higher ground that machines have not yet claimed. Today, as artificial intelligence encroaches on knowledge work, it can be hard to see how humans will remain employed in large numbers." Boden (1984), back in the 1980s, already believed that the traditional manufacturing and clerical-administrative jobs would be decimated because AI could potentially be used to all jobs where the personal human contact is not essential.

The replacement scenario is one of the key anxieties of what Makridakis (2017) calls the Pessimists and Gurkaynak *et al* (2016) the Unfriendly AI. The concern is about the "magnitude of the challenge and the potential dangers which can arise from thinking machines and intelligent robots" that start replacing humans at work (Makridakis, 2017). Thinkers like Elon Musk, Steve Wozniak, Bill Gates, Bill Joy, Stephen Hawking and

[60] https://www.onetonline.org/link/summary/41-9041.00

others point out that in a utopian world of abundance, work would be done by machines and robots, and humans would be relegated to second rate status and have no control over the future (Makridakis, 2017). Considering this point of view, one may be inclined to associate the replacement scenario to the Strong AI claim. But this association is not necessarily true. As Frey & Osborne (2017) show in their article, there are already a lot of algorithms and AI solutions that could perform a human's job, without the need to show intentionality or consciousness. Harari (2016) agrees with this point of view, explaining that non-conscious but highly intelligent algorithms may soon know better than we do about ourselves and about our jobs.

This entire situation results in obvious economic consequences. This revolution has shown that the virtuous feedback loop between the economy and technology that worked as perfect symbiosis in the past may be severely weakened or even disrupted. This virtuous loop explained that, as machines used in production improved, the productivity of the workers likewise increased, making them more valuable and with higher wages. Those workers, in turn, went out and spent their ever-increasing incomes, further driving demand for the products and services they were producing in a win-win scenario (Ford, 2015). With massive unemployment caused by the replacement of human labor by machines, as some authors believe, all the fundaments of the modern economy could be at stake, increasing the gap in social equality and several other perverse implications (Davenport & Kirby, 2015). As DeCanio (2016) explains, "expansion of AIs' skill sets is likely to depress wages over time" and this "will increase measured inequality unless the returns to robotic assets are broadly spread across the population".

Augmentation and Complementation by Artificial Intelligence

This second scenario also considers a full scale and widespread application across industries and business areas of Artificial Intelligence machines (computers or programs), that combined with other advances, would be able to perform routine and non-routine activities that require some level of intelligence. However, these advanced machines, instead of substituting humans, would have to collaborate with them and vice versa to do things neither of them can do well on their own (Davenport & Kirby, 2015). "Instead of seeing work as a zero-sum game with machines taking an ever-greater share, we might see growing possibilities for employment. We could reframe the threat of automation as an opportunity for augmentation" suggest Davenport & Kirby (2015).

Therefore, the key idea here is that humans will not be replaced, but will be complemented by AI, just like other productivity tools offered by IT in the last decades. Or as Brynjolfsson & McAfee (2011) put it, a race *with* the machine instead of a race (or rage) *against* the machine. And this is the view that several market players are trying to back up, at least those few companies that are commercializing AI, like IBM, Amazon, Google, and a handful more. According to Ginni Rometty, IBM's CEO, the AI solutions must be "build for the people, by the people, with the people"[61] meaning with the right purpose, but also aligned with the augmentation train of thought. Autor (2015) goes in the same direction, he believes in "strong complementarities (between human and

[61] https://www.weforum.org/events/world-economic-forum-annual-meeting-2017/sessions/the-real-impact-of-artificial-intelligence

machine) that increase productivity", "tasks that cannot be substituted by computerization are generally complemented by it" (Autor, 2015).

Going back to the telemarketer example suggested before, instead of replacing, AI would work in collaboration with the operator. So, this worker could still do the communication with the customers thru telephones, leveraging the advantages (abilities and skills) of humans. On the other hand, the same operator would have support based on AI tool that, after understanding what was set, would be able to provide better answers (Autor, 2015). In fact, this is a similar idea of Cogito, a company that delivers a solution that "(…) analyzes the human voice and provides real-time guidance to enhance behavior"[62]. The analogy here is a positive and wealthy symbiosis between man and machine with both bringing into table their best abilities and skills, especially creativity from humans and computation for machines. This is the view that Autor (2015) shares in his article, explaining a feasible division of labor, where machines perform routine technical tasks, and workers the human tasks such as conversation and persuasion. "Routine and nonroutine tasks will generally coexist within an occupation to the degree that they are complements - that is, the quality of the service improves when the worker combines technical expertise and human flexibility" (Autor, 2015) .

Vermeulen *et al* (2018) agree with Autor (2015)'s point of view. They believe that automation indeed substitutes labor, however, it can also complement it. According to them, journalists and some experts tend to overstate the extent of machine substitution for human labor, ignoring the strong complementarities between human and machine and the subsequent increase in productivity. Moreover, as Boden (1984) assumed back in the 1980s, AI will alter the nature of work and jobs citing nurses and lawyers, but in both cases, "while the mystique of the human experts may be lessened, their opportunity for exercising their specifically human powers may be increased."

Jarrahi (2018) also contributes to understanding how AI can aid and augment, rather than replace, human decision making, proposing a symbiosis scenario and even detailing the responsibilities of each part in Figure 2. According to the author, "the rise of AI calls for a new human-machine symbiosis, which presents a shifting division of work between machines and humans. Pervasive visions of partnerships between humans and machines suggest that machines should take care of mundane tasks, allowing humans to focus on more creative work" (Jarrahi, 2018).

[62] http://www.cogitocorp.com/company/

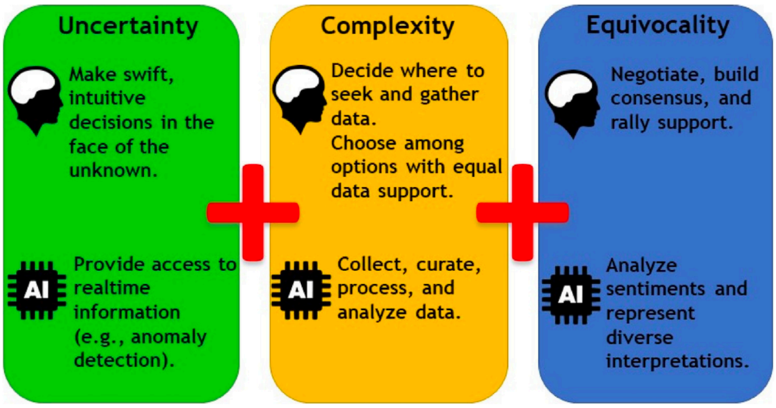


Figure 2. Complementarity of Humans and AI in Decision-Making

Source: (Jarrahi, 2018)

Artificial Intelligence Bottlenecks

No matter the macro consequences scenarios discussed, either if humans will be replaced or if humans will be augmented or complemented by Artificial Intelligence, some authors have tried to define different capabilities that would more or less susceptible to automatization by AI. This is what Frey & Osborne (2017) call computerization bottlenecks, meaning limitations that "set the boundaries for the computerization of non-routine tasks". We interpret this as an important effort because it helps in understanding where humans' capabilities are more required, clearly identifying what's left for humans and, in a way, helping us prepare, as individuals and society, for the future.

Frey & Osborne (2017) explain that, in their point of view, there are 3 greater categories of tasks that are currently bottlenecks of AI: perception and manipulation tasks, creative intelligence tasks and social intelligence tasks. The first group deals with dexterity (manual and finger), difficult moving situations and manipulation, and therefore, is more about Robotics than AI. According to the authors, "most industrial manipulation makes use of workarounds to these challenges, but these approaches are nonetheless limited to a narrow range of tasks" (Frey & Osborne, 2017). The second group is comprised basically by creativity and its expressions, like Fine Arts. Finally, the third group is focused on social abilities such as Negotiation, Persuasion, and care, as well as a social perception which includes affection and empathy.

Autor (2015) increments that initial list of limitations of current technology to accomplish nonroutine tasks. According to the author, "tasks that have proved most vexing to automate are those demanding flexibility, judgment, and common sense – skills that we understand only tacitly" (Autor, 2015). He explains that occupations requirements for flexibility, object recognition, physical dexterity, and fine motor coordination are human-specific, and humans deal with these tasks in a manner that it uses our inherent flexibility, problem-solving, and judgment. Levy and Murnane (2003) in Autor (2015) discuss two groups of tasks that are particularly challenging to machines: one set includes tasks that require problem-solving capabilities, intuition, creativity and persuasion, similarly to some of Frey & Osborne (2017)'s observations; the other are tasks that require situational adaptability, visual and language recognition, and in-person interactions.

Autor (2015)'s work in particularly interesting because it discusses a bottleneck that is hard to measure, and which affects several other activities, which is the tacit knowledge. According to him, "this constraint is more binding than one might initially surmise because there are many tasks that we understand tacitly and accomplish effortlessly for which we do not know the explicit rules or procedures" (Autor, 2015). This is what the author calls the Polanyi's paradox, following Michael Polanyi's (1966) observation, that there is much more knowledge than we actually see. In this discussion, Autor (2015) criticizes those that believe Artificial Intelligence can perform any task. According to him, what is usually seen as countermeasures to this issue, is end-runs, simplifications or simply tricks. "Through a process of exposure, training, and reinforcement, machine learning algorithms may potentially infer how to accomplish tasks that have proved dauntingly challenging to codify with explicit procedures", but "at its core, machine learning is an atheoretical brute force technique – what psychologists call 'dustbowl empiricism' – requiring only large training databases, substantial processing power, and, of course, sophisticated software" (Autor, 2015).

Final Considerations

There is no consensus among authors over the extension of the implications and few studies are available with conclusive results. There are several discussions in progress though, even in Davos during the recent World Economic Forums[63], led by key players in the marketplace. There are those who are more optimistic, believing that like in other revolutions, new opportunities of employment will be created (Boden, 1984), or arguing that this revolution it is not about substitution, but more likely about collaboration and complementation of human labor (Autor, 2015). Others think that this wave of automation seems scarier than previous ones and with good reasons (Davenport & Kirby, 2015): extreme unemployment (Frey & Osborne, 2017) and several other impacts for individuals, organizations, and society[64].

Nonetheless, many agree that jobs, from low to high end, will be impacted somehow during the next years (Frey & Osborne, 2017; Ford, 2015; Loebbecke & Picot, 2015), with several careers ceasing to exist and others entirely new being generated for businesses yet to mature (Vermeulen *et al*, 2018). Actually, some say that all jobs will be impacted by Artificial Intelligence[65]. The menace in this employment equation though, is the mismatch in volume and speed of these concurring trends: while 47% of total U.S. employment is at risk of being potentially extinguished by automatization in a decade or two according to Frey & Osborne (2017), new hires in traditional organizations are flat and brand new companies flourishing are highly hi-tech driven, with only a handful of people taking care of million-dollars businesses like Waze, the traffic app. In other words, a

[63] https://www.weforum.org/events/world-economic-forum-annual-meeting-2017/sessions/the-real-impact-of-artificial-intelligence
[64] http://www.futuristgerd.com/wp-content/uploads/2016/09/Technology-versus-Humanity-Gerd-Leonhard-Presentation-Futurist-London.pdf
[65] https://www.cnbc.com/2019/04/02/ibm-ceo-ginni-romettys-solution-to-closing-the-skills-gap-in-america.html

"mismatch between rapidly advancing digital technologies and slow-changing humans" (Brynjolfsson & McAfee, 2011). Even though 2009 depression seemed to be over and U.S. GPD started to grow again, in 2011 the rate of unemployment in the country still kept the recession levels (Brynjolfsson & McAfee, 2011). In Brazil, the computerization is affecting not only the automotive industry, reducing employment and increasing production, but civil engineering, financial services (including banking) and several other industries[66], examples of what could be a worldwide trend.

Vermeulen *et al* (2018) explain that we are possibly facing an economically and socially sustainable future with a high level of employment for a skilled workforce, in which the recent wave of automation is merely a period. The fact is that, with the successes in AI comes increased responsibility to consider the societal implications and educate decision-makers and the general public so they can plan for them (Buchanan, 2006). These are risks and issues that we, as a society, must take very seriously.

[66] http://opiniao.estadao.com.br/noticias/geral,robotizacao-e-desemprego,70001643188

4. Research Method

In this chapter, we cover the background, definitions and key characteristics of the Delphi Technique, as the main research method for this work. We also present its key benefits and limitations, as well as its applications in a scientific research context. We close this chapter by explaining the reasons that made us chose this method, contextualized to the particularities of this research.

4.1. Delphi Background and Definition

Delphi Background

The Delphi Technique was designed, developed and applied for the first time by the Rand Corporation for military forecasting purposes back in the early 1950s and its creation is unquestionably credited to Norman Dalkey and Olaf Helmer (Linstone & Turoff, 2002; Murry Jr & Hammons, 1995). Rand Corporation is an American nonprofit and independent organization created back in 1948 and known as a global policy think tank which helped different U.S. governmental departments in a wide variety of research, planning and development activities[67].

Delphi (either known as Method or Technique) was the derivation of what was called Project Delphi within Rand, which had as its key objective to achieve the most reliable consensus in a specific Defense topic based on the opinion of different experts, thru a series of interactions by questionnaires combined with controlled feedback (Dalkey & Helmer, 1962). Delphi was an alternative solution designed to respond to scenarios where accurate information was unavailable or too expensive to obtain (Linstone & Turoff, 2002) – in other words, a simpler solution with an acceptable result.

Some statements in the literature claim that the term Delphi was not chosen by chance. Considering the prognostic nature of the method, the name was suggested as a reference to the ancient Greek town of Delphi, which hosted the temple and oracle of Apollo[68]. Nonetheless, the name selected also had considerable downsides and a misleading appellation (Dalkey, 1969) – it clearly carried with it a divination connotation based on communication with gods and it also conveyed the idea of lack of framework. However, the Delphi method is quite the contrary: a stable, systematic and robust qualitative method with a long and successful track history, very compatible with academic and scientific research.

While used to evaluate classified and strategic questions, some of them related to military and national security decisions in a wartime period, the method remained confined and limited for a decade or so. However, in the next decade, the 1960s, "the Delphi procedures received a very large boost in general interest with the publication of Gordon and Helmer's study of forecasting technological events" (Dalkey, 1969). Dissemination of

[67] https://www.rand.org/about/history/a-brief-history-of-rand.html
[68] https://www.britannica.com/topic/oracle-religion#ref207522

Delphi to other fields thus began (Linstone & Turoff, 2002), as soon as the content of the experiment was declassified and the first papers were released for publication (Dalkey & Helmer, 1962). According to Linstone & Turoff (2002), industries that were highly dependent of research and development were particularly sympathetic to the new method as a complementary tool for their classical mathematical models, incorporating an important subjective, non-quantitative factor. While diffusion started, challenges also arose. Researchers directly involved in the method had to prove that Delphi could be generalized and applied to other realities and circumstances.

If the 1950s were marked by the secrecy and obscurity, with the exclusive application in the Defense context and the 1960s by the novelty, after the declassification of the method and the introduction to the public, the early 1970s were the period of popularity, with its distribution to Western Europe and other regions, in addition to turning a major forecasting tool in business (Rieger, 1986) in von der Gracht (2012). Moving on the development stages of Delphi, the late 1970s were marked by scrutiny with critical evaluation of the technique's reliability and validity and the 1980s were based on continuity, acceptance in science and practice combined with stable application patterns (Rieger, 1986) in von der Gracht (2012). According to von der Gracht (2012) “after a time of stagnation in the 1980s, the Delphi Technique received increasing interest in the early 1990s again” and the numbers kept increasing in the 2000s, as demonstrated by Landeta (2006).

Nowadays, Delphi is a consolidated research method, mature and very adaptable (Skulmoski *et al*, 2007). It has been used in several studies in Health Sciences and Social Sciences fields (Landeta, 2006), over and above the Information Systems area, with a very successful track history. Over the last century, its “(…) ubiquity has grown, so has the method evolved, with the development of numerous variants (…)” (Rowe & Wright, 2011), its use has increased both in breadth and depth thanks to its reliability and versatility, especially in situations where the exploratory and prognostic features are particularly obvious and where the knowledge or theory seems to be incomplete (Yeoh & Koronios, 2010). As an illustration of this widespread use, Linstone & Turoff (2011) confirm that “over the past four decades more articles in Technological Forecasting and Social Change Journal have been devoted to Delphi than to any other technique in the domain covered by the Journal.”

Delphi Definition and Types

In the reference literature evaluated, the definition of the Delphi Technique seems to be stable and recognized among authors and researchers, probably due to its single point creation and early controlled dissemination. Even so, the definition is two-folded, since there are two different perspectives on the key distinguishing feature of the method: the objective (meaning its nature) or the process (meaning its ways of working).

Regarding its objective, Helmer (1967) defines Delphi as a methodological solution to, as systematically as possible, obtain relevant intuitive insights with informed judgment from experts about specific topics, especially – but not limited – to situations where there may be an absence of a proper theoretical foundation. Thru elicitation and refinement, the intended outcome of Delphi is to reach a combined informed judgment from a group of individual opinions, a decision that is usually more valid than those taken from a single individual (Murry Jr & Hammons, 1995). As Dalkey (1969) suggests, the advantage of building a combined judgment from several independent ones is that it tends to reduce the influence of outliers besides giving higher accuracy and higher reliability to results than individual judgments - as long as the group of participants is really comprised of true experts. According to Dalkey (1969), Delphi is "(…) above all, a rapid and relatively efficient way to 'cream the tops of the heads' of a group of knowledgeable people". When debating Delphi's nature, there is also the predictive and forward-looking feature, though the method cannot be limited to this application. Schmidt (1997) explains that "forecasting has been a major area of application of the method in many different fields" and, in most areas of foresight and future forecasting, conditional forecasts which can clarify the potential relationships among future events are of special importance and are adequately covered by this method (Linstone & Turoff, 2011).

Regarding its process, the Delphi Technique is a procedure that consists of a "(…) carefully designed program of sequential individual interrogations (by questionnaires) interspersed with information and opinion feedback derived by computed consensus" (Helmer & Rescher, 1958), a similar view from Murry Jr & Hammons (1995). This procedure undergoes a controlled communication process, as Linstone & Turoff (2002) explain: "Delphi may be characterized as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem". Actually, Linstone & Turoff (2011) insist that, Delphi is "a method for structuring a group communication process", rather than a method to produce consensus in outcomes, a similar view of Hasson & Keeney (2011) that explain that "(…) not all Delphi techniques aspire to achieve consensus, for instance, the policy Delphi aims to support decisions by structuring and discussing the diverse views of the 'preferred future'".

According to Linstone & Turoff (2002), in order to achieve this structured communication, four elements are necessary: feedback, assessment, revision, anonymity. By feedback, they mean the individual contributions with information and knowledge on a particular topic; by assessment; they mean the evaluation and synthesis of the different judgments and views; by revision, they mean the opportunity for the individuals to revise their views in light of the group; and by anonymity, they mean the privacy of the individual responses to ensure participation without concerns or limitations (Dalkey, 1969). Skinner *et al* (2015) enhance this explanation adding three additional elements: experts, panel, and rounds. By expert, they mean individuals fit for this type of research, top and recognized specialists in their fields of technical knowledge; by panel, they mean limited groups of carefully selected experts; and by rounds, they mean successive iterations of feedback, assessment, revision for achieving consensus or refinement.

The Delphi method is a qualitative, inductive and (mostly) predictive type of research. As Pare *et al* (2013) confirm, "the Delphi method represents an inductive, data-driven approach that is often used in exploratory studies on specific topics or research questions for which no or limited empirical evidence exists". Delphi is one of the key methods of qualitative research, along with Case Study, Action Research, Ethnographic Research, Content Research, Focus Groups, and In-depth Interviews. Delphi shares similarities with these methods, especially in the particular features that define a qualitative research type. Among the qualitative methods, Focus

Group and Nominal Group Technique (NGT) are the ones that share more similarities with the Delphi Technique, especially because of their characteristic of group decision making – the adage ‘two heads are better than one’ (Dalkey, 1969) and that “(…) combining individual judgments may lead to ‘process gain’, where groups may perform better than their best member” (Rowe, Wright & Bolger, 1991).

As in the other qualitative methods, Delphi faced early prejudices regarding subjectivity and validity, especially when contrasted with quantitative methods that have allegedly greater precision, scientific care, and dependence on hard data. Dalkey (1969) defends the validity of the method detailing the experiments performed and assuring the improved average accuracy. An additional characteristic that complicates, even more, this discussion is the prediction nature of most Delphi researches, what can be viewed as a conflicting feature with the scientific method, as explained in Chapter 1. To address this challenge, Helmer (1967) explains it was necessary to systematize the process as much as possible so that it could grant one of the key scientific investigation features which is reproducibility – that is, getting to similar results when re-executing the research. And in regard to subjectivity, the other common reproach of Delphi, Helmer & Rescher (1958) explain that “(…) the utilization of intrinsic expert judgment within the framework of an inductive procedure expert judgment is not incompatible with scientific subjectivity.”

As in other methods, Delphi has some variations, with different types and classifications found in the literature. Linstone & Turoff (2002), for instance, differentiate Delphi in two types: Conventional Delphi (also known as Paper and Pencil Delphi) and Conference Delphi (also known as Real Time Delphi). The key distinction lies in who performs the mediation role (either a person or a computer) and how automatized the process is (if the compilation of results is completely manual or, on the other hand, executed by a computer with predefined rules). From Schmidt (1997)’s observations, another segregation is possible between the Traditional Delphi form, meaning the one created and used by Rand in the early 1950s for forecasting and estimation and the Ranking Delphi Form, a variation seen first in the management disciplines, that focuses on getting consensus over the importance of criteria in regards a particular subject. Pare *et al* (2013) expand this typology, increasing it to four major types of Delphi, which are presented in Table 4. Based on Keeney (2009), Hasson & Keeney (2011) expand this categorization even further into ten main categories of Delphi: classical, modified, decision, policy, real-time, e-Delphi, technological, online, argument, and disaggregative.

	Classical Delphi	**Policy Delphi**	**Decision Delphi**	**Ranking-type Delphi**
Focus	Facts	Ideas	Decisions that influence future directions	Rankings
Goal	Create consensus	Define and differentiate views	Prepare and support decisions	Identify and rank key issues
Panelists	Unbiased experts	Lobbyists	Decision makers	Experts
Participation	Need many panelists (in relation to the complexity of the questions being asked)	Consider all relevant groups	Cover a high percentage of the relevant decision makers	Number of panelists should not be too large (in order to facilitate consensus)
Common uses	In the natural sciences and engineering where underlying physical 'laws of nature' guide experts's answers	In social and political contexts to analyze policy issues	In contexts where small, well-defined group have decision making power	In business to guide future management action or research agendas

Table 4. Types of Delphi Techniques

Source: Pare *et al* (2013)

According to Linstone & Turoff (2011), in recent years, “derivatives of Delphi have emerged under names such as prediction markets, collaborative tagging, recommender systems (like Netflix), and social networks that usually serve a commercial objective.” However, the authors warn to the fact that a new name does not necessarily imply a new field or a new method.

4.2. Delphi Process

According to Linstone & Turoff (2002), the Conventional Delphi Method has basically four major and distinct phases:

- Exploring: the topic under discussion is presented and each of the experts contributes with their relevant and subjective point of view to the matter, without too many constraints and/or structure
- Framing: the opinions are compiled seeking a general understanding of the group view on the issue, pursuing convergence (if possible) and evaluating eventual disagreement
- Refining: the disagreements are explored in more detail to make sense of the underlying reasons for such different opinions and the feedback on the convergences are collected
- Evaluating: once all information is gathered and refined (in several rounds, if necessary), it is analyzed and for final evaluation and considerations

Generally speaking, the successive rounds of iteration with the respondents focus on the first three bullet points, while the researcher manages the controlled communication and feedback with participants. In the first round the objective may usually be to motivate general response to wider questions, exploring, the subsequent rounds often focus in framing and refining the findings thru considerations, ranking, rating, and arguing over the compiled responses from previous rounds (Murry Jr & Hammons, 1995) and eventually additional data that may be relevant to the discussion. The key objective of this subsequent iterations is to reduce the dispersion in previous estimates and opinions so that group convergence can be improved (English & Kernan, 1976), if this is the objective. Figure 3 is a graphical representation of these phases and the whole Delphi process based on a generic three-round execution.

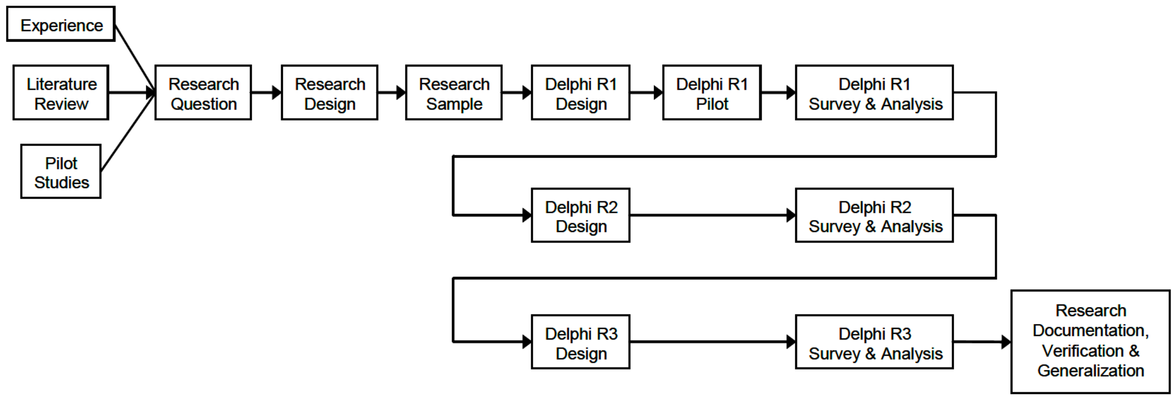


Figure 3. Three Round Delphi Process

Source: Skulmoski *et al* (2007)

Several critical factors must be carefully planned for a successful Delphi Method execution. One of them is the panel of experts – "selecting research participants is a critical component of Delphi research since it is their expert opinions upon which the output of the Delphi is based" (Skulmoski *et al*, 2007). In other words, the selection must be carefully conducted, ensuring that the panelists have the right knowledge and the right seniority in the topic, in other words, ensuring they are fit for the research. Lilja, Laakso, and Palomaki (2011) in Skinner *et al* (2015) explain that an expert is appropriate for a Delphi panel if the individual is at the top of their field of technical knowledge, and interested in a wide range of knowledge not only in his/her own field but everything around it, and, in addition, is able to see connections between national and international and present and future development, between different fields of science; he/she needs to be able to disregard traditional viewpoints, to regard problems from not only known and safe angles but also unconventional ones, and interested in creating something new. Another important consideration when choosing participants is to have at least some diversity in the background in order to avoid biases – for instance, reducing the panelists to one same university can lead to a partial response, which is in line with Rowe and Wright (2001) in Skinner *et al* (2015) that suggest using heterogeneous experts for richer and less biased results. Considering an objective way of measuring the expertise of the participants is also a good practice, either by setting a minimum academic degree, a minimum amount of work experience years and such. Skinner *et al* (2015) take this expert panel discussion quite seriously and provide a method for identifying and selecting potential experts, validating their status and informing these possible panelists of study requirements. According to Adler and Ziglio (1996), there are four key requirements for "expertise": knowledge and experience with the issues under investigation; capacity and willingness to participate; sufficient time to participate in the Delphi; and, effective communication skills.

The number of participants in the panel is another crucial factor in the method, and it is a particularly debatable subject in the literature. According to Skinner *et al* (2015) , "the panel should consist of a group of selected experts with no size limitations", "however, because the main task is to include experts who have the greatest knowledge and experience in the field under review, group size often remains fairly small." From Dalkey (1969)'s experiments, the optimal number of participants was 29 experts per group, an quantity where the marginal decrease in the average group error is so imperceptible that it did not justify the addition of more experts in the discussion. This is line with observations from several authors, according to Murry Jr & Hammons

(1995). Skinner *et al* (2015) evaluated several researchers to suggest panels as little as 4 experts under ideal circumstances, but under typical circumstances, between 10 and 30 experts. Chaves (2011) explains that the number of participants usually varies between 4 to 11, 9 to 21 or 11 to 37 in the different analytical evaluations performed. In summary and as a thumb rule, a group should have at least 10 participants with an acceptable drop rate of 10-20% according to English & Kernan (1976), which is a close figure to the one used by Rand Corporation in their first Delphi executions (7 experts). This is a similar point of view to that of Ziglio and Adler (2002) that affirm that useful results can be obtained from a small group of 10-15 experts. "Insofar as research studies have not found a consistent relationship between panel size and decision making effectiveness, it is highly unlikely that another equally expert group will produce radically different results from a panel of 15 experts" (Skinner *et al*, 2015).

The third critical factor in Delphi process is the number of rounds to be executed (and indirectly, the time available for each round and the time elapsed between them), which is a key characteristic of the method. Skinner *et al* (2015) explain that "(…) two rounds are considered the minimum, between three and six rounds, are required to facilitate realistic findings" and "up to 10 rounds have been suggested as necessary for achieving consensus". Skulmoski *et al* (2007), like Rowe and Wright (2001) in Skinner *et al* (2015), consider 3 to be the typical Delphi format and generically sufficient – though the authors mention single and double round Delphi studies also performed with good results (English & Kernan, 1976). Evaluating different supporting evidence, Chaves (2011) explains that the two and three round variations of Delphi are the most common ones in studies, varying from 63% to 88% of the cases, the more common being the three round in a 3 to 1 ration. The key objective of the continuous iterations is obviously the quest for maximum convergence and gradual development of consensus (English & Kernan, 1976) and a practical rule for deciding or not upon a new round is provided by these authors and illustrated in Table 5. However, some authors claim the number of rounds should be defined by how stable the answers are, no matter if they converge or not. This is one of the key reasons why Linstone & Turoff (2002) consider Delphi more art than science. In other words, the number of rounds in a Delphi research depends on either consensus, if this is the ultimate objective of the research, or stability of the answers. Delphi may require additional rounds than the ones initially planned, just like it may disregard rounds if they are not relevant anymore. As an illustration, Chaves (2011) planned for a six-round Delphi but executed it in five. Some of these rounds could have been combined to reduce unnecessary interactions – e.g. round 0 in Chaves (2011) research shared a basic introduction of the research and collected initial data on the profile of the experts, which could have been combined with the first round. Therefore, in a deeper analysis, Chaves (2011) also performed a three-round Delphi.

Coefficient of Variation	Decision Rule
$0.0 < v < 0.5$	Good degree of consensus. No need for additional round.
$0.5 < v < 0.8$	Less than satisfactory degree of consensus. Possible need for additional round.
$v > 0.8$	Poor degree of consesnsus. Definite need for additional round.

Table 5. Coefficient of Variation and Consensus

Source:(English & Kernan (1976)

The number of rounds is also dependable on the time available for respondents to answer the questionnaire and the time between the rounds. The first Delphi studies, known as paper and pencil, were executed manually without computer aid and using letter and post offices to reach out the specialists across the U.S. They could last up to 10 weeks to complete a single round, especially the first round (English & Kernan, 1976). A significant change was already seen in the 1990s with rounds taken approximately a week (Murry Jr & Hammons, 1995). With the internet and other recent tools, Delphi's have been executed in days or almost immediately, like the Real-Time Delphi, a "(…) variation of a Delphi does not have explicit 'rounds' but gives feedback directly when a participant is assessing" (Aengenheyster *et al*, 2017).

One last part of the process is the analysis of data in between rounds and at the end of the final round. According to Schmidt (1997), "researchers have not made good use of available statistical techniques to support their conclusions" on Delphi studies. As recommended by these authors, based on nonparametric statistics, and applied in Chaves (2011), to measure the agreements of a group, Kendall's Coefficient of Concordance (*W*) is the most suitable because it gives "(…) a realistic determination of whether any consensus has been reached, whether the consensus is increasing, and the relative strength of consensus" (Schmidt, 1997). Kendall's *W* is simple to calculate, and its results are easier to interpret, following the guidance in Table 6. Kendall's Coefficient of Concordance ranges from 0.0 (total disagreement) to 1.0 (total agreement) and for its significance test, the recommendation is to use Chi-Square Tests (Chaves, 2011). To evaluate the similarities and, consequently, the agreement between two different groups, when applicable, Kendall's Rank-Order Correlation Coefficient (*T*) is the recommended approach. According to Schmidt (1997), "*T* is used rather than the Spearman rank-order correlation coefficient because it emphasizes the relative ordering of the issues rather than the magnitude of the difference between ranks". A one-tailed test of significance is also used. If the agreement is not significant, then there are different views between the groups.

W	Interpretation	Confidence in Ranks
0.1	Very weak agreement	None
0.3	Weak agreement	Low
0.5	Moderate agreement	Fair
0.7	Strong agreement	High
0.9	Unusually strong agreement	Very High

Table 6. Interpretation of Kendall's W

Source: Schmidt (1997)

4.3. Delphi Advantages and Limitations

Delphi has several similitudes to other qualitative methods, such as Focus Groups and to Nominal Group Technique (NGT) (Adler and Ziglio, 1996), but has also some specific distinctions that make it quite unique. One of the key characteristics and advantages of Delphi (comparing to other qualitative methods) lies in a particular difference between explanation and prediction – a topic already evaluated by some of the original designers of Delphi (Helmer & Rescher, 1958). The methods in the Explanation group are generically focused on describing the past or present and therefore are based on facts collected and interpreted by the researcher. The methods in the Prediction group, where Delphi is mostly used, are concerned in trying to describe the future, dealing with uncertainties thru the use of expert and intuitive judgments. In that sense, as Helmer (1967) explains, the Delphi Technique was a response to the traditional methods applied in Social Sciences which proved to be inadequate especially to the complexity of forecasting or estimating situations, in which the predictive element is preponderant over the explanatory, like in decision making. Dealing with the future without being merely speculative is probably one of the key advantages of the Delphi Technique.

In terms of process, according to Dalkey (1969) and Murry Jr & Hammons (1995), Delphi has three additional key features and advantages that distinguish it from any other group qualitative methods, especially the aforementioned Nominal Group Technique (NGT), which are: (a) anonymous group interaction and response, (b) multiple iterations or rounds of questionnaires with controlled feedback, and (c) statistical group response. Another great advantage is that Delphi is quite flexible – it has "particular designs according to the situation it is applied, so one design may not necessarily work for some other application – one size does not fit all" (Linstone & Turoff, 2002).

Contrary to Focus Groups and NGT, the Delphi Method replaces direct face-to-face debates among experts with indirect moderated and guided discussion. Although this change may limit the positive interaction that may lead to richer findings and insights on one side, it mitigates issues regarding the negative live interactions, a key criticisms of Focus Group and other methods based on live meetings, delivering more accurate responses according to Dalkey (1969) and Murry Jr & Hammons (1995). Delphi avoids conflicting situations from direct confrontation (Dalkey & Helmer, 1962) due to, for instance, different backgrounds and opinions or even personal animosities. It reduces the specious persuasion, inflexible and non-negotiable positions or bandwagon effect, as a result of psychological or external factors (Helmer & Rescher, 1958; Helmer, 1967), and the influence of dominating role(s) / individual(s) (either by respect or persuasion), that can happen in live round tables of experts (Dalkey, 1969; English & Kernan, 1976). Delphi also reduces possible communication issues and semantic noise (Dalkey, 1969), in the sense of minimizing misinterpretations or deviations, since it has controlled feedback from the mediator, who guides the discussion within the boundaries of the research question (or not, depending on the objectives). Dalkey (1969) also explains that Delphi decreases the distortions of individual judgments due to group pressure for conformity. In a comparative analysis, not necessarily to Focus Groups but to live meetings and round tables, Dalkey (1969) performed experiments to show that, although still inconclusive in terms of significance, Delphi could lead to better results or at least to similar results as in live meetings.

Delphi has another considerable advantage towards face-to-face methods, which is the fact that opinions can be collected from a wider group of people, including from geographically disperse experts (Murry Jr & Hammons, 1995), respecting each and everyone's availability. The geographic distance was especially complicated and relevant back in a time where all communication was performed thru letters, post offices and mailboxes, which directly impacted in the duration of Delphi, but this issue was addressed with the internet. Apart from increasing the number of possible participants and reducing logistics costs associated to face-to-face methods, Delphi allows longer time for reflection and correction, from both the designer and the participants, which is not the case in one shot face-to-face methods. Furthermore, unlike Focus Groups, Delphi also ensures the anonymity of the participants, allowing them to share their individual view without limitations and inhibitions. Linstone & Turoff (2002) also describe these same advantages in their work.

However, Delphi has limitations, disadvantages, and deficiencies, some of them already addressed with the method evolution over time. Rowe, Wright & Bolger (1991) explain that "(…) in many circumstances interacting groups do not perform to their optimal level or potential" and Gordon & Helmer (1964), in their seminal work on Delphi, alert to six weak spots in regards to this: the expert panel instability (difficulties in maintaining the group committed and participating along the journey), long time elapse for the process, ambiguity in written questions, respondents diverse competence (not all respondents may be competent in all areas), self-fulfilling and self-defeating prophecies (a bias that can turn responses one way or another) and consensus by undue averaging (deals with the fact of using quartiles and medians to reach the 'right' answer). Based on Steiner (1972) in Rowe, Wright & Bolger (1991) also warn to an additional critical factor which is the inadequate weighting of judgments from group members, "meaning a mismatch between members' status and quality of contributions, through the lack of contribution from proficient yet under-confident members, through the difficulty of evaluating the quality of individual participants, or through the social pressures that may be exerted by an incompetent majority on a competent minority." All these issues are also covered by Landeta (2006).

Murry Jr & Hammons (1995) alert to other key limitations on Delphi method, such as the indirect influence to panel responses from questions formulated by the researcher, the difficulties to fully assess and utilize the expertise of the panel of experts because they never meet face-to-face, the unexpected and uncontrolled that cannot be taken into account, such as a lack of understanding of the study's purpose by the participants or the lack of motivation of respondents in the study may lead to sample attrition. They also discuss the problem of maintaining panel commitment to the study (Murry Jr & Hammons, 1995).

Different authors advise researchers on the dangers and pitfalls to be avoided in the use of the Delphi Method to prevent frustrating experiences. Linstone & Turoff (2002) list the biased (either direct or indirect) influence of the mediator(s), similarly to Murry Jr & Hammons (1995); the over-specification of the Delphi structure by the designer; the poor quality in combining opinions and feeding it back to the experts; the negligence (intentional or not) of analyzing eventual disagreements; the creation of an artificial consensus or a nonexistent consensus; the lack of trade-off to participants of the Delphi (affecting response quality and/or response rate). Apart from those, there are further risks that, though not exclusive of the Delphi Method, must also be considered when applying it, just like any other qualitative method. The overall list of advantages and disadvantages of Delphi is plotted in Table 7.

Advantages / Strengths	Limitations / Weaknesses
Consensus building	Group pressure for consensus—may not be true consensus
Future forecasting	Feedback mechanism may lead to conformity rather than consensus
Bring geographically dispersed panel experts together	No accepted guidelines for determining consensus, sample size, and sampling techniques
Anonymity and confidentiality of responses	Outcomes are perceptual at best
Limited time required for respondents to complete surveys	Requires time/participant commitment
Quiet, thoughtful consideration	Possible problems in developing initial questionnaire to start the process
Avoids direct confrontation of experts with one another	May lead to hasty, ill-considered
Structured/organized group communication process	Requires skill in written communication
Decreasing somewhat a tendency to follow the leader	Potential danger of bias-surveys are open to researchers' manipulation
Focused, avoids unnecessary side-tracking for panelists	Selection criteria for panel composition
Ties together the collective wisdom of participants	Time delays between rounds in data collection process
Cost effective and flexible/adaptable	May force a middle-of-the-road consesnsus
Validity, as the content is driven by panelists	Concerns about the reliability of the technique
Fairly simple to use	Drop-outs, response rates
Beneficial for long-range educational planning and short-term decision making	
Applicable where there is uncertainty or imperfect knowledge	
Effectively used to establish the basis for future studies	
Accommodates a moderately large group	

Table 7. Delphi Method Key Advantages and Limitations

Source: Hung *et al* (2008)

Considering all these issues aforementioned, several authors share their golden rules and lessons learned about the Delphi. Among those are the (1) definition and selection of an adequate group of participants (Linstone & Turoff, 2002; Murry Jr & Hammons, 1995; Helmer, 1967); (2) honesty and transparency of the mediator(s) in his/her/their interpretations and representations (Linstone & Turoff, 2002); (3) differences in cultural and education background, such as language, logic and research field of participants (Linstone & Turoff, 2002); (4) defining the right balance between number and depth of interactions and an efficient communication process (Linstone & Turoff, 2002); (5) create proper conditions under which they can perform accordingly (Helmer, 1967); and (6) be cautious in deriving a single combined position from various opinions (Helmer, 1967). Based on these, it is important to highlight the role of the mediator in the method. Maybe in no other method, this role is so critical and essential to the model, in the sense that he/she not only organizes and designs the structure but also participates with his/her own opinions and values, especially when analyzing, evaluating, combining and feedbacking the products to the respondents.

4.4. Delphi Applications

Linstone & Turoff (2002) consider that "while many people label Delphi a forecasting procedure because of its significant use in that area, there is a surprising variety of other application areas". The method is not only about looking forward, such as forecasting and planning activities. It can be also be used for looking backward as in historical events examination and historical data gathering, or to particular research opportunities in the present, such as policy-making and social and economic phenomena understanding. According to the authors, Delphi is not so much about the what is studied, but certainly about the how it is studied – in other words, it is not the nature of the application which determines the appropriateness of the method, but the "(…) particular circumstances surrounding the necessarily associated group communication process" (Linstone & Turoff, 2002).

Taken from Linstone & Turoff (2002), Murry Jr & Hammons (1995) and Dalkey (1969), the following are examples of circumstances where the Delphi Method is applicable:

- Gathering current and historical data not accurately known or available
- Examining the significance of historical events
- Evaluating possible budget allocations
- Exploring urban and regional planning options
- Planning university campus and curriculum development
- Putting together the structure of a model
- Delineating the pros and cons associated with potential policy options
- Developing causal relationships in complex economic or social phenomena
- Distinguishing and clarifying real and perceived human motivations
- Exposing priorities of personal values, social goals
- Performing industry technological forecasting
- Evaluating corporate strategic planning
- Identifying desired goals and major problems of curriculums
- Developing strategic scenario planning process for universities
- Developing assessment criteria for determining the managerial effectiveness
- Identifying the competencies and personal characteristics needed

Delphi has been used in different fields of research since its inception. In the began in the 1950s aiding Defense decision making, but after almost 70 years it reached almost every knowledge field one can think of, including Social Sciences like Management, especially in Information and Communication Technologies (Keller and von der Gracht, 2014 in Aengenheyster *et al*, 2017) and Biological Sciences like Nursing and Medicine, besides Education (Murry Jr & Hammons, 1995), Transportation and Logistics (English & Kernan, 1976), Tourism (Landeta, 2006), Security and many other, as detailed by Aengenheyster *et al* (2017). According to Gallego & Bueno (2014), "the results of the analysis reveal the large amount of research that has applied the Delphi method in the fields of Medicine and Biological Sciences. Furthermore, we can observe that the diffusion of Delphi in the Information Systems and Information Technology field is highly similar (around 5–7%) to other areas in the total period (2005–2012), apart from Medicine and Biological Sciences (close to 50%) and R&D (close to 2.50%)".

Regarding the Information Systems Delphi research, Skinner *et al* (2015) surveyed journals and conference proceedings for the period January 1991 to December 2014 and identified 61 prominent IS research papers that applied Delphi method. According to the authors, "the prevalent theme in these IS Delphi studies is issue identification (i.e., recognizing the key strategic IS issues either at a country level, the organizational executive level, or in specific technological contexts)" (Skinner *et al*, 2015). Among these 60 works, study topics included critical elements of IS infrastructure flexibility, development of a taxonomy of knowledge creation mechanisms, scope and requirements of a knowledge management systems, risk identification, identification of factors necessary for a successful ITIL implementation, and top ten remedies for runaway IT projects (Skinner *et al*, 2015).

In Brazil, the distributions are similar to what was found by these different authors. According to Chaves (2011), in his research back in 2010, 23 works were found in the University of São Paulo's database of dissertations and thesis that used Delphi. Nursing and Health areas were accountable per 43% of the total number, followed by Management with 17% (includes Human Resources, IT and General Business). The remaining studies were in areas such as Engineering, Nuclear Technology, Accounting, Education and Sports.

4.5. Method Justification

As Skinner *et al* (2015) highlight, based on Benbasat, Goldstein, and Mead (1987), "(…) researchers' goals and the nature of their research topic influence what research strategy they select." In this section, we share key motives that we believe justify the use of Delphi in this research taking into account this important guidelines.

First and foremost, as mentioned in Chapter 1, the nature of this research is forward-looking, experimental and propositional. Its overarching research question is focused on current and future impacts of a topic that is in the knowledge frontier and in constant transformation and evolution, which is Artificial Intelligence. Considering this prognostic and predictive approach, and supported by several authors, Delphi is the method that had more adherence to our purpose. According to Aengenheyster *et al* (2017) "Delphi Method is undisputedly a commonly used method in futures research", an opinion that is shared by Schmidt (1997), who considers that forecasting is a major area of application of the method in many different fields. Gordon & Helmer (1964) also provide support for this decision, explaining that a major cornerstone to Delphi Method is the intent to assess "(…) the direction of long-range trends, with special emphasis on science and technology, and their probable effects on our society and our world", which is exactly in line to our key objectives.

The second key justification for using Delphi is the limited knowledge on the topics covered here, especially in the Information System and Information Technology fields of research, as previously mentioned in Chapter 2. According to Linstone & Turoff (2002), using Delphi is justified "(…) when accurate information is unavailable or expensive to obtain, or evaluation models require subjective inputs to the point where they become the dominating parameters." This idea is complemented by Pare *et al* (2013) that confirm that "the Delphi method represents an inductive, data-driven approach that is often used in exploratory studies on specific topics or research questions for which no or limited empirical evidence exists", an opinion similar to that of Yeoh & Koronios (2010), that see particular relevance of the method where the knowledge or theory seems to be incomplete. Powell (2003) observes that the method is exceptionally useful where the judgments of individuals are needed to address a lack of agreement or incomplete state of knowledge.

Taking into account that these knowledge limitations, assessing experts on the matter is an acceptable approach to evaluate the problem because they have at their ready disposal a large store of mostly inarticulate background knowledge and a refined sensitivity to its relevance, which is of great importance to fields within inexact sciences, as social sciences (Helmer & Rescher, 1958). Linstone & Turoff (2011) explain that the original Delphi effort using experts "(…) turned out much more insightful results than the use of the Census tapes providing only floor space data and much less expensive (…)" and according to Dalkey (1969), Delphi is "(…) above all, a rapid and relatively efficient way to 'cream the tops of the heads' of a group of knowledge people". This helps in "(…) combining individual judgments may lead to process gain, where groups may perform better than their best member" (Rowe, Wright & Bolger, 1991).

Bearing in mind that we need to interact with several experts to address our objectives, an efficient approach to communicate with them was required. As previously mentioned, Linstone & Turoff (2002) believe that Delphi is more about the how then the what is studied – in other words, it is not the nature of the application which determines the appropriateness of the method, but the "(…) particular circumstances surrounding the necessarily associated group communication process". In dealing with the experts, Delphi is helpful for obtaining group consensus on uncertain events (English & Kernan, 1976). Moreover, "Delphi may be characterized as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem" (Linstone & Turoff, 2002). Considering the requirements of a group with ~~a~~ heterogeneous background and potentially from different locations, Delphi also provided a cheaper and feasible way to make these experts interact without the usual distractions (and costs) normally associated with more traditional face-to-face meetings, another key reason for choosing Delphi.

Rowe and Wright (2001) in Skinner *et al* (2015) suggest that the Delphi method is also an effective alternative when statistical method use is unsuitable, inapplicable or hard to use, several experts are available, the alternative is simply to average the forecasts of several individuals, or the alternative is using a traditional group.

Finally, there is also a considerable adherence and compatibility between the Delphi method and the Information Systems and Information Technology fields, which we understand to be an important complementary justification for choosing this method. According to Skinner *et al* (2015), "(…) Delphi method is particularly appropriate for acquiring expert recommendations when addressing an IS research issue" (…) "due to these specialist authorities having extensive knowledge of specific areas of IS interest". Gallego & Bueno (2014) also explain that findings show that Delphi is a current method used to develop studies in the IS/IT field and Landeta (2006) in the Social Sciences fields.

In spite of Delphi being the key method selected for this work, it is complemented with other techniques and methods, either quantitative or qualitative, to fulfill different purposes. In that sense, we follow Skulmoski *et al* (2007)'s observation that explains that Delphi may be only one component of the research project. "The researcher would select the Delphi method when he wants to collect the judgments of experts in a group decision-making setting. Both qualitative and quantitative methods can be used in the Delphi process. The Delphi method may be only one component of the research project; for example, the Delphi outputs may be verified and generalized with a survey" (Skulmoski *et al*, 2007). This is compatible with Rowe & Wright (2011), that understand Delphi not “as a standalone approach, but as a method that may be enhanced by other approaches, or that may contribute as input to others.”

5. Research Design and Execution

In this chapter, we cover the design, planning, and execution of the research method. We begin with preliminary considerations required to understand the rationale behind the method design, and application, considering Frey & Osborne (2017)'s findings as a major reference and starting point. The key design features are explained in detail, as well as the execution itself before the current research results are presented, analyzed and discussed in the following chapters. This is a key component within the research in the sense that it should clearly explain the research procedure and set the bridge between literature, method and application, allowing for scrutinization, validation and possible replication, key features of academic research and the scientific method.

5.1. Preliminary Considerations

Since Frey & Osborne (2017)'s research is a reference and one of the key starting points to this work, two important topics must be evaluated in advance to make sense of the research design and execution. The first one is an essential awareness about the database used for both researches and its underlying conceptual framework, which are used and discussed throughout this work. The second one is the understanding of Frey & Osborne (2017)'s research method, and its outcomes and limitations, which are evaluated and challenged in this research with a different approach, as is explained in further detail later on.

O*NET Database Understanding

Frey & Osborne (2017), as Blinder (2009) before them, used in their 2013-2016 research the continuously up-to-date database on occupations from the O*NET Resource Center, a U.S. primary source of occupational information sponsored by the U.S. Department of Labor[69]. O*NET offers an organized, comprehensive and standardized dataset that is occupation-specific, covering almost a thousand occupations found in the U.S. labor market, and as an extension, worldwide. In Brazil, to best of our knowledge and research, no database with similar structure and statistics were found. Thus, to mitigate the risk of including an additional variable to the complex equation at hand and to leverage the excellent work in terms of data quality, method robustness, and strong conceptual background, it was the researchers' choice to also use the occupational data from O*NET database.

Occupations in O*NET are detailed based on 20 textual and categorical descriptors, most of them backed up with the theoretical background. These descriptors are, according to Frey & Osborne (2017), an important feature because they are measurable and grounded in a pre-defined set of common variables that serve as building blocks, breaking down all occupations in a quite homogeneous way. On one hand, some of these descriptors are textual (open-ended variables) with specific values per occupation, which are very hard to manage for research purposes. On the other hand, some are categorical descriptors (nominal variables) with cross

[69] https://www.onetcenter.org/overview.html

occupation values that can be very useful for several objectives, including eventual comparisons between two or more occupations.

O*NET organizes these 20 descriptors in a structure called Content Model, a framework that combines and classifies the several types of information about occupations into 6 domains (groups of characteristics) and 4 major orientations (different visions on the characteristics). Figure 4 is a graphical representation of Content Model, with its descriptors, domains, and orientations. Additionally, O*NET has 5 other descriptors that focus on additional information and that are not considered and detailed in the Content Model – thus, are not represented in the illustration.

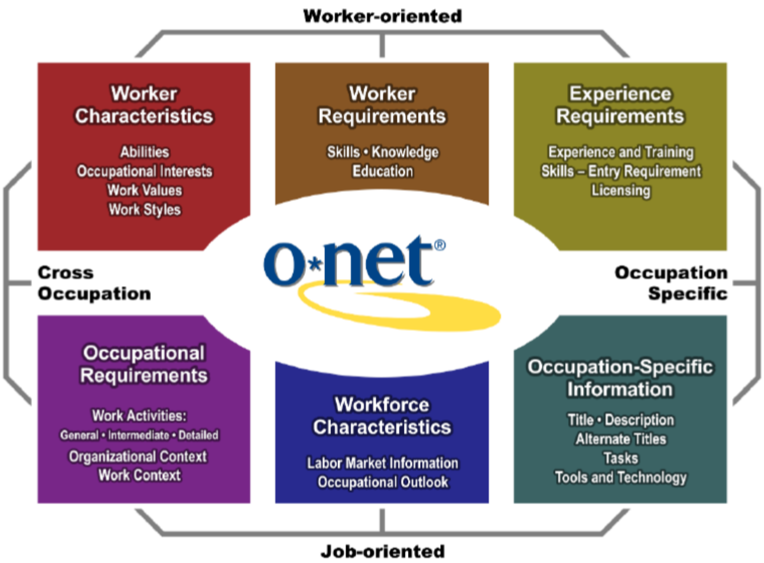


Figure 4. O*NET's Content Model

Source: O*NET (2019)[70]

From the overall number of descriptors (20+5), half of them (12) are fully standardized with pre-defined values and can be considered as categorical (nominal) variables (with *n* values each). As an example, we have Work Values, a nominal variable that has 6 values, which are: Realistic, Investigative, Artistic, Social, Enterprising and Conventional[71]. The remaining descriptors (13) are mostly open text free descriptions without any particular rigor that cannot be considered as useful variables for this particular research (more variation, less homogeneity). These can be immediately discarded unless previous particular handling is performed. The entire set of descriptors are detailed in Table 8. For further detail on the values for Abilities, our major focus in this research, we share the complete list of the 52 values in Appendix 2.

[70] https://www.onetcenter.org/content.html
[71] https://www.onetonline.org/find/descriptor/browse/Interests/

Descriptor	Description	Orientation	Type	Values
Abilities	Enduring attributes of the individual that influence performance.	Worker	Nominal	52
Occupational Interests	Person's preferences for work environments and outcomes.	Worker	Nominal	6
Work Values	Global aspects of work that are important to a person's satisfaction.	Worker	Nominal	6
Work Styles	Personal characteristics that can affect how well someone does a job.	Worker	Nominal	16
Skills	Developed capacities that facilitate learning and the performance of activities that occur across jobs.	Worker	Nominal	35
Knowledge	Organized sets of principles and facts that apply to a wide range of situations.	Worker	Nominal	33
Education	Required level of education to perform a job	Worker	Nominal	12
Experience and Training	Type of experience required	Worker	Nominal	4
Credentials and Licensing	Relevant training programs, certifications, licenses, and registered apprenticeships for this occupation.	Worker	Text	-
Work Activities	Work Activities summarize the kinds of tasks that may be performed across multiple occupations.	Job	Nominal	41
Detailed Work Activities (DWAs)	DWAs provide information on the common work activities required across occupations.	Job	Text	-
Organizational Context	Characteristics of the organization that influence how people do their work.	Job	Text	-
Work Context	Work Context refers to physical and social factors that influence the nature of work.	Job	Nominal	57
Labor Market Information	Current labor force characteristics of occupations.	Job	Text	-
Occupational Outlook	Projections of future economic conditions and labor force characteristics of occupations.	Job	Text	-
Wages & Employment	Summary national wage and employment data.	Job	Text	-
Job Openings	Search for job postings relevant to this occupation.	Job	Text	-
Title	Primary title and code used to identify a single occupation.	Job	Text	-
Description	Statement of required or important duties performed by workers in an occupation.	Job	Text	-
Alternate Title	Alternate or "lay titles" include related job titles and occupational titles.	Job	Text	-
Tasks	Specific work activities that can be unique for each occupation.	Job	Text	-
Tools and Technology	Machines, equipment, tools, softwareworkers may use for optimal functioning.	Job	Text	-
Technology Skills	Technology Skills provide examples of software that workers may use.	Job	Text	-
Job Zone	Group of occupations with similar experience, education, and training requirements.	Job	Nominal	-
Related Occupations	Individuals looking to change careers can pursue these occupations with minimal additional preparation.	Job	Nominal	~1000

Table 8. O*NET Descriptors

Source: O*NET (2019)[72]

Using these descriptors as building blocks, and collecting and updating data frequently thru job incumbents and occupational experts through detailed questionnaires, O*NET details every occupation in its database,

[72] https://www.onetonline.org/help/online/summary

considering their distinguishing characteristics of (a) knowledge, skills, and abilities requirements mix, (b) activities and tasks performed and (c) other additional descriptors.

The outcome of this work can be illustrated by the telemarketer occupation. Telemarketer occupation's goal is to "solicit donations or orders for goods or services over the telephone"[73]. It does not require a college degree (89% have high school or less than high school), but, on the other hand, it demands several communication abilities like Oral Expression, Oral Comprehension, Speech Clarity, Speech Recognition, Selective Attention, Written Comprehension; and skills like Speaking, Persuasion, Active Listening, Service Orientation, Social Perceptiveness, and Reading Comprehension. A complete profile of telemarketers taken from O*NET for reference can be found in Appendix 3.

Some nominal descriptors have an additional feature called scale[74]. There are seven scales available (each one with their numerical ruler): Level, Importance, Relevance, Frequency, Occupational Interest, Extent, and Content, but their application depends on specific domains – the descriptors. The two most commonly used and with broader availability in O*NET – the predominant pair as Frey & Osborne (2017) put it – are Importance and Level. Importance measures the relevance of a descriptor required for a particular occupation (from 1, not important to 5, extremely important), while Level measures the complexity of a descriptor required for a particular occupation (from 0, lowest complexity to 7, highest complexity).

The meaning of each, as well as their distinction, are easier to understand with an example. In the Telemarketers case, 33 abilities (out of 52) are marked as being relevant to the occupation (meaning Importance scale is higher than 1). Of those, 6 are marked as more important than the average (Importance scale is higher than 3), which means they are highly relevant and necessary to adequately perform the duties of that particular occupation. They are Oral Comprehension, Written Comprehension, Oral Expression, Selective Attention, Speech Recognition, and Speech Clarity. From this subset of the highly relevant, Oral Expression is the one more demanding, reaching 4 out of 7 in the Level scale, meaning that it would be necessary to do a relatively complex task such as "giving instructions to a lost driver" as part of the occupation, while Selective Attention is the one less demanding, reaching out 2,6 out of 7 in the Level scale, meaning that it would be necessary to do simpler tasks like "answer a business call with coworkers talking nearby".

Figure 5 and Figure 6 illustrate with examples the Importance and Level scales for Oral Expression and Selective Attention, already normalized (from 0 to 100) for better understanding and with the correspondent anchors. Anchors are representations of the different degrees within a scale, especially in the Level scale, as the examples already mentioned: "giving instructions to a lost driver" or "answer a business call with coworkers talking nearby". Anchors were developed by O*NET and are used in their questionnaires to make it easier for respondents. Anchors are ability dependent, meaning that they are specific per ability, and not by occupation. This allows having the same ruling standard for all occupations, although the anchors themselves can be hard to understand when applied to an occupation.

[73] https://www.onetonline.org/link/summary/41-9041.00
[74] https://www.onetonline.org/help/online/scales

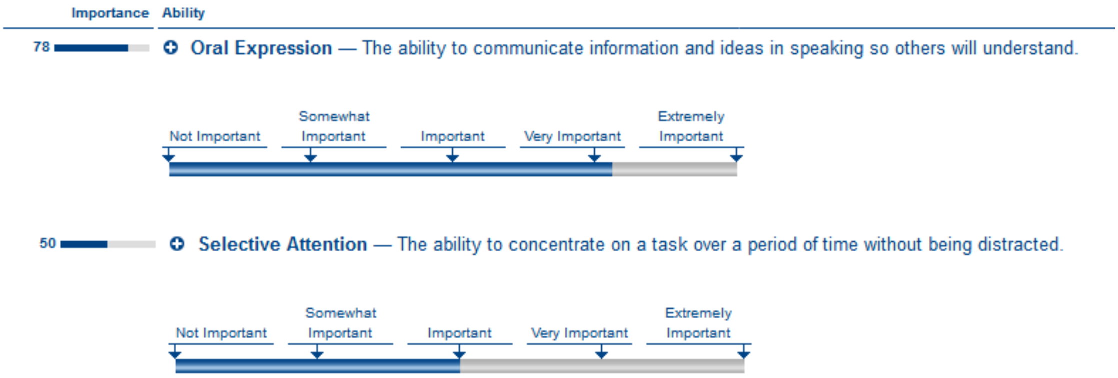


Figure 5. Sample of Ability Importance

Source: O*NET (2019)

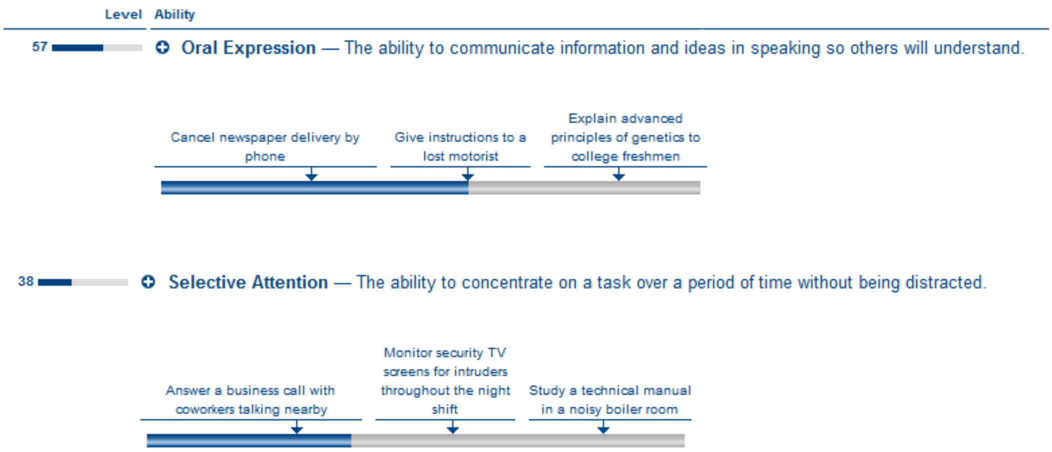


Figure 6. Sample of Ability Level

Source: O*NET (2019)

With this occupational framework, O*NET provides an open database that covers all occupations and their specific details thru textual and categorical descriptors with the respective numeric scales available. This is a good starting point for researches like this one.

Frey and Osborne (2017)'s Method Analysis

Considering the objectives defined for this work, one of the key motivations was to evaluate and possibly challenge Frey & Osborne (2017)'s ranking of occupations according to their susceptibility to computerization, as well as their analysis, methods, and conclusions. But a deeper previous understanding of the authors' method is required to proceed.

Using the aforementioned O*NET database and based on Blinder (2009)'s approach, the first step in Frey and Osborne's method to reach a ranking was to subjectively hand-label a subset of 70 occupations (the ones the authors had more confidence in doing so) according to their susceptibility of being automated. This analysis was done based on the occupation's descriptions and tasks taken from O*NET, considering whenever possible task simplification. Researchers questioned themselves "can the tasks of this job be sufficiently specified, conditional on the availability of big data, to be performed by state of the art computer-controlled equipment?" and answered assigning 0 (not automatable) or 1 (automatable) for each one of the 70 occupations (Frey & Osborne, 2017). The chore was performed with the support from a group of specialists in Machine Learning in a live workshop held in Oxford (Frey & Osborne, 2017). As a result, occupations like Taxi drivers and chauffeurs (53-3041), according to the analysis of the authors and experts, was granted 1 (automatable), while Athletes and sports competitors (27-2021) was granted 0 (not automatable).

Since relying in text descriptions and subjective determining their susceptibility limits a broader analysis and brings along several biases, a second step was necessary to overcome drawbacks and "(…) to create a purely objective ranking based on standardized and measurable variables" using a probabilistic classification algorithm (Frey & Osborne, 2017). This second step, according to the authors, is inspired in Jensen and Kletzer (2005)'s approach and relies one more time on the O*NET database, but in a different way (Frey & Osborne, 2017).

First, authors evaluated all the values of nominal descriptors available in O*NET and, considering the literature review previously executed, selected 9 of them as bottlenecks of computerization - by bottlenecks they basically meant challenging or hindering areas for technologies to automate. These bottlenecks were single values from different descriptors: Finger Dexterity, Manual Dexterity and Originality (all taken from the 52 possible values of descriptor Ability); Cramped Work Space, Awkward Positions (taken from the 57 possible values of descriptor Work Context); Fine Arts (taken from the 33 possible values of descriptor Knowledge); Social Perceptiveness, Negotiation and Persuasion (taken from the 35 possible values of descriptor Skills); and finally Assisting and caring for others (taken from the 41 possible values of descriptor Work Activities). The selection is represented in Table 9.

Descriptor	Type	Possible Values	Selected by Frey&Osborne	Features (values selected)
Abilities	Nominal	52	3	Finger Dexterity, Manual Dexterity and Originality
Occupational Interests	Nominal	6	0	-
Work Values	Nominal	6	0	-
Work Styles	Nominal	16	0	-
Skills	Nominal	35	3	Social Perceptiveness, Negotiation and Persuasion
Knowledge	Nominal	33	1	Fine Arts
Education	Nominal	12	0	-
Experience and Training	Nominal	4	0	-
Work Activities	Nominal	41	1	Assisting and caring for others
Work Context	Nominal	57	1	Cramped Work Space, Awkward Positions
Total		**262**	**9**	

Table 9. Selected Bottlenecks

Thenceforth, Frey & Osborne (2017) extracted from O*NET a dataset containing the Level scale of the 9 bottlenecks for all the occupations available. In other words, they built a data matrix of 9 bottlenecks per 702 occupations - the complete dataset, where the 70 previously hand-labeled subsets of occupations were segregated into a training and a validation dataset.

Considering these bottlenecks as independent variables X's and the hand label of susceptibility or likelihood of being automated from step one as the dependent variable Y, the authors applied a probabilistic classification machine learning algorithm in the dataset with three different models (logistic regression, rational quadratic and exponentiated quadratic) to evaluate their fit to the data. According to the authors, the exponentiated quadratic algorithm was the one that offered the best results in the training and validating datasets and was the chosen one to proceed (Frey & Osborne, 2017). Therefore, the algorithm successfully managed to reproduce and confirm the hand-labels occupations from step 1 and verified their subjective judgments systematically and consistently. This logic was then applied to the complete dataset, returning the susceptibility of each one of the 702 occupations evaluated, building their final ranking.

Frey & Osborne (2017)'s method and results are a worthy initiative, a major cornerstone in the occupations automation susceptibility debate, which in no case is a simple task. Yet, we understand there are some limitations in the method applied by the researchers and consequently in their findings, some of them humbly acknowledged by themselves. These key limitations are explained next.

Subjectivity: O*NET does not cover any particular measure about how automatable an occupation is, any attempt in creating a ranking based on indirect variables will have drawbacks, especially in terms of subjectivity, and this is not limited to Frey and Osborne findings. If based on the individual analysis of textual tasks and descriptions, like what was done by Blinder (2009), the risks are of biasing the results and not being able to replicate it (Frey & Osborne, 2017). If based on evaluating objective variables, as Jensen & Kletzer (2005) in Frey & Osborne (2017), the subjectivity lies on which variables and values to use and how to use them. In other words, although considering different methods, both approaches have, to a greater or lesser extent, some degree of subjectivity from whoever performs the ranking. Frey & Osborne (2017) tried to overcome this issue by creating a mixed approach, a resourceful idea already explained. But this alternative may be also questionable because it can bring in fact both the drawbacks (hopefully to a minor extent) of the two original approaches. And although using an algorithm to generate the ranking in their second step may look far more objective, the author's model is based on top of an independent variable that was subjectively defined, using completely different criteria. It is worthwhile to mention that O*NET has a variable within the descriptor Work Context called Degree of Automation that evaluates how automated is an occupation. Though interesting, this variable measures the current situation of the occupations in terms of automation but gives no indication to how automatable it could be in the near future with the technologies discussed in this thesis.

Simplification: In the process of building their ranking, the authors made a restricted use of the data available in O*NET (both in values and descriptors) based on the bottlenecks taken from the literature, reaching a simplification of the problem at hand. Occupations are a complex construct comprised of several categories that are intertwined, dependable on each other. Although necessary and valuable because of all the effort in standardization, the O*NET system itself is a simplification of this intricate ecosystem. While simplifications are acceptable and necessary in complex problems like this, one can argue that the authors' method was, in fact, an oversimplification. Frey & Osborne (2017) basically used only a subset of values taken from a combination of descriptors like Abilities, Skills, Knowledge, Work Context and Work Activities, 5 out of 9 O*NET nominal descriptors, setting aside Interests, Values, Styles and Education without much considerations. Moreover, and as already mentioned, the way to reach this simplification was not covered in much detail. It is quite comprehensible that some descriptors are hard to make sense in the automation discussion, like Occupational Interests, which is defined as a person's preferences for work environments and outcomes. Nonetheless, it is not clear why Knowledge should be considered at all (considering knowledge is, after all, a database), but in the case of doing so, why only one value was marked as a bottleneck (Fine Arts). In summary, considering that a simplification was executed, Frey & Osborne (2017) should have been more meticulous in explaining the motivations and rationale for using or turning away descriptors and values in their research (once again, adding more subjectivity).

Importance: In their dataset, Frey & Osborne (2017) considered the Level scale for their calculations. As mentioned, and simply put, Level measures the complexity degree of a descriptor required for a particular occupation. As explained by Frey & Osborne (2017), in Manual Dexterity, for instance, low corresponds to "screw a light bulb into a light socket", medium to "pack oranges in crates as quickly as possible" and high to "perform open-heart surgery with surgical instruments". The use of Level is consistent because as shown, it considers the nuances of complexity from the bottlenecks (let's say, light or hard bottleneck). However, the author's model does not consider the Importance scale in the analysis, which means that all characteristics have the same weight when evaluating occupations. This has a particular countereffect: even though two distinct occupations may use a bottleneck Ability up to the same Level score – like Originality, the logic does not differentiate between the one where this Ability is very relevant and the other where it is not. This issue appears when Importance is taken out of the equation. Maybe this explains a confusing situation seen in the authors raking: in spite of having 2 of the 9 bottlenecks selected (Persuasion and Social Perceptiveness), which are marked as very important features, telemarketers hold the number one position in the ranking, as the most likely occupation to be replaced or computerized in the next 20 years.

Bottlenecks: Two of the important decisions taken by Frey & Osborne (2017) in their method as starting points are (a) the definition of bottlenecks and (b) the hand-label of 70 occupations. In regard to the first, the bottlenecks, the authors explain that it was based on a literature review, which can be disputed regarding its extensiveness. These so-called Computerization Bottlenecks set the boundaries of computerization of non-routine tasks and Frey & Osborne (2017) indicate three basic groups: Perception and Manipulation, Creative Intelligence and Social Intelligence, drawing upon the literature, and a workshop held at the Oxford University Engineering Sciences Department. However, as shown in

Table 9, when translating these into the values and variables descriptors of O*NET, only 9 values out of 262 possible values were marked as bottlenecks, or 9 out of 218 possible values if we consider only 5 descriptors used by the authors – 4.13% of the total amount of possibilities. We believe this percentage shows a slightly pro-technology bias in the evaluation. Additionally, in a superficial review of the descriptors, we can see several cases that were not marked as bottlenecks but should have been and others marked, that should have not. Management of Personnel Resources value from Skill descriptor, for instance, is about motivating, developing, and directing people as they work, identifying the best people for the job. We think this a hard skill of being performed autonomously by a machine and yet, it was not selected as a bottleneck. On the other hand, Fine Arts value from Knowledge descriptor, which is the awareness of "the theory and techniques in regard to composing, producing, and performing music, dance, visual arts, drama, and sculpture" was selected as a bottleneck, but other knowledge like Therapy and Counseling, Education and Training were not – and no justification was provided.

Labeling: The second point of debate already mentioned was the occupation hand-labeling task, which was executed in the Oxford workshop and that had the participation of some other specialists (Frey & Osborne, 2017). In regard to this workshop, little information is shared with the reader about planning, logistics, and execution. What were the circumstances of this workshop? What was the method used to extract the group opinion? Who were the participants selected and how experts were they in the matter? Where they mostly scholars, professionals or a mix and how were they selected? As seen in Chapter 4 when discussing the Delphi method, group decisions made in live meetings can be vulnerable to several psychological factors, such as the wagon effect, that may pose at least some reservations in regard to the findings of these workshops. Again, subjectivity plays a major role when performing the hand labeling, because Frey and Osborne consider possible task simplification, which allows some currently non-automatable tasks to be considered automatable, again without many details.

While the approach used by the authors may have some limitations or even issues that can be used to dispute the conclusions, not much can be criticized about the machine learning technique used for reaching the ranking. Apart from the careful and detailed explanation of the concepts and use of the technique, allowing for replication if desired, Frey & Osborne (2017) used some of the best practices in machine learning algorithms. They applied different logics to find the better fit, they segregated data into different subsets for training, testing, and validation, avoiding the overfitting matter. Chicco (2017) and Tetko *et al* (1995) explain that "overfitting happens every time an algorithm excessively adapts to the training set, and therefore performs badly in the validation set (and test set)."

5.2. Delphi Plan and Design Scheme

As previously mentioned, Delphi was the selected method for field research. Considering Powell (2003)'s recommendation to ensure credibility in Delphi findings, we believe it was essential to include a clear decision trail to defend the appropriateness of the method to address the problem selected, including its specific features like choice of the expert panel, data collection procedures, and discussion on consensus levels. This is the key intention of this section, which is complemented further ahead with the details on the execution.

Based on the methodological research discussed in Chapter 4, to adequately and successfully run this type of research, some features are required in terms of planning, designing, and executing. They are summarized in Figure 7.

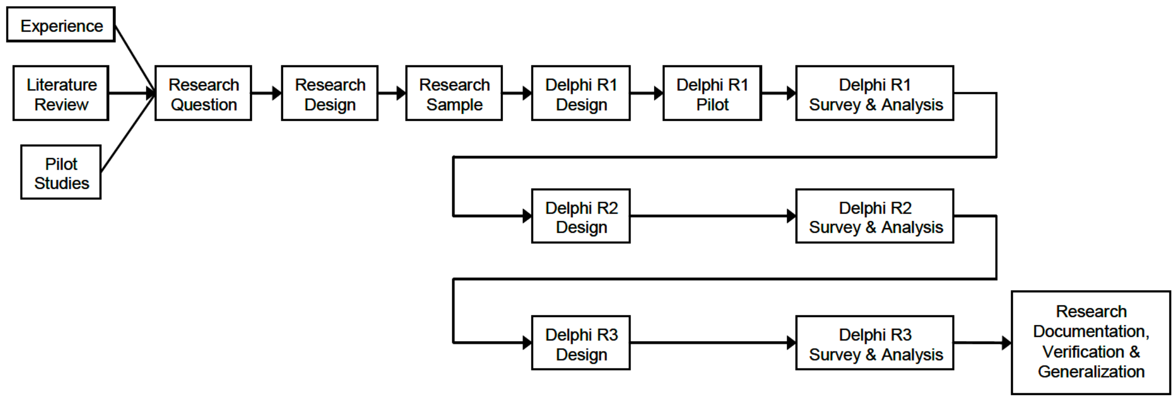


Figure 7. Three Round Delphi Process

Source: Skulmoski *et al* (2007)

Four items are of particular relevance: the design, the experts, the questionnaires and the logistics. The first three are related to the overall design and are covered in detail in the following paragraphs using Skulmoski *et al* (2007)'s scheme as the main reference and theoretical backup. The logistics planning and execution, on the other hand, is detailed in the following section.

Research Question and Design

Considering Skulmoski *et al* (2007)'s Delphi Process Representation as the main reference to design and plan the research, the first concern prior to selecting Delphi itself was to clearly define and refine the Research Question, either based on experience, literature and/or possibly even pilot studies. This process and its content are already covered in the initial chapters of this work (in introduction, questions, objectives, motivations and literature review) and were performed, presented and validated by a competent committee prior to discussing the method itself, as part of the broader scientific research method.

Next phase was performing the Research Design which basically meant evaluating the proper method to address questions and objectives. As explained and justified in Chapter 4, Delphi was selected considering the overarching question and characteristics of this work. Nonetheless, Skulmoski *et al* (2007) explain that Delphi may be only one component of the research project, which means it can be complemented with other research methods, either quantitative or qualitative, for different purposes. In this case, while Delphi may address the key impacts and bottlenecks of artificial intelligence discussion in an adequate manner, the evaluation of Frey &

Osborne (2017)'s ranking demanded a different approach. Therefore, we complemented the first Delphi questionnaire with a limited survey on abilities, designed to leverage the expert opinions in regard to the automation susceptibility ranking. This survey is treated separately in the following sections.

During the Research Design phase, six other relevant strategic decisions about Delphi were taken in order to modify and adjust the method to best answer the proposed research questions, as suggested by Skulmoski *et al* (2007):

- Delphi Mode: First decision was to run the Delphi Technique in its qualitative ranking form mode, which basically means to use Delphi as a way to reach a consensus on the relative relevance of different criteria set regarding a particular theme, without specific estimations as in its traditional form. This ranking form option is more suitable to the characteristics and context of the issue at hand because it helps in exploring questions about impacts and bottlenecks related to artificial intelligence and in defining ordered lists of the most important items of each group according to expert opinions (Chaves, 2011). Nonetheless, we are not necessarily concerned with the consensus itself, meaning that we decided not to run several iterations just for reaching an agreement.

- Number of Rounds: Second decision was to define that execution of Delphi would be done in three rounds for this particular research, what Skulmoski *et al* (2007) consider to be the typical Delphi format – though the authors mention single and double round Delphi studies also performed with good results. Evaluating different supporting evidence, Chaves (2011) explains that the two and three round variations of Delphi are the most common ones in studies, varying from 63% to 88% of the cases, with the more common being the three round in a 3 to 1 ration. Evidently, the number of rounds depends on the consensus, if this is the ultimate objective of the research, and time availability. In other words, Delphi may require additional rounds than the ones initially planned, just like it may disregard rounds if they are not relevant anymore.

- Design of Rounds: Considering the execution in three rounds, the objective and format of each round were then planned. For round 1, the key objectives were (a) to present the researchers along with the objectives and context of the research, (b) to collect from experts relevant information about their profiles (background, experience, inclination towards artificial intelligence, etc.), (c) to collect from experts their opinions about AI impacts and bottlenecks (open-ended questions) and (d) to collect from experts responses in an Abilities survey about their susceptibility of being executed or emulated by machines. Based on the data gathered with the open questions, we analyzed and carefully combined impacts and bottlenecks and developed 5 lists of about 30 items each. For round 2, the key objectives were (a) to feedback the results of the previous round, presenting the five lists developed, (b) to request the experts to select the most relevant impacts and bottlenecks for each one of the lists (closed-ended questions) and (c) to request the experts to rank the items on each list according to their individual opinion (closed-ended questions). Once again, based on the selected items and the individual rankings, we combined them and created collective rankings with the aid of statistical indicators. For round 3, the key objectives were (a) to feedback the results of the previous round, presenting the five lists collectively ranked with the top 10 for each, (b) to show the experts a comparison of their individual rankings and the collective rankings and (c) to request the experts to review (if necessary) their rankings based on the feedback provided (closed-ended questions).

- Comparative Analysis: Third key decision was to run two separate and parallel Delphi's for two groups of experts. During the selection of participants, which is covered in the next bullet point, an interesting opportunity was evaluated based on the supporting literature on the Delphi method. The approach, first proposed by Couger (1988), later reanalyzed and improved by Schmidt (1997), was to run the Delphi in two separate and parallel groups of experts with the objective of running a comparative analysis on the findings of each group by the end of the research. Couger (1988)'s Delphi focused on the most important human resource issues in information systems, but segregated it into two distinct groups, IS executives and HR managers. In this research, where the key concern is the artificial intelligence impacts and bottlenecks, we were interested in evaluating how distinctively the topics could be perceived by scholar and market professionals. More details are presented in the following sections on this approach.

- Number of Participants: Fourth decision was on the adequate number of experts, which was decided to be 24. Backed by evidence found in the literature evaluated, Chaves (2011) explained that the number of participants usually varied between 4 to 11, 9 to 21 or 11 to 37 in the different analytical evaluations performed. Despite the different points of view in literature in regard to the acceptable and/or optimal size for a Delphi panel evaluated in Chapter 4, it was decided to consider and use as a technical backup English & Kernan (1976)'s recommendation who states that "a group number of 10 is considered a minimum and a 10-20% drop out rate per round must be allowed for". Ten is also the minimum panel size according to Murry Jr & Hammons (1995) and adequate considering the homogeneity of the members (in terms of meaning background and expertise). Therefore, this Delphi was executed considering 24 experts, half of them (12) from the Scholar group and the other half (12) from the Market group (or Professionals). An additional rule determined regarding experts was not to permit replacements, in order to avoid possible discrepancies as stated by Gordon & Helmer (1964), aware that this could reduce the final number of participants.

- Interaction Mode: The fifth decision was to define that the key communication channel between mediator and experts would be electronic mail, instead of paper mail (too old and too slow) or telephone (not reliable). Electronic mail was the primary communication channel, nevertheless, complemented as needed by the use of newer methods, such as social networks like LinkedIn and WhatsApp and eventually calls – e.g. to introduce the research or reach out those participants that took too long to reply. On the other hand, the interaction per se was executed thru three different digital questionnaires (build-in pdf forms), one for each phase. Again, paper mail option was disregarded (since it is too slow and limited), just like the telephone (since it lacks traceability). Online questionnaires using internet providers were evaluated but since they have their own limitations, costs and have also reduced traceability, the decision was to opt for the pdf version. There was no specific support from any kind of software to execute communications or interactions.

Research Participants

"Selecting research participants is a critical component of Delphi research since it is their expert opinions upon which the output of the Delphi is based" (Skulmoski *et al*, 2007). Therefore, the first decision on the expert selection was to define a feasible geographic dispersion of participants. Due to time, logistics and networking constraints, this research was restricted to the opinions of experts that had Brazil as their major influence area, no matter their nationality or working place, though most were Brazilians, working in Brazil. Aware of the consequences of this decision to the research – e.g., restricting the findings to a specific country and handicapping generalization, the researchers believed that this would not jeopardize the overall results achieved, especially because most of the experts selected already had international experience. Still, we consider this effort a first and limited application, and we foresee potential rollouts to other geographies and other periods in time, allowing future comparative studies.

The second decision on the expert selection was to define the adequate background required. This was a particular challenge because of the combination of different subjects, areas, and fields evaluated in the research. On one hand, hard technical mathematical and computer science topics like Artificial Intelligence (and related technologies); on the other, applied social sciences, management, organizations, and occupational marketplace, not to mention the association between them, either by impacts or bottlenecks. It is fair to assume that few people in Brazil (and possibly worldwide) have such broad knowledge and capability to cover satisfactorily all of these areas with equal sound quality and expertise. As feasible alternatives, we came up with two other profiles, simpler to find than the omni knowledge expert just mentioned: (a) Artificial Intelligence researchers and practitioners with strong technical background, still with possibly limited knowledge in business themes or (b) business and management researchers and practitioners with strong expertise in organizations, but with possibly limited knowledge in Artificial Intelligence. Faced with this choice between the two groups, we decided to proceed for this research with the first profile only, Artificial Intelligence researchers and practitioners with strong technical background, considering four main reasons. First, considering the misuse, confusion and the science fiction component of Artificial Intelligence (already covered in the literature review), we believed it was more relevant to have experts that could cover adequately the hard science knowledge rather than the management perspective (which, by the way, most of the experts have some knowledge, being part of organizations themselves). Second, as explained further ahead in this chapter, the Ability survey requires a real knowledge on the hard science topics to answer adequately – otherwise, it is just mere guessing, especially for those without a technical background. Third, our background, knowledge and expertise are in Information Technology, Business and Management, but not in hard Artificial Intelligence fields. With this configuration, experts in Artificial Intelligence and researchers in Business, we assumed that the research would have a better balance between the two fields. And fourth, while searching for experts within the first group is, to a certain extent, easier, seeking for experts in Management that have some basic knowledge in AI is hard and subjective –

during the time of the research, only a handful was evaluated, not reaching the minimum number required. Expanding this research to the second group could be an interesting future complementation of this academic effort.

Based on the previous choice, the third decision was to deep dive and define the detailed profile of the participants. Since the early stages of Delphi, it was the researchers' design to run two groups of experts in the Artificial Intelligence topic, but with sound distinct experiences, thus the Scholar and the Market group segregation previously mentioned. The key objectives in using this approach were (a) to create a stronger consensus within the homogeneous groups, while, at the same time, (b) to evaluate a weaker consensus between groups. This would allow comparing responses from experts with different backgrounds and professions, confirming if there is some kind of gap between the opinions of these two groups in the matter at hand. Historically and in several field areas, including Information Technology and Artificial Intelligence, the gap between academy and market has been a topic of heated discussion. Executing this parallel and independent Delphi would then provide data to run comparative analysis to verify the size of the gap, at least for the topic of impacts and bottlenecks. No initial hypothesis was defined in terms of possible differences between Scholar and Market groups, because of the several variables involved and the lack of the previous background.

The categorization of these two groups is as follows. The Scholar group was defined as the one with a stronger and longer academic and educational background, composed by professionals that either teach or research as their major activities (if possible, with publications in the Artificial Intelligence area) – e.g. university AI professors and researchers. The Market group was defined as the one with a stronger market and commercial background, composed by professionals that develop, sell or buy AI solutions in the marketplace as their major activities – e.g. AI executives, architects, practitioners, and specialists. The segregation was done considering the résumés of the experts and validated by themselves in the first question of the background check section. Evidently, in working with a group of experts in such a complex area, it was already expected that the groups would have some level of overlap – either market professionals with a strong academic background or academic teachers that also have market orientation. This issue was considered as tolerable, without negative impacts on the findings or comparisons as long as it wasn't preponderant within the groups. Again, based on résumé analysis and in the responses of the 24 initial participants, this assumption was kept: all the members of the Scholar group marked in the questionnaire Academy as being their key concentration area, while all the members of the Market group marked Market as their main concentration area. This also permitted a further validation of our segregation and substantiates the next steps of analysis.

To select the participants of the Scholar group, the decision was to choose active professors and researchers with at least the Ph.D. degree preferably in technical careers (such as Engineering and Computer Sciences) and which had Artificial Intelligence as an area of interest in their curriculums. Active meant experts that were researching, publishing or delivering classes university courses. An initial list was built based on the current and past steering committees[75] of the Brazilian Artificial Intelligence Special Committee (CEIA), an academic commission from

[75] http://comissoes.sbc.org.br/ce-ia/pg/?p=composicao&l=Composi%E7%E3o

the Brazilian Computation Society (SBC)[76] – the assumption was that these scholars were already submitted to careful scrutiny to be part of the committee and that the group itself was already quite diversified in background, gender, geography, etc. These experts were also among the top 200 publishers in the Artificial Intelligence area. The number of distinguished scholars found was 41, which was defined as the initial set. Résumés and contact info (e-mail and telephone numbers) were collected one by one from Plataforma Lattes[77], a unified database of Brazilian researchers maintained by the Brazilian Scientific and Technologic Development Council (CNPq). Three of the initial 41 were removed from the scholar list due to lack of information, being replaced by three other experts with similarly unremarkable credentials (indications from other participants). The list of scholar experts is provided in Table 10 in alphabetical order.

Name	**Institution**	**CEIA**
Alexandre da Silva Simões	UNESP	Y
Aline Marins Paes	UNIRIO	Y
Ana Lucia Cetertich Bazzan	UFRGS	Y
Anarosa Alves Franco Brandão	USP	N
Antonio Carlos da Rocha Costa	FURG	Y
Ariadne Maria Brito Rizzoni Carvalho	UNICAMP	Y
Augusto Loureiro da Costa	UFBA	Y
Celso Antônio Alves Kaestner	UTFPR	Y
Denis Deratani Mauá	USP	Y
Diana Francisca Adamatti	UFRG	Y
Díbio Leandro Borges	UNB	Y
Edson Satoshi Gomi	USP	N
Estevam Rafael Hruschka Júnior	UFSCar	Y
Fabio Gagliardi Cozman	USP	Y
Fernando Santos Osório	USP SC	Y
Flavia Cristina Bernardini	UFF	Y
Flávio Moreira de Oliveira	PUC-RS	Y
Flavio Tonidandel	FEI	Y
Francisco de Assis Tenorio de Carvalho	UFPE	Y
Frederico Luiz Goncalves de Freitas	UFPE	Y
Geber Lisboa Ramalho	UFPE	Y
Gerson Zaverucha	UFRJ	Y
Graçaliz Pereira Dimuro	UFRG	Y
Gustavo Alberto Giménez Lugo	UTFPR	Y
Heloisa de Arruda Camargo	UFSCar	Y
Jacques Wainer	UNICAMP	Y
Jaime Simão Sichman	USP	Y
Jomi Fred Hübner	UFSC	Y
Karina Valdivia Delgado	USP EACH	Y

[76] CEIA - Comissão Especial de Inteligência Artificial, da Sociedade Brasileira de Computação (SBC)
[77] http://buscatextual.cnpq.br/buscatextual/busca.do?metodo=apresentar

Kate Cerqueira Revoredo	UNIRIO	Y
Leliane Nunes de Barros	USP	Y
Luis Fernando Mello Barreto	USP	N
Luis Otávio Campos Alvares	UFSC	Y
Marcelo Finger	USP	Y
Maria Carolina Monard	USP SC	Y
Paulo Eduardo Santos	FEI	Y
Renata Vieira	PUC-RS	Y
Ronaldo Cristiano Prati	UFABC	Y
Rosa Maria Viccari	UFRGS	Y
Sheila Regina Murgel Veloso	UFRJ	Y
Solange Oliveira Rezende	USP SC	Y

Table 10. Scholar Experts

Source: CEIA (2019)

To select the participants of the Market group, a similar approach to the one just presented was planned, but the necessary effort was higher than anticipated. A previous step was necessary since there was no similar list to CEIA that could be leveraged to easily find the experts. Therefore, an initial auxiliary set of companies working and developing Artificial Intelligence was defined based on the 18 company members of the Brazilian Artificial Intelligence Association (ABRIA)[78]. This set was complemented by other startups and small and medium organizations with similar profile to those members of ABRIA (but not members) and by larger multinational players like Microsoft, IBM, Amazon, Google and others, all of them remarkably known for their work or application of Artificial Intelligence and with subsidiaries in Brazil that perform and solution AI locally. Based on this set of companies, extensive research began to find AI specialists employed by these companies. For the smaller companies, preference was given to choosing CIOs, CTOs and executive positions, while for the larger companies, the preference was given to architects and specialists involved in this type of research and application. This quest for experts was done with the help of social networks, mainly LinkedIn, where résumés and contact info (e-mail and telephone numbers), wherever possible were collected one by one, resulting in a list of 47 market professionals. The list is provided in Table 11 in alphabetical order.

Name	**Company**	**ABRIA**
Alessandro Jannuzzi	Microsoft	N
Alexandre Bernardoni	Hi PlatForm	Y
Alexandre Del Rey	I2AI	N
Alexandre Dietrich	IBM	N
Allison Garcia	Google	N
André Murta	Fhinck	Y
Bennett Bulock	Nama	Y
Bruno Alano	Neurologic	Y
Bruno Daniel Maia	BRQ	N

[78] http://abria.com.br/

Cezar Taurion	i2a2	N
Claudio Santos Pinhanez	IBM	N
Daniel Lindenberg	Docbot	Y
Daniel Mendes	Dataholics	Y
Danilo Jimenez Rezende	Google	N
David Dias	Accenture	N
Eder Gonzaga	Next	N
Emmanuel Santana	Ocapi	N
Evandro Barros	i2a2	N
Fabio Scopeta	Microsoft	N
Felipe Furtado Palma Dias	Dataholics	Y
Felipe Zmoginski	Baidu	Y
Fernando Itano	Banco Votorantim	N
Gustavo Gattass Ayub	Microsoft	N
Heitor Tancredo	Intexfy	Y
Henrique Oliveira Martins	Mvisia	Y
Jose Papo	Google	N
Juliano Viana	Kunumi	N
Leandro Santos	Semantix	Y
Leonardo Dias	Semantix	Y
Leonardo Santos	Semantix	Y
Luiz Claudio Macedo	Allgoo	Y
Marcelo Camara	Bradesco	N
Marcia Asano	Hekima	N
Marta Duarte Teixeira	Geofusion	Y
Mauricio Brentano	Hi PlatForm	Y
Paulo Castello	Fhinck	Y
Pedro Pazzini	Geofusion	Y
Rayssa Küllian	Amazon	N
Renato Leal	IBM	N
Roberto Frossard	Accenture	N
Rodrigo Scotti	Nama	Y
Samir Araujo	Amazon	N
Thiago Avelino	Nuveo	Y
Thiago Cardoso	Hekima	N
Viviane Silva	Mars	N
William Colen	Stilingue	Y
Yan Di	Baidu	Y

Table 11. Market Experts

Source: ABRIA (2019), and additional searches

The key difficulties in setting up the Market group were: (a) several of the startups and small and medium organizations could not be found or contacted – e.g. no employees for Mecasei.com and NexusEdge were found in LinkedIn and Allgoo, Baidu and DocBot did not have a CTO, CIO or senior executive available in LinkedIn; (b) some of the company members of ABRIA were not involved whatsoever with Artificial Intelligence – e.g. Startadora and Horizon Four key focus is in organizing hackathons, not Artificial Intelligence; (c) ABRIA list may be a good starting point, but didn't really offered an adequate foundation to define if its members are experts or not, which required an extra analysis on the seniority and expertise of the participants; and (d) LinkedIn limits the conversation with potentials participants, restricting the number of resources that can be reached and actively engaged in the research.

The number of respondents and answering rates for each of the rounds are shared in the following sections when the Delphi results are evaluated in detail. Nevertheless, contrary to what English & Kernan (1976) implied, the key challenge faced in this particular Delphi research in regard to experts was not their selection, but the ability to successfully contact, engage and ensure their participation throughout the research, especially in the first round. Actually, even with all the channels of communication available today, this remains a significant issue. Gordon & Helmer (1964) mention some weak spots with Delphi and the participant commitment is covered in the Instability of Membership item. According to the authors, there are several circumstances and many competing demands on the time of experts that may impede their participation, justify dropouts or unanswered requests, but the ultimate effects to the research are less consensus (in case the experts are replaced), less significance (in case the number is reduced) and/or longer rounds (in case the researcher keeps waiting for the answers) (Gordon & Helmer, 1964).

Research Questionnaire

The questionnaire was our main instrument for data collection in the research, but considering this is a Delphi work, it was also the central communication channel to successfully interact with the experts, either by sending or receiving feedback, which is an essential part of the technique. The questionnaire was designed since its inception to have two major parts, one covering the Delphi on the Impacts and Bottlenecks of Artificial Intelligence and another covering the Ability Survey as an alternative method to that of Frey & Osborne (2017). We explain these two parts next.

Delphi Form

The first part of the questionnaire was comprised of a presentation letter and three additional sections. The presentation letter objectives were to introduce researchers, communicate the participant he/she had been selected as an expert, thank in advance for the participation and commitment, share contact information of the researchers, and finally, indicate the due date for the particular execution round. Since we had 3 Delphi rounds planned, this presentation letter was adjusted accordingly.

Subsequent, we had the first section which was an opening one, called Introduction, intended to give participants the background, objectives and overall method of the research, requirements, and limitations of the panel and guiding instructions to respond the questionnaire. In this section we informed experts that all the opinions shared would be treated as confidential and that they would only be evaluated conjointly as a group, ensuring anonymity. This section was included only in the execution of the 1st Round, being removed in the following ones.

The second section was a General Data segment which its key objective was to collect demographic characteristics of the participant. In that sense, we asked experts (a) their main area of expertise (Academic or Non-Academic, meaning Market) to confirm if they belonged to the adequate group; (b) their degree of education, academic background, experience years either in general and in Artificial Intelligence to confirm their level of expertness; and (c) their inclination towards Artificial Intelligence and Robotics, to measure their eventual bias in answers. This last question about inclination is illustrated in Figure 8. This section was included only in the execution of the 1st Round, being removed in the following ones.

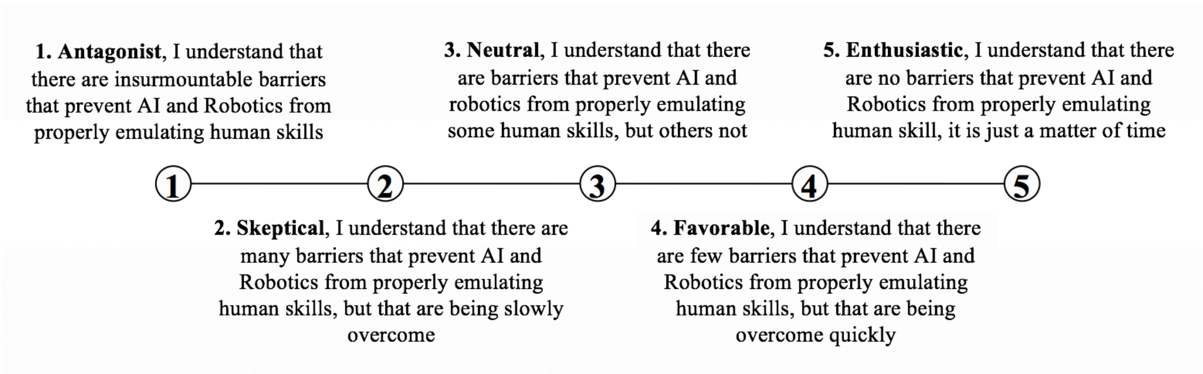


Figure 8. Expert's Inclination Towards Technology

The third section was called Impacts and Bottlenecks of Artificial Intelligence and its major objective was to collect personal opinions from the experts on those themes. Considering that the term Artificial Intelligence is a broad concept with several definitions and misconceptions, often used as a buzzword as seen in Chapter 3, we explained experts we were bearing in mind Nilsson (1998)'s definition of AI as "intelligent behavior in artifacts" that "involves perception, reasoning, learning, communicating and acting in complex environments", with the key goal of "developing machines that can do things as well as humans can, or possibly even better". We also asked experts to consider as AI all fields and topics related to Artificial Intelligence, including but not limited to Machine Learning (ML), Data Mining (and Big Data), Machine Vision (MV), Computational Statistics, and also Mobile Robotics (MR). Other research fields in technology, Computer Sciences, Robotics and Mathematics related to AI not mentioned here, were also welcomed in the answers.

Taking into account this definition and orientation, we then focused the attention of the experts to 5 key questions on Artificial Intelligence Impacts and Bottlenecks, the key structure of this section, since they were repeated in all 3 rounds, each one with a specific objective. The 5 questions were:

- What will be the key **Positive Impacts** of AI (and related technologies) **to Organizations** (public and private companies and non-governmental) in the next twenty years?

- What will be the key **Negative Impacts** of AI (and related technologies) **to Organizations** (public and private companies and non-governmental) in the next twenty years?

- What will be the key **Positive Impacts** of AI (and related technologies) **to Employment and the Labor Market** in the next twenty years?

- What will be the key **Negative Impacts** of AI (and related technologies) **to Employment and the Labor Market** in the next twenty years?

- What are the key **Bottlenecks** for the progress of AI (and related technologies), in other words, which areas AI will not be able to advance and will remain essentially human in the next twenty years?

For the 1st Round questionnaire, we included these questions as open-ended and requested experts to respond to them based on their personal opinions, without any kind of restrictions or limitations. Open-ended questions are suitable for identifying variables, while formulated questions allow the collection of numbers for structured situations (English & Kernan, 1976). Normally, open-end questions are used for first rounds to stimulate an anonymous and remote brainstorming of ideas, while structured are using in subsequent rounds when seeking out for convergence (Murry Jr & Hammons, 1995). We asked them to include at least three items for each question and a brief explanation that could help us interpret their thoughts, as recommended by Schmidt (1997), who explains that "to maximize the chance of unearthing the most important issues, the respondents should be encouraged to submit as many issues as possible in this first phase", and "having the respondents describe each issue is essential at this stage, because several respondents are likely to raise the same issue using different terms". After evaluating the answers, consolidating and combining similar opinions, we generated lists of around 30 items for each one of the 5 questions.

For the 2nd Round, thus, we shared these lists as feedback to experts and for their verification to confirm the terms had been properly mapped (Schmidt, 1997). We also requested them to select the 10 most relevant and to rank them in ascending order of relevance in order to achieve a combined top 10. According to Schmidt (1997), if the study intends to compare the responses of two or more groups, as in this research, the groups should be separated from the second phase on. Meaning that "groups develop a common list of issues with a common set of definitions in the first phase, then in the second phase, they can diverge in composing the list for ranking" (Schmidt, 1997). Considering this guidance and recalling the objective of eventually comparing Scholar and Market opinions for relevant differences, we had to wait for all the answers from both groups to then consolidate and create common lists. Once the results were collected and a new evaluation was performed, we selected the top 10 items for each of the questions, a process that is explained in detail in Chapter 0.

For the 3rd Round, again we shared the results of the previous phase as feedback. We presented the top 10 items of each question and, in doing so, we also shared the overall combined ranking of all the experts, as well as each individual experts' ranking so that he/she could compare his evaluation against the group. This demanded to create 24 individual and personalized questionnaires. Experts were requested to one more time rank the top 10 them in ascending order of relevance, considering the group and the individual ranks, in order to finetune the combined top 10. The questionnaires of each one of the Delphi Rounds are presented in Appendix 4 and more details are shared in the Delphi analysis, in Chapter 0.

Abilities Survey

As previously mentioned, the Delphi research was complemented with a limited survey. Thus, the second part of the first questionnaire (only for 1st Round) was designed to leverage the expert opinions on possible bottlenecks and indirectly evaluate and, if possible, confirm or refute Frey & Osborne (2017)'s susceptibility ranking thru a different approach. This survey was developed considering several assumptions that are covered next.

Frey & Osborne (2017)'s cornerstone in defining their ranking was to select bottlenecks of computerization from the occupational variables available in O*NET. As mentioned, authors subjectively selected 9 values as bottlenecks backed up by the literature on the topic. The subjectivity in this selection is evidently open to some degree of criticism and can be considered a potential weakness in their process. Taking into account this circumstance, we understood that the opinion of the Delphi experts could also be used to evaluate these values and check their validity as bottlenecks, thus, setting up a more objective way than the one offered by Frey & Osborne (2017) - i.e. based on the collective knowledge and practice of a group of experts rather than subjective selection.

Ideally, the maximum numbers of descriptors from O*NET that are used to constitute an occupation should be evaluated in order to reduce potential errors or gaps (being O*NET already a simplification). However, this is an unmanageable task since several of the variables are not homogenized at all and some are not relevant or applicable to the context – i.e. do not impact and/or are not impacted by Artificial Intelligence and Computerization (like Job Zone). Amid the remaining 10 nominal descriptors available, the number of possible values (262) is still quite high, which makes it unfeasible to request this in a single questionnaire. Therefore, a selection must be made among the nominal descriptors available. Table 12 details these nominal descriptors, with the exception of Related Occupations and Job Zone, the number of total values per descriptor and how many of those were chosen by Frey & Osborne (2017) as bottlenecks.

Descriptor	Description	Values	Bottlenecks?
Abilities	Enduring attributes of the individual that influence performance.	52	3
Occupational Interests	Person's preferences for work environments and outcomes.	6	0
Work Values	Global aspects of work that are important to a person's satisfaction.	6	0
Work Styles	Personal characteristics that can affect how well someone does a job.	16	0
Skills	Developed capacities that facilitate learning and the performance of activities that occur across jobs.	35	3
Knowledge	Organized sets of principles and facts that apply to a wide range of situations.	33	1
Education	Required level of education to perform a job	12	0
Experience and Training	Type of experience required	4	0
Work Activities	Work Activities summarize the kinds of tasks that may be performed across multiple occupations.	41	1
Work Context	Work Context refers to physical and social factors that influence the nature of work.	57	1

Table 12. O*NET Nominal Descriptors

Source: O*NET (2019)[79]

When evaluating which descriptor to select, 3 of them were considered not applicable to the task at hand: Education, Experience and Training and Work Context. The first two deal with education and experience levels required for humans performing occupations, characteristics that can be considered less relevant from a technology standpoint. In other words, these concepts are not pertinent in their original interpretation of computers and/or algorithms (even though Artificial Intelligence algorithms do gather experience over time). The third one is related to the work conditions (physical and social) that influence the overall performance, which is split into three major groups: Interpersonal Relationships, Physical Work Conditions, and Structural Job Characteristics. Most of the factors within this descriptor list have little or no influence at all in the application of computerization, either Artificial Intelligence or Robotics. Actually, most of them, especially in the physical work conditions, justify using these technologies to prevent humans of performing roles in a wide range of hazardous contexts. Therefore, instead of possible bottlenecks, work context descriptors could be used as motivators to replace or complement the human workforce. Frey & Osborne (2017) did not use Education and Experience and Training at all but assumed that at least one value of Work Context was relevant as a bottleneck, Cramped workspace, Awkward positions – though no justification was shared.

Three other descriptors were also discarded because of the idea they encapsulate and type of data they assess, which are basically human characteristics and/or preferences. These are not able to be emulated and properly measured in computers, algorithms, robots or machines. Occupational Interests measures a person's preferences, Work Values considers aspects relevant to a person's satisfaction and Work Styles evaluates personal characteristics. In other words, these personal preferences, satisfaction, and characteristics apart from not being possible to emulate by technology, are not really relevant to inhibit a machine from adequately performing a job. Frey & Osborne (2017) also discarded these descriptors in their analysis, with no values selected as bottlenecks.

[79] https://www.onetonline.org/help/online/summary

Another descriptor disregarded was Knowledge, which is the required understanding and set of principles and information about a particular subject, either obtained by experience or study, necessary to perform the occupation. In O*NET, this descriptor covers multiple areas of human knowledge: humanities, social sciences, natural sciences, formal sciences and applied sciences thru 33 possible values. The assumption of overlooking this descriptor relies on the fact that most of today's information that comprises our society's body of knowledge in multiple themes is already digitalized and, in that sense, ready for consumption by machines as databases. Clearly, not all information is available, most of it is yet unstructured data and to really make sense of all this information, a basic knowledge of several topics is required, which makes it difficult to emulate in machines. Nonetheless, as Watson showed in Jeopardy!, it is feasible to be emulated by machines[80]. Frey & Osborne (2017) used one single value of Knowledge as a bottleneck, which was Fine Arts.

Therefore, three descriptors were left: (a) Abilities, which are persistent attributes of the individual that influence performance, (b) Skills, which are developed capabilities that facilitate learning and the performance of activities that occur across jobs and (c) Work Activities, which are a summarization of kinds of tasks that may be performed across multiple occupations. We considered these 3 as highly relevant to be evaluated, since they are the determinant capabilities that allow people (or machines) to successfully perform occupations, all the others being accessory variables; additionally, all of them have both Importance and Level scales available in the dataset, which is a critical requirement for the following calculations and analysis. Besides, these were the descriptors that had most of Frey & Osborne (2017)'s selected bottlenecks (7 out of 9). Since the volume of values to assess was still quite high (128) we decided to cover in this research only one of these descriptors, which was Abilities and its 52 values. The rationale that supports the decision of choosing Ability as the key variable in scope was that it is the most complicated of the 3 aforementioned, dealing with what O*NET calls enduring attributes, more complex to understand, learn and emulate. The list of the 52 abilities and their meaning is presented in Table 13. Frey & Osborne (2017)'s bottlenecks in Abilities were Finger Dexterity, Manual Dexterity, and Originality.

[80] https://www.youtube.com/watch?v=lI-M7O_bRNg

Ability	Ability Type	Ability Category
Oral Comprehension	Verbal Abilities	Cognitive Abilities
Written Comprehension	Verbal Abilities	Cognitive Abilities
Oral Expression	Verbal Abilities	Cognitive Abilities
Written Expression	Verbal Abilities	Cognitive Abilities
Fluency of Ideas	Idea Generation and Reasoning Abilities	Cognitive Abilities
Originality	Idea Generation and Reasoning Abilities	Cognitive Abilities
Problem Sensitivity	Idea Generation and Reasoning Abilities	Cognitive Abilities
Deductive Reasoning	Idea Generation and Reasoning Abilities	Cognitive Abilities
Inductive Reasoning	Idea Generation and Reasoning Abilities	Cognitive Abilities
Information Ordering	Idea Generation and Reasoning Abilities	Cognitive Abilities
Category Flexibility	Idea Generation and Reasoning Abilities	Cognitive Abilities
Mathematical Reasoning	Quantitative Abilities	Cognitive Abilities
Number Facility	Quantitative Abilities	Cognitive Abilities
Memorization	Memory	Cognitive Abilities
Speed of Closure	Perceptual Abilities	Cognitive Abilities
Flexibility of Closure	Perceptual Abilities	Cognitive Abilities
Perceptual Speed	Perceptual Abilities	Cognitive Abilities
Spatial Orientation	Spatial Abilities	Cognitive Abilities
Visualization	Spatial Abilities	Cognitive Abilities
Selective Attention	Attentiveness	Cognitive Abilities
Time Sharing	Attentiveness	Cognitive Abilities
Arm-Hand Steadiness	Fine Manipulative Abilities	Psychomotor Abilities
Manual Dexterity	Fine Manipulative Abilities	Psychomotor Abilities
Finger Dexterity	Fine Manipulative Abilities	Psychomotor Abilities
Control Precision	Control Movement Abilities	Psychomotor Abilities
Multilimb Coordination	Control Movement Abilities	Psychomotor Abilities
Response Orientation	Control Movement Abilities	Psychomotor Abilities
Rate Control	Control Movement Abilities	Psychomotor Abilities
Reaction Time	Reaction Time and Speed Abilities	Psychomotor Abilities
Wrist-Finger Speed	Reaction Time and Speed Abilities	Psychomotor Abilities
Speed of Limb Movement	Reaction Time and Speed Abilities	Psychomotor Abilities
Static Strength	Physical Strength Abilities	Physical Abilities
Explosive Strength	Physical Strength Abilities	Physical Abilities
Dynamic Strength	Physical Strength Abilities	Physical Abilities
Trunk Strength	Physical Strength Abilities	Physical Abilities
Stamina	Endurance	Physical Abilities
Extent Flexibility	Flexibility, Balance, and Coordination	Physical Abilities
Dynamic Flexibility	Flexibility, Balance, and Coordination	Physical Abilities
Gross Body Coordination	Flexibility, Balance, and Coordination	Physical Abilities
Gross Body Equilibrium	Flexibility, Balance, and Coordination	Physical Abilities
Near Vision	Visual Abilities	Sensory Abilities
Far Vision	Visual Abilities	Sensory Abilities
Visual Color Discrimination	Visual Abilities	Sensory Abilities
Night Vision	Visual Abilities	Sensory Abilities
Peripheral Vision	Visual Abilities	Sensory Abilities
Depth Perception	Visual Abilities	Sensory Abilities
Glare Sensitivity	Visual Abilities	Sensory Abilities
Hearing Sensitivity	Auditory and Speech Abilities	Sensory Abilities
Auditory Attention	Visual Abilities	Sensory Abilities
Sound Localization	Visual Abilities	Sensory Abilities
Speech Recognition	Visual Abilities	Sensory Abilities
Speech Clarity	Visual Abilities	Sensory Abilities

Table 13. O*NET Categories, Types, and Abilities

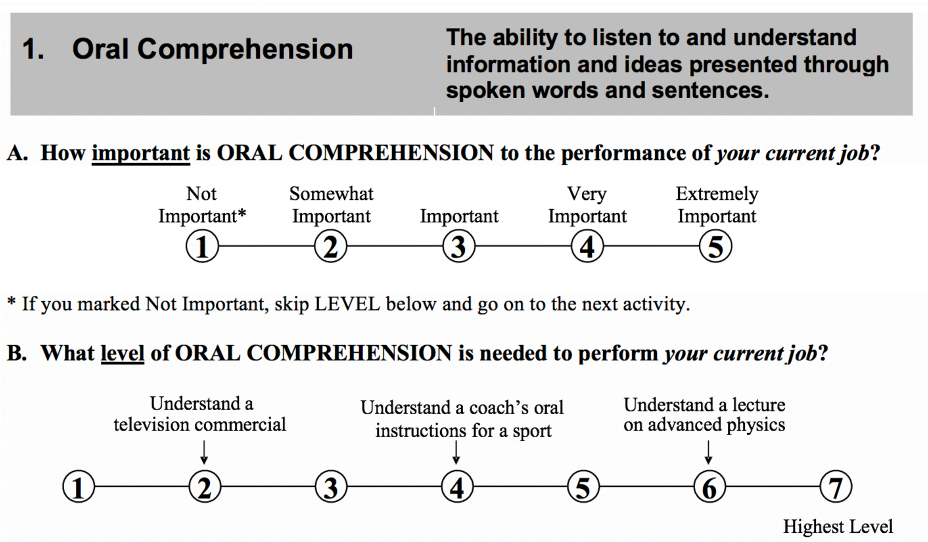
Source: O*NET (2019)[81]

Once the key variable was decided, the attention was turned into the questionnaire. Instead of elaborating a survey from scratch with all the complexities associated in this task, the decision was to leverage as much as possible O*NET's current survey on abilities and to adapt it to the research needs. This decision had four key motivations: (a) reduce development complexity and time, especially design and validation phases, (b) leverage O*NET robust and proven method that support the overall framework presented, (c) use the same terms and concepts, making it easier to compare and (d) use the rich occupation database provided with no cost by O*NET.

O*NET's survey on abilities is used to collect information from incumbents to define and update the occupations. The questionnaire is occupation-based, which means that participants answer their abilities based

[81] https://www.onetonline.org/help/online/summary

on their current job. For each one of the 52 abilities mapped in O*NET, a brief description is presented, and participants must respond the Importance of the Ability to perform the current job and the Level (of complexity) of the ability required to perform the current job, the two key scales already mentioned. Both of them use Likert scales but with different ranges. In Level, anchors are presented to equalize understanding among respondents. Figure 9 illustrates the type of question in the questionnaire.



1. Oral Comprehension — **The ability to listen to and understand information and ideas presented through spoken words and sentences.**

A. How <u>important</u> is ORAL COMPREHENSION to the performance of *your current job*?

Not Important* (1) — Somewhat Important (2) — Important (3) — Very Important (4) — Extremely Important (5)

* If you marked Not Important, skip LEVEL below and go on to the next activity.

B. What <u>level</u> of ORAL COMPREHENSION is needed to perform *your current job*?

(1) — (2) Understand a television commercial — (3) — (4) Understand a coach's oral instructions for a sport — (5) — (6) Understand a lecture on advanced physics — (7) Highest Level

Figure 9. Sample of O*NET Questionnaire - Abilities

Source: O*NET (2019)

Clearly, using O*NET without any adjustments would not address the current research objectives, so, several adaptations were required for our research.

- While O*NET questionnaire is focused on occupations, our main focus is on Abilities cross occupationally. Therefore, instead of asking questions about the Abilities of a particular occupation, experts were asked about the 52 Abilities individually, occupation independent, and their relationship with technology.

- Experts were requested to respond subjectively and for each Ability at a time, the level of complexity that they believed Artificial Intelligence, Robotics, and related technologies would be able to satisfactorily emulate. The Level scale served as support and was illustrated with the specific anchors of each Ability taken from O*NET. In that sense, it was essential to define what we meant by emulating: to imitate humans and perform abilities as good as (or better than) humans in an autonomous way and not necessarily using the same approach.

- The Importance scale, on the other hand, was discarded from the questionnaire because it covers the relevance from an occupation perspective, and this is given by O*NET database.

- Experts were asked the same question twice, but in different timeframes, 2018 as the current state and 2038 as the future state. The twenty-year window was defined based on Frey & Osborne (2017)'s research and the current position was also considered in order to better make sense of the answers and possibly even compare situations and check the validity of conclusions.

Three complementary questions were designed and included in the questionnaire for each ability: (a) justification: expert's explanation with a rationale, briefly mentioning specific technologies, concepts, researches, references and/or applications to support their opinion; (b) competence: expert's level of competence (knowledge) to evaluate that ability (from 0, 'no competence' to 10, 'full competence'); and (c) confidence: expert's level of confidence in their answer (from 0, 'no confidence, pure guess' to 10, 'full confidence, absolute certainty'). This information was relevant to better evaluate the responses and was viewed in English & Kernan (1976), where the authors suggested self-rating expert's own expertise thru a field called competence. The idea of asking confidence and competence was to weight the responses and ensure better quality in the overall result since knowledge in several and distinct technology topics were requested. Participants were encouraged to answer all 52 Abilities and assign a number to all components (mandatory questions), no matter how confident they were with the answers or how knowledgeable they considered themselves in the subject. The final looks for the abilities is illustrated in Figure 10. Questions, anchors, and all information were translated and sent in Portuguese, to reduce any possible difficulties and improve communication.

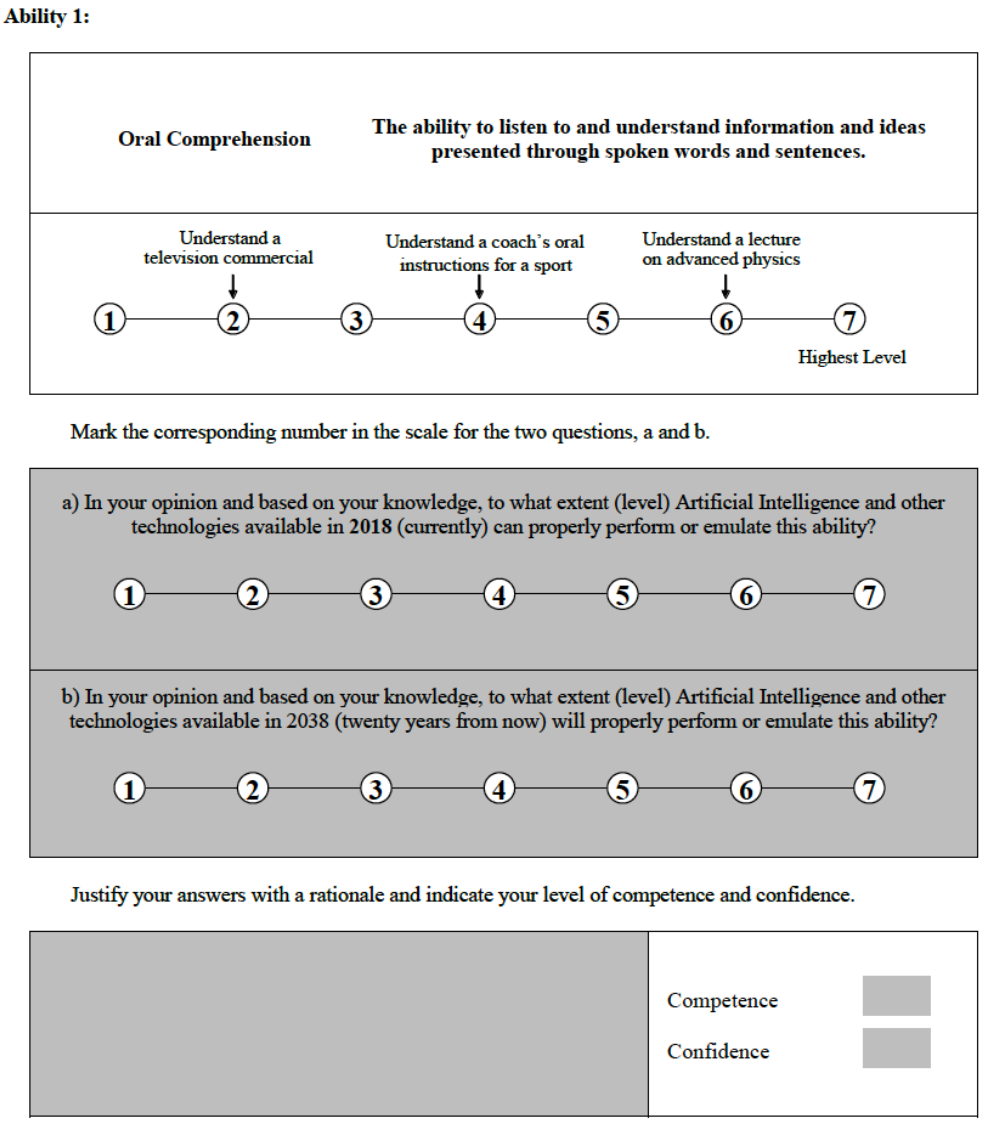


Figure 10. Question Sample from the Questionnaire

Once the questionnaire was defined, we started the execution phase, which is explained next.

5.3. Delphi Execution

After Delphi was designed and planned, it was time for its execution. In this section, we explain the logistics and the implementation of the 1 (pilot) plus 3 rounds.

Pilot Round

During the definition and design of the questionnaire for the 1st Round, experts and non-experts were consulted to check the overall quality of the research instrument. We had different feedback regarding both content and form, which helped to improve the questionnaire. Also, all ideas in design were shared with an extended group of fellow postgraduate students of the NETS USP study group[82] from the Business School of the University of São Paulo which also contributed with ideas, validations, and challenges.

Once the trial version of the questionnaire was completed, a pilot run was performed with an expert (with an academic background) in April 2018. The suggestions, attention points and risks shared by this pilot expert were very important to review the questionnaire before launching the actual research. Errors and ambiguities were corrected, and the instrument quality was improved. The main feedback about the two parts of the questionnaire, Delphi Research, and Ability Survey, and actions taken to mitigate the weak spots were:

- Total duration: estimated time for filling up the 60 pages questionnaire prior to the pilot was 90 minutes, which was already a challenge considering the lack of time of most experts. However, during the pilot execution, the actual time spent was close to 3 hours (180 minutes), twice the expected. According to the pilot expert, the abilities questionnaire was very demanding in terms of volume of questions (52) and information required, which combined with other difficulties, like the ease of use and language, increased the overall time to respond. To reduce the time, several adjustments were made and are explained in the next bullet points.

- Ease of use: although we had decided on using Portable Document Format (pdf) forms as the format for the questionnaire, the trial version was sent in a Microsoft Word format (docx) and, in this temporary version, no actions were taken to ensure a friendly interface with the respondent. The feedback proved that doing it in PDF was important for the success of the research because DOCX format made it more difficult and time-consuming to respond the abilities questions and also made it harder to ensure the right answers to the mandatory questions (in PDF we could include version control). Therefore, a PDF form was built and used as the interaction mode with the experts which reduced the time spent on answering the questionnaire. Online versions were not considered due to the complex structure of the questionnaire and to have complete traceability of the answers.

- Form language: since the whole thesis is in English, as well as the O*NET questionnaire on abilities that was leveraged, the trial version was also sent in English, which did not pose a challenge to the pilot expert. Nonetheless, considering that all experts contacted were from Brazil and that their proficiency in a foreign language, English, could diverge significantly, it was recommended that the form was switched to Portuguese in order to guarantee a better understanding of the questions and quality of the answers. The translation to Portuguese was particularly important when dealing with the anchors of Level scale, and, as a result, it helped in reducing the time spent on answering the questionnaire.

- Enthusiasm question: considering the responses from the pilot expert in the trial run, an additional question was included in the background section of the questionnaire, which was meant to rate the enthusiasm of the participants towards Artificial Intelligence, Robotics, and related technologies.

[82] http://www.netsusp.com.br

Possible answers were antagonist, skeptical, neutral, sympathetic and enthusiast, on a built scale which intended to cover from one side to the other of the spectrum, from clear opponent to sound advocate. With this variable, the idea was evaluating possible biases in responses based on the expert's passion toward those technologies. This question was presented in the questionnaire section, but the idea was derived from the pilot execution.

- Complementary questions: according to the feedback, the complementary questions asked on each of the abilities (justification, competence, and confidence) also affected the time spent. Justification posed the major issue because pilot expert felt compelled to search for rationales that could support his ratings. Ideally, that would be the case to ensure higher quality. However, to reduce the overall time spent to answer the questionnaire, justification and competence were set to optional and confidence was removed from the questionnaire, considering the fact that only experts were part of the survey and already covered part of this variable.

1st, 2nd, and 3rd Rounds

Before start running the Delphi, a preliminary step was taken in order to increase participation of individuals, which was to collect phone numbers in order to share a brief introduction of the research, create some kind of rapport and increase the number of potential participants. This activity was only possible with the scholar experts, who shared their contact on Plataforma Lattes. Nonetheless, the success rate of telephone calls was quite low.

After all the adjustments based on the feedback of the pilot run were executed, the questionnaire was issued. In the 1st Round, 88 experts were contacted either by telephone, email, and LinkedIn and were requested to take part in the Delphi, 41 from Scholar group and 47 from Market one. Of those, the questionnaire was actually sent to 67 because several market experts were inaccessible – LinkedIn does not allow to maintain conversations unless the counterpart accepts your first contact. We also faced some declinations, but in most cases, there was simply no response. After several weeks of persistence, 24 satisfactory responses were gathered, equally divided between the two groups (Scholar and Market). The effectiveness rate was of 27.3% and the final quantity of responses was within the requirements mentioned in the design phase.

This first round was launched in two separate consecutive waves due to operational reasons. Our plans and requests were focused on having answers in one month, but we considered as acceptable and were prepared to have all answers in two months. We kicked off Scholar group by mid-May 2018 and closed it by early August 2018 when we reached 12 answers, taking approximately three months to be completed. The Market group was offset in two months starting by the end of July 2018, and was closed by early November 2018, taking approximately four months to be completed. Despite the efforts and actions in trying to make it shorter, this first phase took more time to be completed than planned, even in our worst-case scenario.

The Market group response rate and time was a greater challenge than the Scholar group, reason unknown to us. After many weeks waiting for answers – actually months, we chose to make a critical move to ensure the success of the research. We decided to terminate the Ability Survey part since it was the greatest and longest piece of the questionnaire and it inhibited responses of the Delphi part, as confirmed in different feedbacks. Therefore, we removed it from the instrument and created a second version of the 1st Round questionnaire, the light version, that was promptly shared with participants that had not yet responded but showed interest in doing so. That way, the response rate increased, and it was possible to achieve the number of answers committed in the design phase for the Delphi, with 12 answers from Market professionals too. The Ability Survey part was stopped with 14 answers, which we considered as acceptable.

Denials in taking part in the research had several causes. Apart from the obvious responses of not having spare time or interest in academic research, three of them were more relevant and worth mentioning. The first reason was the size of the questionnaire and time necessary for responding to it. Although the estimation of 90 minutes was shared in the introductory section of the questionnaire, several experts complained about this issue and did not take part. The duration was also a negative feedback from those that successfully responded, a recurrent complaint: “questionnaire is too long”, “too many open questions and justifications”, “abilities part is exhausting”, “took more time than expected”, etc. The second reason was that some experts shared the sentiment of not being comfortable enough with the role imposed to them as specialists, particularly in a research that covered two distinct fields (technology and business). This was somewhat expected in light of the choice in profile made in design – i.e. Artificial Intelligence researchers and practitioners with strong technical background, still with limited knowledge in business themes. This situation occurred in the Scholar group with an expert that commented he/she had no knowledge of the management topics and therefore could not take part of the research. The third reason was related to the method of the research. One single participant, with an academic background, was uncomfortable with the proposition and the methodology used. He/she questioned the objective of the research and informed he/she was not suitable to respond the questions proposed. After a brief conversation, it was clear that his lack of confidence in the research was related to what he considered an oversimplification of the problem, that should consider many other variables. While this feedback was important, it was essential to simplify the problem to evaluate it, aware of the limitations. This criticism was somehow balanced with other recognized researchers with a strong background that showed a great deal of interest in the research, method, and findings, with limited or no criticisms whatsoever, which reassured that the research had its positive aspects. After all, the feedbacks were considered and helped in making the research stronger.

Once the answers from the previous phase were collected and analyzed, a modified version of the questionnaire was developed and released for the 2nd Round, with the focus on enhancing the data of the 5 key questions previously mentioned about impacts and bottlenecks. For this second round, we released only one version of the questionnaire for both groups (Scholar and Market) and in a single wave. We kicked it off in early November 2018, sending the questionnaire to the same 24 respondents from the previous round and we closed it by the end of December 2018, with 20 out of 24 satisfactory responses (11 from Scholar and 9 from Market). The effectiveness rate was of 83.3% and the total time was two months. Two of the missing participants did not reply back in spite of the numerous contacts and the other two kept promising an answer but never delivered. We understood that this was an acceptable withdrawal rate, especially when considering Hasson *et al* (2000)'s guidance, that to maintain the rigor of this technique, a response rate of 70% is suggested for each round.

Responses from 2nd Round were collected and consolidated and lists were fine-tuned and reduced to 10 items each. A new questionnaire was developed and released for the 3rd Round. For this round, we had to create personalized questionnaires for each one of the 20 participants – feedback was required the individual answers from the previous round. We launched the 3rd Round in mid-January 2019, sending the questionnaire to the same 20 respondents from the previous round and we closed it by early March 2019, with 20 out of 20 satisfactory responses (again, 11 from Scholar and 9 from Market). The effectiveness rate was of 83.3% and the total time was around two months, as expected. No denials or unanswered requests.

6. Abilities Survey Analysis

This chapter addresses the data and findings gathered during the execution of the field research focusing on the abilities survey. First, we share our initial considerations and guidance on how the results were analyzed. Later, we present the overall statistics on the combined responses and evaluate all abilities, cross-checking with justifications and comments by the participants, considering the four major abilities categories in O*NET (Cognitive, Psychomotor, Physical and Sensory) and their respective abilities types and individual abilities. In the final section of this chapter, we present key considerations, conclusions, and limitations regarding the survey.

6.1. Preliminary Considerations

The Abilities Survey was included in the Delphi's first-round questionnaire in order to leverage the participation of the experts and evaluate their opinions on the likelihood of having these human abilities properly emulated by Artificial Intelligence, Robotics, and related technologies. Planning and logistics, as well as the number of participants, response rate and other relevant information of this piece of the research, were explained in Chapter 5.

In the following sections, we present, analyze and discuss expert's evaluations and considerations about the O*NET abilities based on a set of descriptive statistics, cross-checking with Frey & Osborne (2017) results. The Descriptive Statistics aim to summarize and harmonize – whenever possible – the key findings in terms of likelihood ratings from a reduced sample of experts. It was neither the objective nor the intention of the authors of this research to extrapolate, infer or promote any sample abstraction that may lead to population conclusions. In other words, this is not an Inferential Statistics (or Inductive Statistics) study, meaning it was not developed based on the probability theory.

We present the descriptive statistics by abilities and group of abilities using a template table with the key descriptive statistics, which is illustrated in Table 14. In the later sections of this chapter, this template table is enhanced and presented with three sections. In the upper section, we summarize the results of the current state (2018) for all abilities of a particular group. In the middle section, we summarize the results of the future state (2038). In the lower section, we provide a comparison between both states, using 2038 as the baseline since all abilities in the dataset increased their level in twenty years, without exceptions. Thus, all calculations in this comparison, including the combined values of the abilities, are simple subtractions of 2018 rates from 2038 rates.

Throughout this chapter, the key objective is to evaluate which abilities are more likely to be emulated by Artificial Intelligence, Robotics, and related technologies in the near future (twenty years from now) or, on the other hand, which are less likely, thus potential bottlenecks or challenges for these technologies. By emulating we mean to imitate humans and perform abilities as good as (or better than) humans in an autonomous way and not necessarily using the same approach. An important observation is that experts were requested to point out the level of complexity for each ability that they believed is (in 2018) or would be (2038) emulated by these technologies. The likelihood of the ability is, therefore, an interpretation of these opinions by the researcher. Basically, if the complexity level covered is high, then the likelihood of that ability being emulated is also high; if, on the other hand, complexity level covered is low, then the likelihood of emulation is lower too.

	Year	2018								
	Ability	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.a.1	Oral Comprehension									
1.A.1.a.2	Written Comprehension									
1.A.1.a.3	Oral Expression									
1.A.1.a.4	Written Expression									
1.A.1.a	Verbal Abilities									

	Year	2038								
	Ability	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.a.1	Oral Comprehension									
1.A.1.a.2	Written Comprehension									
1.A.1.a.3	Oral Expression									
1.A.1.a.4	Written Expression									
1.A.1.a	Verbal Abilities									

	Year vs Year	Differences between 2038 - 2018								
	Ability	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.a.1	Oral Comprehension									
1.A.1.a.2	Written Comprehension									
1.A.1.a.3	Oral Expression									
1.A.1.a.4	Written Expression									
1.A.1.a	Verbal Abilities									

Table 14. Descriptive Statistics Template

For a better understanding of the results, we provide next a brief explanation of the metrics used.

- Answers: Is the number of valid ratings taken from the questionnaires, where the maximum quantity available is 14. To calculate the total amount of answers per ability group, we consider the sum of all available and valid answers.
- Mean^A: Is the arithmetic mean of valid ratings in regard to the Level of the ability that could be emulated by machines, varying from 1 (low level, low complexity) and 7 (high level, high complexity). To calculate the mean^A per ability group, we consider the simple mean of all the means calculated, which is mathematically acceptable.
- Mean^B: Is the weighted mean of valid ratings in regard to the Level of the ability that could be emulated by machines, varying from 1 (low level, low complexity) and 7 (high level, high complexity) and using the Competence indicator (0 to 10) as the weight. To calculate the mean^B per ability group, we consider the simple mean of all the weighted means calculated, which is also mathematical acceptable.
- Dif. Means: Is the difference between the two means just mentioned, the weighted mean and the simple mean, to evaluate cases where there may be a considerable difference. To calculate the differences of means per ability groups, we consider this same logic.

- Deviation: Is the simple standard deviation of valid ratings. To calculate the standard deviation of the groups, the standard deviation of all the observations from all the abilities of that particular group is recalculated.
- CV: Is the Coefficient of Variance, a standardized measure of dispersion that considers the ratio between standard deviation and mean[A] of observations. To calculate the coefficient of the groups, we used the same formula, dividing the group's standard deviation by the group's mean[A].
- Min: Is the minimum, smallest value in a set of ratings and can be no lower than 1, the lowest Level possible. To define the minimum for the group of abilities, the smallest value among all the abilities of the group it is verified and used.
- Median: Is the second quartile, meaning, the value in which all observations are divided into exactly 2 groups with equal observations – it is a measure of distribution. To calculate the median for the combined set of abilities, the median among all the abilities of the group it is verified and used.
- Max: Is the maximum, greatest value in a set of ratings and can be no higher than 7, the highest Level possible. To define the maximum for the group of abilities, the greatest value among all the abilities of the group it is verified and used.

The two means presented (simple arithmetic mean and weighted mean) differ on the calculation and the use of competence, an additional element per ability per expert requested in the questionnaire. Having these two measures allows to evaluate and compare a simple average on opinions against a more qualified judgment, reinforcing the views of those experts that believe to be more skilled and lessening the views of those less experienced. However, as previously stated, competence was an optional field in the questionnaire and not all respondents informed it – 10 out of 14 adequately filled out the competence field, with some degree of variation. In spite of the advantages of using the weighted mean, we decided to proceed with the simple mean for the following analysis. The reason for this choice was to avoid decreasing the number of observations, which in turn, could further endanger the significance of findings, which is already reduced due to the number of respondents (14).

Since means and medians are key in the analysis and they have a clear range limitation, and in order to facilitate visual identification, we evaluate all the following tables using the scale depicted in Figure 11. We also mark the difference between the two means in colors: black for minor differences (between 0.00 and 0.50), yellow for intermediate differences (between 0.51 and 1.00) and red for higher differences (greater than 1.00).

very low	low	below avg.	average	above avg.	high	very high
1.00 - 1.50	1.51 - 2.50	2.51 - 3.50	3.51 - 4.49	4.50 - 5.49	5.50 - 6.49	6.50 - 7.00

Figure 11. Mean and Median Reference Scale

Additionally, we point out with colors standard deviations and coefficients of variance to highlight possible homogeneity issues in the combined opinions: black is used for homogeneous answers (between 0.00 and 0.75 and 0.00% and 30.00%), yellow for intermediate (between 0.75 and 1.50 and 30.00% and 60.00%) and red for heterogeneous answers (greater than 1.50 and greater than 60.00%).

6.2. General Outcomes

In this section we present and evaluate the overall statistics of the 52 individual abilities, highlighting the tops and bottoms. We do the same evaluation for the 15 abilities types. The complete list of the 52 abilities and ability types as well as the anchors for reference are in Appendix 2.

Individual Evaluation

Table 15, Table 16 and Table 17 present the key individual statistics of the 52 abilities considering the current state (2018), the future state (2038) and the differences between them, respectively.

	Ability	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.a.1	Oral Comprehension	14	2.64	2.64	-	0.93	35.14%	1.00	2.50	4.00
1.A.1.a.2	Written Comprehension	14	3.43	3.43	0.00	1.09	31.77%	1.00	3.50	5.00
1.A.1.a.3	Oral Expression	14	3.64	3.93	0.29	1.50	41.15%	1.00	4.00	7.00
1.A.1.a.4	Written Expression	14	3.00	3.39	0.39	1.47	48.92%	1.00	3.00	6.00
1.A.1.b.1	Fluency of Ideas	14	3.36	3.95	0.59	1.78	53.04%	1.00	3.00	7.00
1.A.1.b.2	Originality	13	1.62	1.49	- 0.12	0.96	59.48%	1.00	1.00	4.00
1.A.1.b.3	Problem Sensitivity	14	3.21	3.76	0.54	1.81	56.16%	1.00	3.00	6.00
1.A.1.b.4	Deductive Reasoning	14	4.07	4.35	0.28	1.44	35.35%	2.00	4.00	7.00
1.A.1.b.5	Inductive Reasoning	14	3.86	3.96	0.10	1.70	44.16%	2.00	3.50	7.00
1.A.1.b.6	Information Ordering	14	4.43	4.87	0.44	1.70	38.31%	2.00	4.00	7.00
1.A.1.b.7	Category Flexibility	14	4.64	5.06	0.41	1.74	37.41%	2.00	4.50	7.00
1.A.1.c.1	Mathematical Reasoning	14	4.21	4.35	0.14	1.72	40.76%	1.00	4.50	7.00
1.A.1.c.2	Number Facility	13	6.23	6.06	- 0.17	1.69	27.14%	2.00	7.00	7.00
1.A.1.d.1	Memorization	13	5.77	6.15	0.38	1.30	22.55%	4.00	6.00	7.00
1.A.1.e.1	Speed of Closure	14	4.43	4.78	0.35	1.60	36.21%	2.00	4.00	7.00
1.A.1.e.2	Flexibility of Closure	14	4.36	4.56	0.20	1.45	33.21%	1.00	4.00	6.00
1.A.1.e.3	Perceptual Speed	14	5.57	5.90	0.33	1.09	19.55%	3.00	5.50	7.00
1.A.1.f.1	Spatial Orientation	14	4.64	5.11	0.47	1.60	34.43%	1.00	4.50	7.00
1.A.1.f.2	Visualization	14	4.07	4.52	0.45	1.90	46.67%	1.00	4.50	7.00
1.A.1.g.1	Selective Attention	14	5.71	5.97	0.26	1.64	28.66%	2.00	6.50	7.00
1.A.1.g.2	Time Sharing	13	5.08	5.68	0.60	1.44	28.39%	3.00	5.00	7.00
1.A.2.a.1	Arm-Hand Steadiness	14	4.57	5.54	0.96	1.83	39.98%	2.00	4.50	7.00
1.A.2.a.2	Manual Dexterity	14	3.93	4.58	0.65	1.82	46.26%	1.00	4.00	7.00
1.A.2.a.3	Finger Dexterity	14	3.71	4.75	1.03	1.82	48.88%	1.00	4.00	7.00
1.A.2.b.1	Control Precision	14	4.71	5.66	0.95	1.64	34.73%	2.00	4.00	7.00
1.A.2.b.2	Multilimb Coordination	14	3.93	4.59	0.67	1.54	39.26%	1.00	4.00	6.00
1.A.2.b.3	Response Orientation	14	4.07	4.64	0.57	1.54	37.88%	2.00	4.00	7.00
1.A.2.b.4	Rate Control	14	3.79	4.95	1.16	2.01	53.01%	1.00	4.00	7.00
1.A.2.c.1	Reaction Time	14	4.36	5.38	1.02	1.91	43.74%	2.00	4.00	7.00
1.A.2.c.2	Wrist-Finger Speed	14	3.50	4.66	1.16	2.07	59.03%	1.00	3.00	7.00
1.A.2.c.3	Speed of Limb Movement	14	3.86	4.74	0.88	1.75	45.31%	2.00	3.50	7.00
1.A.3.a.1	Static Strength	14	5.57	6.34	0.77	1.65	29.63%	2.00	6.00	7.00
1.A.3.a.2	Explosive Strength	14	3.79	4.59	0.81	1.67	44.17%	1.00	4.00	7.00
1.A.3.a.3	Dynamic Strength	14	4.43	5.75	1.32	2.21	49.88%	1.00	5.00	7.00
1.A.3.a.4	Trunk Strength	14	4.50	5.82	1.32	2.24	49.88%	2.00	4.00	7.00
1.A.3.b.1	Stamina	14	5.14	5.99	0.84	2.07	40.25%	1.00	5.50	7.00
1.A.3.c.1	Extent Flexibility	14	3.93	5.02	1.09	1.86	47.32%	1.00	4.00	7.00
1.A.3.c.2	Dynamic Flexibility	14	3.36	4.42	1.06	1.69	50.40%	1.00	3.00	7.00
1.A.3.c.3	Gross Body Coordination	14	2.86	3.57	0.71	1.35	47.27%	1.00	2.00	6.00
1.A.3.c.4	Gross Body Equilibrium	14	3.14	3.52	0.38	0.86	27.50%	2.00	3.00	4.00
1.A.4.a.1	Near Vision	14	5.14	5.73	0.59	1.56	30.37%	2.00	5.00	7.00
1.A.4.a.2	Far Vision	14	5.29	5.82	0.54	1.49	28.19%	2.00	5.00	7.00
1.A.4.a.3	Visual Color Discrimination	14	4.57	4.72	0.14	1.28	28.08%	2.00	5.00	6.00
1.A.4.a.4	Night Vision	14	4.57	5.33	0.76	1.95	42.65%	2.00	4.50	7.00
1.A.4.a.5	Peripheral Vision	14	4.71	5.56	0.85	1.90	40.27%	1.00	4.50	7.00
1.A.4.a.6	Depth Perception	13	4.46	4.59	0.13	1.51	33.76%	2.00	5.00	7.00
1.A.4.a.7	Glare Sensitivity	14	4.21	4.32	0.10	1.72	40.76%	2.00	4.00	7.00
1.A.4.b.1	Hearing Sensitivity	14	4.57	4.87	0.30	1.74	38.10%	2.00	4.50	7.00
1.A.4.b.2	Auditory Attention	13	4.15	4.36	0.20	1.77	42.67%	2.00	4.00	7.00
1.A.4.b.3	Sound Localization	13	4.23	4.54	0.31	1.79	42.23%	2.00	4.00	7.00
1.A.4.b.4	Speech Recognition	14	4.00	4.09	0.09	0.88	21.93%	2.00	4.00	5.00
1.A.4.b.5	Speech Clarity	14	3.79	3.65	- 0.14	1.58	41.67%	2.00	4.00	7.00

Table 15. Individual Abilities Statistics – 2018

	Ability	Answers	Mean^{A}	Mean^{B}	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.a.1	Oral Comprehension	14	4.93	5.20	0.27	1.07	21.74%	3.00	5.00	7.00
1.A.1.a.2	Written Comprehension	14	5.50	5.54	0.04	1.16	21.10%	3.00	6.00	7.00
1.A.1.a.3	Oral Expression	14	5.36	5.64	0.29	1.15	21.48%	3.00	5.50	7.00
1.A.1.a.4	Written Expression	14	4.79	5.06	0.27	1.37	28.60%	2.00	5.00	7.00
1.A.1.b.1	Fluency of Ideas	14	5.07	5.46	0.39	1.33	26.19%	3.00	5.00	7.00
1.A.1.b.2	Originality	13	3.92	4.03	0.11	1.61	40.92%	1.00	4.00	7.00
1.A.1.b.3	Problem Sensitivity	14	5.14	5.56	0.42	1.79	34.83%	2.00	5.50	7.00
1.A.1.b.4	Deductive Reasoning	14	5.71	5.91	0.20	1.20	21.08%	4.00	6.00	7.00
1.A.1.b.5	Inductive Reasoning	14	5.71	5.50	- 0.21	1.20	21.08%	3.00	6.00	7.00
1.A.1.b.6	Information Ordering	14	5.86	6.10	0.25	1.23	21.02%	4.00	6.00	7.00
1.A.1.b.7	Category Flexibility	14	6.14	6.28	0.13	1.03	16.72%	4.00	6.50	7.00
1.A.1.c.1	Mathematical Reasoning	14	5.86	5.80	- 0.06	1.23	21.02%	4.00	6.00	7.00
1.A.1.c.2	Number Facility	13	6.92	6.40	- 0.53	0.28	4.01%	6.00	7.00	7.00
1.A.1.d.1	Memorization	13	6.77	6.83	0.06	0.44	6.48%	6.00	7.00	7.00
1.A.1.e.1	Speed of Closure	13	6.08	5.37	- 0.71	1.12	18.35%	4.00	7.00	7.00
1.A.1.e.2	Flexibility of Closure	14	6.36	6.62	0.26	0.84	13.24%	5.00	7.00	7.00
1.A.1.e.3	Perceptual Speed	14	6.86	6.90	0.05	0.36	5.30%	6.00	7.00	7.00
1.A.1.f.1	Spatial Orientation	14	6.36	6.56	0.20	1.01	15.86%	4.00	7.00	7.00
1.A.1.f.2	Visualization	13	5.54	5.59	0.05	1.51	27.20%	2.00	6.00	7.00
1.A.1.g.1	Selective Attention	14	6.57	6.80	0.23	0.85	12.96%	4.00	7.00	7.00
1.A.1.g.2	Time Sharing	12	6.83	7.00	0.17	0.58	8.45%	5.00	7.00	7.00
1.A.2.a.1	Arm-Hand Steadiness	14	6.07	6.48	0.41	1.14	18.80%	4.00	6.50	7.00
1.A.2.a.2	Manual Dexterity	14	5.79	6.25	0.46	1.31	22.67%	3.00	6.00	7.00
1.A.2.a.3	Finger Dexterity	14	5.64	6.44	0.80	1.34	23.68%	2.00	6.00	7.00
1.A.2.b.1	Control Precision	14	6.21	6.69	0.48	0.97	15.69%	4.00	6.50	7.00
1.A.2.b.2	Multilimb Coordination	14	6.07	6.52	0.44	0.92	15.10%	4.00	6.00	7.00
1.A.2.b.3	Response Orientation	14	6.00	6.28	0.28	0.78	13.07%	5.00	6.00	7.00
1.A.2.b.4	Rate Control	14	5.79	6.38	0.60	1.25	21.63%	3.00	6.00	7.00
1.A.2.c.1	Reaction Time	14	6.00	6.33	0.33	1.11	18.49%	4.00	6.00	7.00
1.A.2.c.2	Wrist-Finger Speed	14	5.43	6.32	0.89	1.79	32.88%	2.00	6.00	7.00
1.A.2.c.3	Speed of Limb Movement	14	5.43	6.07	0.64	1.34	24.73%	3.00	5.50	7.00
1.A.3.a.1	Static Strength	14	6.71	6.86	0.14	0.47	6.98%	6.00	7.00	7.00
1.A.3.a.2	Explosive Strength	14	5.93	6.45	0.53	1.14	19.25%	4.00	6.00	7.00
1.A.3.a.3	Dynamic Strength	14	5.79	6.56	0.77	1.37	23.66%	3.00	6.00	7.00
1.A.3.a.4	Trunk Strength	14	5.64	6.50	0.86	1.65	29.17%	3.00	6.50	7.00
1.A.3.b.1	Stamina	14	6.07	6.36	0.29	1.73	28.50%	1.00	7.00	7.00
1.A.3.c.1	Extent Flexibility	14	5.64	6.50	0.86	1.34	23.68%	3.00	6.00	7.00
1.A.3.c.2	Dynamic Flexibility	14	5.29	5.92	0.64	1.38	26.16%	3.00	5.50	7.00
1.A.3.c.3	Gross Body Coordination	14	5.00	5.47	0.47	1.36	27.17%	2.00	5.00	7.00
1.A.3.c.4	Gross Body Equilibrium	14	5.57	6.02	0.45	1.09	19.55%	3.00	6.00	7.00
1.A.4.a.1	Near Vision	14	6.36	6.60	0.24	0.84	13.24%	5.00	7.00	7.00
1.A.4.a.2	Far Vision	14	6.71	6.82	0.11	0.61	9.10%	5.00	7.00	7.00
1.A.4.a.3	Visual Color Discrimination	14	6.14	6.10	- 0.04	1.10	17.90%	3.00	6.00	7.00
1.A.4.a.4	Night Vision	14	6.07	6.29	0.22	0.83	13.65%	5.00	6.00	7.00
1.A.4.a.5	Peripheral Vision	14	6.14	6.58	0.44	1.17	19.00%	3.00	6.50	7.00
1.A.4.a.6	Depth Perception	13	6.15	6.30	0.15	0.90	14.60%	4.00	6.00	7.00
1.A.4.a.7	Glare Sensitivity	14	5.79	5.77	- 0.01	1.31	22.67%	3.00	6.00	7.00
1.A.4.b.1	Hearing Sensitivity	14	6.21	6.29	0.08	0.80	12.90%	5.00	6.00	7.00
1.A.4.b.2	Auditory Attention	13	6.15	6.36	0.20	0.90	14.60%	4.00	6.00	7.00
1.A.4.b.3	Sound Localization	13	6.15	6.27	0.12	0.99	16.04%	4.00	6.00	7.00
1.A.4.b.4	Speech Recognition	14	6.14	6.37	0.23	0.77	12.54%	5.00	6.00	7.00
1.A.4.b.5	Speech Clarity	14	5.57	5.52	- 0.06	1.45	26.07%	2.00	6.00	7.00

Table 16. Individual Abilities Statistics – 2038

	Ability	Answers	Mean^{A}	Mean^{B}	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.a.1	Oral Comprehension	-	2.29	2.56	0.27	0.14	6.25%	2.00	2.50	3.00
1.A.1.a.2	Written Comprehension	-	2.07	2.11	0.04	0.07	3.42%	2.00	2.50	2.00
1.A.1.a.3	Oral Expression	-	1.71	1.71	0.00	- 0.35	20.32%	2.00	1.50	-
1.A.1.a.4	Written Expression	-	1.79	1.67	- 0.11	- 0.10	5.53%	1.00	2.00	1.00
1.A.1.b.1	Fluency of Ideas	-	1.71	1.51	- 0.21	- 0.45	26.39%	2.00	2.00	-
1.A.1.b.2	Originality	-	2.31	2.54	0.23	0.64	27.93%	-	3.00	3.00
1.A.1.b.3	Problem Sensitivity	-	1.93	1.81	- 0.12	- 0.01	0.71%	1.00	2.50	1.00
1.A.1.b.4	Deductive Reasoning	-	1.64	1.56	- 0.08	- 0.23	14.30%	2.00	2.00	-
1.A.1.b.5	Inductive Reasoning	-	1.86	1.54	- 0.31	- 0.50	26.86%	1.00	2.50	-
1.A.1.b.6	Information Ordering	-	1.43	1.24	- 0.19	- 0.47	32.57%	2.00	2.00	-
1.A.1.b.7	Category Flexibility	-	1.50	1.22	- 0.28	- 0.71	47.31%	2.00	2.00	-
1.A.1.c.1	Mathematical Reasoning	-	1.64	1.44	- 0.20	- 0.49	29.60%	3.00	1.50	-
1.A.1.c.2	Number Facility	-	0.69	0.33	- 0.36	- 1.41	204.17%	4.00	-	-
1.A.1.d.1	Memorization	-	1.00	0.68	- 0.32	- 0.86	86.24%	2.00	1.00	-
1.A.1.e.1	Speed of Closure	- 1.00	1.65	0.59	- 1.06	- 0.49	29.63%	2.00	3.00	-
1.A.1.e.2	Flexibility of Closure	-	2.00	2.05	0.05	- 0.60	30.25%	4.00	3.00	1.00
1.A.1.e.3	Perceptual Speed	-	1.29	1.00	- 0.29	- 0.73	56.49%	3.00	1.50	-
1.A.1.f.1	Spatial Orientation	-	1.71	1.44	- 0.27	- 0.59	34.43%	3.00	2.50	-
1.A.1.f.2	Visualization	- 1.00	1.47	1.07	- 0.40	- 0.39	26.83%	1.00	1.50	-
1.A.1.g.1	Selective Attention	-	0.86	0.83	- 0.03	- 0.79	91.68%	2.00	0.50	-
1.A.1.g.2	Time Sharing	- 1.00	1.76	1.32	- 0.43	- 0.86	49.18%	2.00	2.00	-
1.A.2.a.1	Arm-Hand Steadiness	-	1.50	0.94	- 0.56	- 0.69	45.77%	2.00	2.00	-
1.A.2.a.2	Manual Dexterity	-	1.86	1.67	- 0.19	- 0.51	27.23%	2.00	2.00	-
1.A.2.a.3	Finger Dexterity	-	1.93	1.70	- 0.23	- 0.48	24.86%	1.00	2.00	-
1.A.2.b.1	Control Precision	-	1.50	1.03	- 0.47	- 0.66	44.17%	2.00	2.50	-
1.A.2.b.2	Multilimb Coordination	-	2.14	1.92	- 0.22	- 0.63	29.19%	3.00	2.00	1.00
1.A.2.b.3	Response Orientation	-	1.93	1.64	- 0.29	- 0.76	39.30%	3.00	2.00	-
1.A.2.b.4	Rate Control	-	2.00	1.43	- 0.57	- 0.76	37.77%	2.00	2.00	-
1.A.2.c.1	Reaction Time	-	1.64	0.95	- 0.69	- 0.80	48.47%	2.00	2.00	-
1.A.2.c.2	Wrist-Finger Speed	-	1.93	1.66	- 0.27	- 0.28	14.57%	1.00	3.00	-
1.A.2.c.3	Speed of Limb Movement	-	1.57	1.33	- 0.24	- 0.41	25.80%	1.00	2.00	-
1.A.3.a.1	Static Strength	-	1.14	0.51	- 0.63	- 1.18	103.43%	4.00	1.00	-
1.A.3.a.2	Explosive Strength	-	2.14	1.86	- 0.28	- 0.53	24.79%	3.00	2.00	-
1.A.3.a.3	Dynamic Strength	-	1.36	0.81	- 0.55	- 0.84	61.90%	2.00	1.00	-
1.A.3.a.4	Trunk Strength	-	1.14	0.68	- 0.46	- 0.60	52.40%	1.00	2.50	-
1.A.3.b.1	Stamina	-	0.93	0.38	- 0.55	- 0.34	36.59%	-	1.50	-
1.A.3.c.1	Extent Flexibility	-	1.71	1.48	- 0.23	- 0.52	30.49%	2.00	2.00	-
1.A.3.c.2	Dynamic Flexibility	-	1.93	1.51	- 0.42	- 0.31	16.03%	2.00	2.50	-
1.A.3.c.3	Gross Body Coordination	-	2.14	1.91	- 0.24	0.01	0.38%	1.00	3.00	1.00
1.A.3.c.4	Gross Body Equilibrium	-	2.43	2.50	0.07	0.22	9.26%	1.00	3.00	3.00
1.A.4.a.1	Near Vision	-	1.21	0.87	- 0.35	- 0.72	59.30%	3.00	2.00	-
1.A.4.a.2	Far Vision	-	1.43	1.00	- 0.43	- 0.88	61.50%	3.00	2.00	-
1.A.4.a.3	Visual Color Discrimination	-	1.57	1.39	- 0.18	- 0.18	11.74%	1.00	1.00	1.00
1.A.4.a.4	Night Vision	-	1.50	0.95	- 0.55	- 1.12	74.75%	3.00	1.50	-
1.A.4.a.5	Peripheral Vision	-	1.43	1.02	- 0.41	- 0.73	51.18%	2.00	2.00	-
1.A.4.a.6	Depth Perception	-	1.69	1.71	0.02	- 0.61	35.91%	2.00	1.00	-
1.A.4.a.7	Glare Sensitivity	-	1.57	1.46	- 0.12	- 0.41	25.86%	1.00	2.00	-
1.A.4.b.1	Hearing Sensitivity	-	1.64	1.42	- 0.22	- 0.94	57.20%	3.00	1.50	-
1.A.4.b.2	Auditory Attention	-	2.00	2.00	-	- 0.87	43.68%	2.00	2.00	-
1.A.4.b.3	Sound Localization	-	1.92	1.73	- 0.19	- 0.80	41.58%	2.00	2.00	-
1.A.4.b.4	Speech Recognition	-	2.14	2.28	0.13	- 0.11	4.98%	3.00	2.00	2.00
1.A.4.b.5	Speech Clarity	-	1.79	1.87	0.09	- 0.13	7.01%	-	2.00	-

Table 17. Individual Abilities Statistics - 2018 / 2038

In the following paragraphs we analyze the top 5 and bottom 5 rankings for means and deviations of individual abilities, summarized in Table 18.

	Year	2018								
	Top 5 (mean)	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.c.2	Number Facility	13	6.23	6.06	- 0.17	1.69	27.14%	2.00	7.00	7.00
1.A.1.d.1	Memorization	13	5.77	6.15	0.38	1.30	22.55%	4.00	6.00	7.00
1.A.1.g.1	Selective Attention	14	5.71	5.97	0.26	1.64	28.66%	2.00	6.50	7.00
1.A.3.a.1	Static Strength	14	5.57	6.34	0.77	1.65	29.63%	2.00	6.00	7.00
1.A.1.e.3	Perceptual Speed	14	5.57	5.90	0.33	1.09	19.55%	3.00	5.50	7.00

	Year	2018								
	Bottom 5 (mean)	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.b.2	Originality	13	1.62	1.49	- 0.12	0.96	59.48%	1.00	1.00	4.00
1.A.1.a.1	Oral Comprehension	14	2.64	2.64	-	0.93	35.14%	1.00	2.50	4.00
1.A.3.c.3	Gross Body Coordination	14	2.86	3.57	0.71	1.35	47.27%	1.00	2.00	6.00
1.A.1.a.4	Written Expression	14	3.00	3.39	0.39	1.47	48.92%	1.00	3.00	6.00
1.A.3.c.4	Gross Body Equilibrium	14	3.14	3.52	0.38	0.86	27.50%	2.00	3.00	4.00

	Year	2018								
	Top 5 (deviation)	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.3.a.4	Trunk Strength	14	4.50	5.82	1.32	2.24	49.88%	2.00	4.00	7.00
1.A.3.a.3	Dynamic Strength	14	4.43	5.75	1.32	2.21	49.88%	1.00	5.00	7.00
1.A.2.c.2	Wrist-Finger Speed	14	3.50	4.66	1.16	2.07	59.03%	1.00	3.00	7.00
1.A.3.b.1	Stamina	14	5.14	5.99	0.84	2.07	40.25%	1.00	5.50	7.00
1.A.2.b.4	Rate Control	14	3.79	4.95	1.16	2.01	53.01%	1.00	4.00	7.00

	Year	2018								
	Bottom 5 (deviation)	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.3.c.4	Gross Body Equilibrium	14	3.14	3.52	0.38	0.86	27.50%	2.00	3.00	4.00
1.A.4.b.4	Speech Recognition	14	4.00	4.09	0.09	0.88	21.93%	2.00	4.00	5.00
1.A.1.a.1	Oral Comprehension	14	2.64	2.64	-	0.93	35.14%	1.00	2.50	4.00
1.A.1.b.2	Originality	13	1.62	1.49	- 0.12	0.96	59.48%	1.00	1.00	4.00
1.A.1.a.2	Written Comprehension	14	3.43	3.43	0.00	1.09	31.77%	1.00	3.50	5.00

Table 18. Individual Abilities Top and Bottom Rankings - 2018

Taking into account the means, Number Facility (mean = 6.23 and median = 7.00), Memorization (mean = 5.77 and median = 6.00), Selective Attention (mean = 5.71 and median = 6.50), Static Strength (mean = 5.57 and median = 6.00) and Perceptual Speed (mean = 5.57 and median = 5.50) were the top 5 abilities in 2018, meaning that experts understand that these abilities are already very likely of being emulated quite well by Artificial Intelligence, Robotics, and related technologies.

On the other side, Originality (mean = 1.62 and median = 1.00), Oral Comprehension (mean = 2.64 and median = 2.50), Gross Body Coordination (mean = 2,86 and median = 2.00), Written Expression (mean = 3.00 and median = 3.00) and Gross Body Equilibrium (mean = 3.14 and median = 3.00) were the bottom 5 of the 52 abilities in 2018 according to specialists. This means that based on the combined opinion of the experts and considering a complexity point of view, these abilities are less likely of being executed by Artificial Intelligence, Robotics, and related technologies in 2018. Based on the analysis of the standard deviations of these abilities, and combining them with the coefficient of variance, we considered that results found for both top 5 and bottom 5 abilities in 2018 are acceptable with some degree of confidence.

In terms of homogeneity of opinions, Trunk Strength (std deviation = 2.24), Dynamic Strength (std deviation = 2.21), Wrist-Finger Speed (std deviation = 2.07), Stamina (std deviation = 2.07) and Rate Control (std deviation = 2.01) were the ones with higher deviation, which means higher heterogeneity in the experts' opinions.

Contrary, Gross Body Equilibrium (std deviation = 0.86), Speech Recognition (std deviation = 0.88), Oral Comprehension (std deviation = 0.93), Originality (std deviation = 0.96) and Written Comprehension (std deviation = 1.09) were the ones with more homogeneity among the experts' opinions in 2018.

	Year	2038								
	Top 5 (mean)	Answers	Mean[A]	Mean[B]	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.c.2	Number Facility	13	6.92	6.40	- 0.53	0.28	4.01%	6.00	7.00	7.00
1.A.1.e.3	Perceptual Speed	14	6.86	6.90	0.05	0.36	5.30%	6.00	7.00	7.00
1.A.1.g.2	Time Sharing	12	6.83	7.00	0.17	0.58	8.45%	5.00	7.00	7.00
1.A.1.d.1	Memorization	13	6.77	6.83	0.06	0.44	6.48%	6.00	7.00	7.00
1.A.3.a.1	Static Strength	14	6.71	6.86	0.14	0.47	6.98%	6.00	7.00	7.00

	Year	2038								
	Bottom 5 (mean)	Answers	Mean[A]	Mean[B]	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.b.2	Originality	13	3.92	4.03	0.11	1.61	40.92%	1.00	4.00	7.00
1.A.1.a.4	Written Expression	14	4.79	5.06	0.27	1.37	28.60%	2.00	5.00	7.00
1.A.1.a.1	Oral Comprehension	14	4.93	5.20	0.27	1.07	21.74%	3.00	5.00	7.00
1.A.3.c.3	Gross Body Coordination	14	5.00	5.47	0.47	1.36	27.17%	2.00	5.00	7.00
1.A.1.b.1	Fluency of Ideas	14	5.07	5.46	0.39	1.33	26.19%	3.00	5.00	7.00

	Year	2038								
	Top 5 (deviation)	Answers	Mean[A]	Mean[B]	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.b.3	Problem Sensitivity	14	5.14	5.56	0.42	1.79	34.83%	2.00	5.50	7.00
1.A.2.c.2	Wrist-Finger Speed	14	5.43	6.32	0.89	1.79	32.88%	2.00	6.00	7.00
1.A.3.b.1	Stamina	14	6.07	6.36	0.29	1.73	28.50%	1.00	7.00	7.00
1.A.3.a.4	Trunk Strength	14	5.64	6.50	0.86	1.65	29.17%	3.00	6.50	7.00
1.A.1.b.2	Originality	13	3.92	4.03	0.11	1.61	40.92%	1.00	4.00	7.00

	Year	2038								
	Bottom 5 (deviation)	Answers	Mean[A]	Mean[B]	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.c.2	Number Facility	13	6.92	6.40	- 0.53	0.28	4.01%	6.00	7.00	7.00
1.A.1.e.3	Perceptual Speed	14	6.86	6.90	0.05	0.36	5.30%	6.00	7.00	7.00
1.A.1.d.1	Memorization	13	6.77	6.83	0.06	0.44	6.48%	6.00	7.00	7.00
1.A.3.a.1	Static Strength	14	6.71	6.86	0.14	0.47	6.98%	6.00	7.00	7.00
1.A.1.g.2	Time Sharing	12	6.83	7.00	0.17	0.58	8.45%	5.00	7.00	7.00

Table 19. Individual Abilities Top and Bottom Rankings - 2038

In 2038, as shown in Table 19, Number Facility (mean = 6.92 and median = 7.00), Perceptual Speed (mean = 6.86 and median 7.00), Time Sharing (mean 6.83 and median 7.00), Memorization (mean 6.77 and median 7.00) and Static Strength (mean = 6.71 and median 7.00) were the top 5 abilities, meaning that experts believe that these abilities could be performed or emulated by Artificial Intelligence, Robotics, and related technologies in high complexity scenarios with acceptable and comparable quality. In practical terms, it means that machines could effectively replace humans (at least partially) in occupations that require these individual abilities. Except for Time Sharing, 4 out of 5 abilities in this raking were preserved from 2018, which shows consistency in terms of abilities.

On the opposite side, Originality (mean = 3.92 and median = 4.00), Written Expression (mean = 4.79 and median = 5.00), Oral Comprehension (mean = 4.93 and median = 5.00), Gross Body Coordination (mean = 5.00 and median = 5.00) and Fluency of Ideas (mean = 5.07 and median = 5.00) were the bottom 5 abilities in 2038 from a mean perspective. This means that based on the combined opinion of the experts and considering a complexity point of view, these abilities were evaluated as being less likely of being emulated by Artificial

Intelligence, Robotics, and related technologies. In spite of being the lower abilities, it is important to note that they are all in the above average range, except Originality, which is in the average range. We believe this clearly means that experts understand that studies and technologies will progress in the next two decades including in these areas. However, comparing 2018 and 2038, these abilities were consistently the lower ones since 4 out of 5 abilities in the raking were preserved – the new one being Fluency of Ideas, which means that these abilities can be considered as eventual bottlenecks.

Homogeneity was evidently higher in 2038, since there is an upper limitation on the scale and all abilities increased their levels. Problem Sensitivity (std deviation = 1.79), Wrist-Finger Speed (std deviation = 1.79), Stamina (std deviation = 1.73), Trunk Strength (std deviation = 1.65) and Originality (std deviation = 1.61) were the ones with higher deviation and consequently heterogeneity, but all in an acceptable level. Number Facility (std deviation = 0.28), Perceptual Speed (std deviation = 0.36), Memorization (std deviation = 0.44), Static Strength (std deviation = 0.47) and Time Sharing (std deviation = 0.58) were the ones with more homogeneity among the experts, validating and increasing the confidence in the top 5 abilities.

	Year vs Year	Differences between 2038 - 2018								
	Top 5 (mean)	Answers	$Mean^A$	$Mean^B$	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.c.2	Gross Body Equilibrium	-	2.43	2.50	0.07	0.22	9.26%	1.00	3.00	3.00
1.A.1.g.1	Originality	-	2.31	2.54	0.23	0.64	27.93%	-	3.00	3.00
1.A.3.b.1	Oral Comprehension	-	2.29	2.56	0.27	0.14	6.25%	2.00	2.50	3.00
1.A.1.d.1	Gross Body Coordination	-	2.14	1.91	- 0.24	0.01	0.38%	1.00	3.00	1.00
1.A.3.a.1	Speech Recognition	-	2.14	2.28	0.13	- 0.11	-4.98%	3.00	2.00	2.00

	Year vs Year	Differences between 2038 - 2018								
	Bottom 5 (mean)	Answers	$Mean^A$	$Mean^B$	Dif Means	Deviation	CV	Min	Median	Max
1.A.3.c.4	Number Facility	-	0.69	0.33	- 0.36	- 1.41	-204.17%	4.00	-	-
1.A.1.b.2	Selective Attention	-	0.86	0.83	- 0.03	- 0.79	-91.68%	2.00	0.50	-
1.A.1.a.1	Stamina	-	0.93	0.38	- 0.55	- 0.34	-36.59%	-	1.50	-
1.A.3.c.3	Memorization	-	1.00	0.68	- 0.32	- 0.86	-86.24%	2.00	1.00	-
1.A.4.b.4	Static Strength	-	1.14	0.51	- 0.63	- 1.18	-103.43%	4.00	1.00	-

	Year	Differences between 2038 - 2018								
	Top 5 (deviation)	Answers	$Mean^A$	$Mean^B$	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.c.2	Number Facility	-	0.69	0.33	- 0.36	- 1.41	-204.17%	4.00	-	-
1.A.3.a.1	Static Strength	-	1.14	0.51	- 0.63	- 1.18	-103.43%	4.00	1.00	-
1.A.4.a.4	Night Vision	-	1.50	0.95	- 0.55	- 1.12	-74.75%	3.00	1.50	-
1.A.4.b.1	Hearing Sensitivity	-	1.64	1.42	- 0.22	- 0.94	-57.20%	3.00	1.50	-
1.A.4.a.2	Far Vision	-	1.43	1.00	- 0.43	- 0.88	-61.50%	3.00	2.00	-

	Year vs Year	Differences between 2038 - 2018								
	Bottom 5 (deviation)	Answers	$Mean^A$	$Mean^B$	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.b.3	Problem Sensitivity	-	1.93	1.81	- 0.12	- 0.01	-0.71%	1.00	2.50	1.00
1.A.3.c.3	Gross Body Coordination	-	2.14	1.91	- 0.24	0.01	0.38%	1.00	3.00	1.00
1.A.1.a.2	Written Comprehension	-	2.07	2.11	0.04	0.07	3.42%	2.00	2.50	2.00
1.A.1.a.4	Written Expression	-	1.79	1.67	- 0.11	- 0.10	-5.53%	1.00	2.00	1.00
1.A.4.b.4	Speech Recognition	-	2.14	2.28	0.13	- 0.11	-4.98%	3.00	2.00	2.00

Table 20. Individual Abilities Top and Bottom Rankings - 2018 / 2038

The differences between 2038 and 2018 from Table 20 show that Gross Body Equilibrium (mean = 2.43), Originality (mean = 2.31), Oral Comprehension (mean = 2.29), Gross Body Coordination (mean = 2.14) and Speech Recognition (mean = 2.14) were the abilities that experienced the highest rating increases between 2018 and 2038, which could mean that experts understand these technologies will improve reasonably in the next twenty years. On the other hand, Number Facility (mean = 0.69), Selective Attention (mean = 0.86), Stamina (mean = 0.93), Memorization (mean = 1.00) and Static Strength (mean = 1.14) were the abilities that, based on the combined opinion of the experts and considering a complexity point of view, experienced the lowest impact by Artificial Intelligence, Robotics, and related technologies. In several of these cases, saturation must be taken into account – i.e. technologies are already so infused in 2018 that the space to increase can be considered as limited.

By comparing these findings with those from Frey & Osborne (2017)'s, we can derive some notable evaluations with the aid from Table 21. First of all, based on the experts' opinions, Originality was the ability that in 2018 and in 2038 is less likely to be adequately executed or emulated by Artificial Intelligence, Robotics, and related technologies. In 2018, the combined opinions were in the low range, with its median in the very low, while in 2038 it increased to the average range, just 0.08 below the perfect mean (4.00). It is, therefore, confirmed as a bottleneck for computerization, similarly to Frey & Osborne (2017)'s outcomes.

	Year	2018								
	Frey & Osborne	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.b.2	Originality	13	1.62	1.49	- 0.12	0.96	59.48%	1.00	1.00	4.00
1.A.2.a.2	Manual Dexterity	14	3.93	4.58	0.65	1.82	46.26%	1.00	4.00	7.00
1.A.2.a.3	Finger Dexterity	14	3.71	4.75	1.03	1.82	48.88%	1.00	4.00	7.00

	Year	2038								
	Frey & Osborne	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.b.2	Originality	13	3.92	4.03	0.11	1.61	40.92%	1.00	4.00	7.00
1.A.2.a.2	Manual Dexterity	14	5.79	6.25	0.46	1.31	22.67%	3.00	6.00	7.00
1.A.2.a.3	Finger Dexterity	14	5.64	6.44	0.80	1.34	23.68%	2.00	6.00	7.00

	Year	Differences between 2038 - 2018								
	Frey & Osborne	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.b.2	Originality	-	2.31	2.54	0.23	0.64	27.93%	-	3.00	3.00
1.A.2.a.2	Manual Dexterity	-	1.86	1.67	- 0.19	- 0.51	-27.23%	2.00	2.00	-
1.A.2.a.3	Finger Dexterity	-	1.93	1.70	- 0.23	- 0.48	-24.86%	1.00	2.00	-

Table 21. Frey & Osborne (2017)'s Bottlenecks Statistics

However, in an opposite direction to Frey & Osborne (2017)'s observations, experts that participated in the survey did not consider Manual Dexterity and Finger Dexterity as key bottlenecks for Artificial Intelligence, Robotics, and related technologies. As backed up by the data, they were both evaluated in the average range in 2018 and were moved to the high range in 2038 with solid means and medians in this range. Out of the 52 abilities and in an ascending order, where Originality was ranked 1st both in 2018 and 2038, Finger Dexterity was ranked as 12th in 2018 and 15th in 2038 and Manual Dexterity was ranked as 18th in 2018 and 18th in 2038.

Nonetheless, other abilities not mentioned by Frey & Osborne (2017) arouse as possible bottlenecks both in current and future state, as shown in Table 22. They were Written Expression (4th in 2018 and 2nd in 2038), the aptitude of "read and understand information and ideas presented in writing"[83]; Oral Comprehension (2nd in 2018 and 3rd in 2038), which is the ability "to listen to and understand information and ideas presented through spoken

[83] O*NET Content Model Reference documentation (2019)

words and sentences"; Gross Body Coordination (3rd in 2018 and 4th in 2038), the ability "to coordinate the movement of your arms, legs, and torso together when the whole body is in motion"; and Fluency of Ideas (7th in 2018 and 5th in 2038), which is the aptitude "to come up with a number of ideas about a topic". Additionally, there were other abilities that could be further evaluated as potential bottlenecks, or at least, as challenges to be overcome. Although several of these abilities were in the above medium range of the evaluation scale, it is reasonable to assume them as bottlenecks based on the opinions and justifications of the experts, which are shared in the following sections. Therefore, as a general consideration, we believe that Frey & Osborne (2017)'s research may have oversimplified the abilities bottlenecks.

	Year	2038								
	Bottom 5 (mean)	Answers	Mean[A]	Mean[B]	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.b.2	Originality	13	3.92	4.03	0.11	1.61	40.92%	1.00	4.00	7.00
1.A.1.a.4	Written Expression	14	4.79	5.06	0.27	1.37	28.60%	2.00	5.00	7.00
1.A.1.a.1	Oral Comprehension	14	4.93	5.20	0.27	1.07	21.74%	3.00	5.00	7.00
1.A.3.c.3	Gross Body Coordination	14	5.00	5.47	0.47	1.36	27.17%	2.00	5.00	7.00
1.A.1.b.1	Fluency of Ideas	14	5.07	5.46	0.39	1.33	26.19%	3.00	5.00	7.00

Table 22. Bottlenecks for Computerization of Abilities

Group Evaluation

Table 23, Table 24 and Table 25 illustrate the key combined statistics of the 15 abilities types (also referred as abilities groups) considering the current state (2018), the future state (2038) and the differences between them, respectively. These groups were based on the combinations of O*NET's ability types, available in the reference model and shown previously in Table 13.

	Year	2018								
	Ability Type	Answers	Mean[A]	Mean[B]	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.a	Verbal Abilities	56	3.18	3.35	0.17	1.29	40.74%	1.00	3.00	7.00
1.A.1.b	Idea Generation and Reasoning A	97	3.60	3.92	0.31	1.82	50.65%	1.00	3.00	7.00
1.A.1.c	Quantitative Abilities	27	5.22	5.21	- 0.01	1.96	37.57%	1.00	6.00	7.00
1.A.1.d	Memory	13	5.77	6.15	0.38	1.30	22.55%	4.00	6.00	7.00
1.A.1.e	Perceptual Abilities	42	4.79	5.08	0.30	1.47	30.80%	1.00	5.00	7.00
1.A.1.f	Spatial Abilities	28	4.36	4.82	0.46	1.75	40.10%	1.00	4.50	7.00
1.A.1.g	Attentiveness	27	5.40	5.82	0.43	1.55	28.74%	2.00	6.00	7.00
1.A.2.a	Fine Manipulative Abilities	42	4.07	4.95	0.88	1.81	44.53%	1.00	4.00	7.00
1.A.2.b	Control Movement Abilities	56	4.13	4.96	0.84	1.68	40.84%	1.00	4.00	7.00
1.A.2.c	Reaction Time and Speed Abilitie	42	3.90	4.93	1.02	1.90	48.59%	1.00	4.00	7.00
1.A.3.a	Physical Strength Abilities	56	4.57	5.62	1.05	2.02	44.12%	1.00	5.00	7.00
1.A.3.b	Endurance	14	5.14	5.99	0.84	2.07	40.25%	1.00	5.50	7.00
1.A.3.c	Flexibility, Balance, and Coordin	56	3.32	4.13	0.81	1.50	45.25%	1.00	3.00	7.00
1.A.4.a	Visual Abilities	97	4.71	5.15	0.46	1.63	34.67%	1.00	5.00	7.00
1.A.4.b	Auditory and Speech Abilities	68	4.15	4.30	0.12	1.56	37.55%	0.09	4.00	7.00
	Total	721	4.21	4.73	0.52	1.62	38.49%	0.09	4.00	7.00

Table 23. Group Abilities Statistics - 2018

Considering the results of the group statistics shown in Table 23, overall, abilities in 2018 were assigned in the average range (mean = 4.21 and median = 4.00), meaning that in the combined opinion of the experts, abilities are being executed and emulated to an intermediate extent from a complexity point of view by Artificial Intelligence, Robotics, and related technologies. Most of the ability types (8 out of 15) were in the below average or average range. In spite of acceptable and intermediate coefficients of variation, deviation among answers in 2018 cannot be ignored (overall std. deviation = 1.62). The deviation is an important metric because it shows homogeneity or heterogeneity among the answers of the experts and in 2018 there seems to be some level of disagreement between the opinion of the experts, especially in Physical Abilities and Endurance. Statistics also show that there was a considerable difference between the two ways to calculate the means (0.52), with Reaction Time and Speed Abilities and Physical Strength Abilities having over one point of difference. Despite this disparity, as previously stated, all the analysis performed in this work uses the arithmetic mean to make the best out of the data volume gathered. The practical effect of this action is that most of the results presented have a more conservative bias.

	Year	2038								
	Ability Type	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.a	Verbal Abilities	56	5.14	5.36	0.22	1.20	23.28%	2.00	5.00	7.00
1.A.1.b	Idea Generation and Reasoning A	97	5.37	5.55	0.09	1.48	27.62%	1.00	6.00	7.00
1.A.1.c	Quantitative Abilities	27	6.39	6.10	- 0.29	1.04	16.33%	4.00	7.00	7.00
1.A.1.d	Memory	13	6.77	6.83	0.06	0.44	6.48%	6.00	7.00	7.00
1.A.1.e	Perceptual Abilities	41	6.43	6.30	- 0.13	0.87	13.49%	4.00	7.00	7.00
1.A.1.f	Spatial Abilities	27	5.95	6.07	0.12	1.32	22.11%	2.00	6.00	7.00
1.A.1.g	Attentiveness	26	6.70	6.90	0.20	0.74	10.98%	4.00	7.00	7.00
1.A.2.a	Fine Manipulative Abilities	42	5.83	6.39	0.56	1.25	21.39%	2.00	6.00	7.00
1.A.2.b	Control Movement Abilities	56	6.02	6.47	0.45	0.98	16.31%	3.00	6.00	7.00
1.A.2.c	Reaction Time and Speed Abiliti	42	5.62	6.24	0.62	1.43	25.46%	2.00	6.00	7.00
1.A.3.a	Physical Strength Abilities	56	6.02	6.59	0.57	1.27	21.14%	3.00	7.00	7.00
1.A.3.b	Endurance	14	6.07	6.36	0.29	1.73	28.50%	1.00	7.00	7.00
1.A.3.c	Flexibility, Balance, and Coordin	56	5.38	5.98	0.60	1.29	23.95%	2.00	6.00	7.00
1.A.4.a	Visual Abilities	97	6.20	6.35	0.20	1.00	16.08%	3.00	6.00	7.00
1.A.4.b	Auditory and Speech Abilities	68	6.05	6.16	0.12	1.01	16.77%	2.00	6.00	7.00
	Total	718	5.88	6.15	0.27	1.11	18.79%	1.00	6.00	7.00

Table 24. Group Abilities Statistics - 2038

Data in Table 24 illustrates that overall, abilities in 2038 were evaluated in the high range (mean = 5.88 and median = 6.00), meaning that in the combined opinion of the experts, abilities could be executed and emulated to a high extent from a complexity point of view by Artificial Intelligence, Robotics, and related technologies. Actually, most of the ability types (11 out of 15) were evaluated as in high or very high ranges. Deviation in 2038 is lower than 2018 (overall std. deviation = 1.11), as with all the coefficients of variation that were less than 30%. Also, the difference between the two ways of calculating means in less in 2038 (0.27).

Table 25 shows the key distinctions between statistics in 2018 and 2038. Data indicate that, overall, responses for 2038 had an increase of 1.67 points in mean and 2.00 points in the median in comparison to 2018. All abilities and all abilities types increased in their ranking, meaning that experts believe that all abilities will have technological progress in the next twenty years (to a higher or lesser extent). In other words, as a combined cohort, we can infer that specialists do not perceive any technical plateaus that could indefinitely block technological progress to perform any of the evaluated abilities. Bottlenecks may exist, as mentioned, but we can conclude that experts trust in the new developments, approaches, and achievements to overcome them. Also, all deviations were reduced as well. An explanation for this behavior could be that there is more homogeneity in the answers of the experts looking forward (2038), but, as previously stated, a fact that cannot be ignored is that the range of possible answers is reduced when reaching the top limit (max. = 7.00).

	Year vs Year	Differences between 2038 - 2018								
	Ability Type	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.a	Verbal Abilities	-	1.96	2.01	0.05	- 0.10	-4.96%	1.00	2.00	-
1.A.1.b	Idea Generation and Reasoning A	-	1.77	1.63	- 0.22	- 0.34	-19.25%	-	3.00	-
1.A.1.c	Quantitative Abilities	-	1.17	0.89	- 0.28	- 0.92	-78.68%	3.00	1.00	-
1.A.1.d	Memory	-	1.00	0.68	- 0.32	- 0.86	-86.24%	2.00	1.00	-
1.A.1.e	Perceptual Abilities	- 1	1.64	1.21	- 0.43	- 0.61	-36.88%	3.00	2.00	-
1.A.1.f	Spatial Abilities	- 1	1.59	1.26	- 0.33	- 0.43	-27.17%	1.00	1.50	-
1.A.1.g	Attentiveness	- 1	1.31	1.08	- 0.23	- 0.81	-62.35%	2.00	1.00	-
1.A.2.a	Fine Manipulative Abilities	-	1.76	1.44	- 0.33	- 0.57	-32.09%	1.00	2.00	-
1.A.2.b	Control Movement Abilities	-	1.89	1.51	- 0.39	- 0.70	-37.16%	2.00	2.00	-
1.A.2.c	Reaction Time and Speed Abilitie	-	1.71	1.31	- 0.40	- 0.47	-27.24%	1.00	2.00	-
1.A.3.a	Physical Strength Abilities	-	1.45	0.97	- 0.48	- 0.74	-51.50%	2.00	2.00	-
1.A.3.b	Endurance	-	0.93	0.38	- 0.55	- 0.34	-36.59%	-	1.50	-
1.A.3.c	Flexibility, Balance, and Coordin	-	2.05	1.85	- 0.20	- 0.22	-10.50%	1.00	3.00	-
1.A.4.a	Visual Abilities	-	1.49	1.20	- 0.26	- 0.64	-42.81%	2.00	1.00	-
1.A.4.b	Auditory and Speech Abilities	-	1.90	1.86	0.01	- 0.54	-28.63%	-	2.00	-
	Total	- 3	1.68	1.42	- 0.26	- 0.51	-30.67%	0.91	2.00	-

Table 25. Group Abilities Statistics - 2018 - 2038

In the following tables, we analyze the top 5 and bottom 5 rankings for means and deviations of abilities types. The objective is to evaluate which are more likely to be emulated by Artificial Intelligence, Robotics, and related technologies or, on the other hand, less likely, thus potential bottlenecks for these technologies.

	Year	2018								
	Top 3 (mean)	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.d	Memory	13	5.77	6.15	0.38	1.30	22.55%	4.00	6.00	7.00
1.A.1.g	Attentiveness	27	5.40	5.82	0.43	1.55	28.74%	2.00	6.00	7.00
1.A.1.c	Quantitative Abilities	27	5.22	5.21	- 0.01	1.96	37.57%	1.00	6.00	7.00

	Year	2018								
	Bottom 3 (mean)	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.a	Verbal Abilities	56	3.18	3.35	0.17	1.29	40.74%	1.00	3.00	7.00
1.A.3.c	Flexibility, Balance, and Coordin	56	3.32	4.13	0.81	1.50	45.25%	1.00	3.00	7.00
1.A.1.b	Idea Generation and Reasoning A	97	3.60	3.92	0.31	1.82	50.65%	1.00	3.00	7.00

	Year	2018								
	Top 3 (deviation)	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.3.b	Endurance	14	5.14	5.99	0.84	2.07	40.25%	1.00	5.50	7.00
1.A.3.a	Physical Strength Abilities	56	4.57	5.62	1.05	2.02	44.12%	1.00	5.00	7.00
1.A.1.c	Quantitative Abilities	27	5.22	5.21	- 0.01	1.96	37.57%	1.00	6.00	7.00

	Year	2018								
	Bottom 3 (deviation)	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.a	Verbal Abilities	56	3.18	3.35	0.17	1.29	40.74%	1.00	3.00	7.00
1.A.1.d	Memory	13	5.77	6.15	0.38	1.30	22.55%	4.00	6.00	7.00
1.A.1.e	Perceptual Abilities	42	4.79	5.08	0.30	1.47	30.80%	1.00	5.00	7.00

Table 26. Group Abilities Top and Bottom Rankings - 2018

Based on findings from Table 26, Memory (mean = 5.77 and median = 6.00), Attentiveness (mean = 5.40 and median = 6.00) and Quantitative Abilities (mean = 5.22 and median = 6.00) were rated as the top 3 ability types in 2018, meaning that experts believe that these abilities groups were already being performed or emulated by Artificial Intelligence, Robotics, and related technologies in high complexity scenarios with adequate quality. On the other hand, Verbal Abilities (mean = 3.18 and median = 3.00), Flexibility, Balance and Coordination Abilities (mean = 3.32 and median = 3.00) and Idea Generation and Reasoning Abilities (mean = 3.60 and median = 3.00) were rated as the bottom 3 ability types in 2018. This means that based on the combined opinion of the experts and considering a complexity point of view, these ability types were not being properly emulated by Artificial Intelligence, Robotics, and related technologies. In terms of deviation, Endurance (std. deviation = 2.07), Physical Strength Abilities (std. deviation = 2.02) and Quantitative Abilities (std. deviation = 1.96) were the top 3, which means higher heterogeneity in the opinions. Verbal Abilities (std. deviation = 1.29), Memory (std. deviation = 1.30) and Perceptual Abilities (1.47) were the ones with more homogeneity among the experts' opinions. Based on the deviations just presented, it is reasonable to say that the results found for Verbal Abilities and Memory, respectively, as the less likely of being currently emulated by machines and as the more likely, can be acceptable with confidence.

	Year	2038								
	Top 3 (mean)	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.d	Memory	13	6.77	6.83	0.06	0.44	6.48%	6.00	7.00	7.00
1.A.1.g	Attentiveness	26	6.70	6.90	0.20	0.74	10.98%	4.00	7.00	7.00
1.A.1.e	Perceptual Abilities	41	6.43	6.30	- 0.13	0.87	13.49%	4.00	7.00	7.00

	Year	2038								
	Bottom 3 (mean)	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.a	Verbal Abilities	56	5.14	5.36	0.22	1.20	23.28%	2.00	5.00	7.00
1.A.1.b	Idea Generation and Reasoning A	97	5.37	5.55	0.09	1.48	27.62%	1.00	6.00	7.00
1.A.3.c	Flexibility, Balance, and Coordin	56	5.38	5.98	0.60	1.29	23.95%	2.00	6.00	7.00

	Year	2038								
	Top 3 (deviation)	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.3.b	Endurance	14	6.07	6.36	0.29	1.73	28.50%	1.00	7.00	7.00
1.A.1.b	Idea Generation and Reasoning A	97	5.37	5.55	0.09	1.48	27.62%	1.00	6.00	7.00
1.A.2.c	Reaction Time and Speed Abilitie	42	5.62	6.24	0.62	1.43	25.46%	2.00	6.00	7.00

	Year	2038								
	Bottom 3 (deviation)	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.d	Memory	13	6.77	6.83	0.06	0.44	6.48%	6.00	7.00	7.00
1.A.1.g	Attentiveness	26	6.70	6.90	0.20	0.74	10.98%	4.00	7.00	7.00
1.A.1.e	Perceptual Abilities	41	6.43	6.30	- 0.13	0.87	13.49%	4.00	7.00	7.00

Table 27. Group Abilities Top and Bottom Rankings - 2038

Based on data from Table 27, Memory (mean = 6.77 and median = 7.00), Attentiveness (mean = 6.70 and median = 7.00) and Perceptual Abilities (mean = 6.43 and median = 7.00) were rated as the top 3 of the ability types in 2038, meaning that experts believe that these abilities could be performed or emulated by machines in high complexity scenarios with quality in twenty years. Memory and Attentiveness in 2038 are consistent to findings in 2018 and the only difference was Perceptual Abilities that was replaced by Quantitative Abilities. In the opposite side were Verbal Abilities (mean = 5.14 and median = 5.00), Idea Generation and Reasoning Abilities (mean = 5.37 and median = 6.00) and Flexibility, Balance and Coordination Abilities (mean = 5.38 and median = 6.00), ranked as bottom 3 of the ability types in 2038. This means that based on the combined opinion of the experts and considering a complexity point of view, these abilities could be emulated only to a lower extent or without the adequate quality by Artificial Intelligence, Robotics, and related technologies. In spite of being the lower ones, it is important to note that they were all placed in the above average range, which means either way that according to panelists opinions, technologies will progress in the next two decades. An important observation is that these three ability types were consistently the lower ones, both in 2018 and 2038, which support the belief that they are also bottlenecks. In terms of deviation, Endurance (std. deviation = 1.73), Idea Generation and Reasoning Abilities (std. deviation = 1.48) and Reaction Time and Speed Abilities (std. deviation = 1.43) were the top 3 in terms of deviation, which means higher heterogeneity. Actually, Endurance was the higher deviation in both states, 2018 and 2038, which means that, besides different opinions, experts may have had different understandings of its concept. Memory (std. deviation = 0.44), Attentiveness (std. deviation = 0.74) and Perceptual Abilities (std. deviation = 0.87) were the ones with more homogeneity among the experts' opinions, validating and increasing the confidence in the top abilities types findings just mentioned.

Overall, data in Table 27 confirms that, according to experts' opinions gathered, Artificial Intelligence, Robotics, and related technologies will, most likely, improve in their power to emulate and perform human abilities required in the marketplace, without exceptions.

	Year vs Year	Differences between 2038 - 2018								
	Top 3 (mean)	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.3.c	Flexibility, Balance, and Coordin	-	2.05	1.85	- 0.20	- 0.22	-10.50%	1.00	3.00	-
1.A.1.a	Verbal Abilities	-	1.96	2.01	0.05	- 0.10	-4.96%	1.00	2.00	-
1.A.4.b	Auditory and Speech Abilities	-	1.90	1.86	0.01	- 0.54	-28.63%	-	2.00	-

	Year vs Year	Differences between 2038 - 2018								
	Bottom 3 (mean)	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.3.b	Endurance	-	0.93	0.38	- 0.55	- 0.34	-36.59%	-	1.50	-
1.A.1.d	Memory	-	1.00	0.68	- 0.32	- 0.86	-86.24%	2.00	1.00	-
1.A.1.c	Quantitative Abilities	-	1.17	0.89	- 0.28	- 0.92	-78.68%	3.00	1.00	-

	Year	Differences between 2038 - 2018								
	Top 3 (deviation)	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.c	Quantitative Abilities	-	1.17	0.89	- 0.28	- 0.92	-78.68%	3.00	1.00	-
1.A.1.d	Memory	-	1.00	0.68	- 0.32	- 0.86	-86.24%	2.00	1.00	-
1.A.1.g	Attentiveness	- 1	1.31	1.08	- 0.23	- 0.81	-62.35%	2.00	1.00	-

	Year vs Year	Differences between 2038 - 2018								
	Bottom 3 (deviation)	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.a	Verbal Abilities	-	1.96	2.01	0.05	- 0.10	-5.10%	1.00	2.00	-
1.A.3.c	Flexibility, Balance, and Coordin	-	2.05	1.85	- 0.20	- 0.22	-10.73%	1.00	3.00	-
1.A.3.b	Endurance	-	0.93	0.38	- 0.55	- 0.34	-36.56%	-	1.50	-

Table 28. Group Abilities Top and Bottom Rankings – 2018 - 2038

Based on findings from Table 28, the most significant growths between 2038 and 2018 were evaluated in Flexibility, Balance and Coordination Abilities (2.05), Verbal Abilities (1.96) and Auditory and Speech Abilities (1.90), which means that experts expected that technologies will impact more this ability types than others. Endurance (0.93), Memory (1.00) and Quantitative Abilities (1.17), on the other hand, were the bottom 3 of the groups. This means that based on the combined opinion of the experts and considering a complexity point of view, these abilities are the ones that would face less impact from Artificial Intelligence, Robotics, and related technologies in twenty years. However, in two of the cases, Memory, and Attentiveness, saturation plays an important role – in these cases, experts saw great achievement already in 2018 so the space to increase is limited.

6.3. Detailed Outcomes

In the following sections, we scrutinize each of the individual abilities and ability types, combining statistics with the qualitative inputs, such as experts' comments and justifications (to support their ratings) and additional research from the authors of this work. All abilities descriptions presented in the following explanations and eventual anchors of complexity mentioned were taken from O*NET's Content Model Reference.

Cognitive Abilities

Cognitive Abilities are "abilities that influence the acquisition and application of knowledge in problem solving"[84]. They take into account perceptual and attentiveness attributes related to the capture of information from the environment, the reasoning and problem-solving capabilities and the communication and/or application of the possible solutions and ideas. There are 21 abilities (out of the 52) in this category and they are divided into 7 types, which are evaluated in as a group and individually next.

Verbal Abilities

The first group of Cognitive Abilities in O*NET is Verbal Abilities, which are the capabilities that "(…) influence the acquisition and application of verbal information in problem-solving" [85], either orally or in written format. This group has 4 abilities: Oral Comprehension, Written Comprehension, Oral Expression, and Written Expression. Based on the answers provided by experts, we summarize the statistics for the Verbal Abilities in Table 29.

[84] O*NET Content Model Reference documentation (2019)
[85] O*NET Content Model Reference documentation (2019)

	Year	2018								
	Ability	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.a.1	Oral Comprehension	14	2.64	2.64	-	0.93	35.14%	1.00	2.50	4.00
1.A.1.a.2	Written Comprehension	14	3.43	3.43	0.00	1.09	31.77%	1.00	3.50	5.00
1.A.1.a.3	Oral Expression	14	3.64	3.93	0.29	1.50	41.15%	1.00	4.00	7.00
1.A.1.a.4	Written Expression	14	3.00	3.39	0.39	1.47	48.92%	1.00	3.00	6.00
1.A.1.a	Verbal Abilities	56	3.18	3.35	0.17	1.29	40.74%	1.00	3.00	7.00

	Year	2038								
	Ability	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.a.1	Oral Comprehension	14	4.93	5.20	0.27	1.07	21.74%	3.00	5.00	7.00
1.A.1.a.2	Written Comprehension	14	5.50	5.54	0.04	1.16	21.10%	3.00	6.00	7.00
1.A.1.a.3	Oral Expression	14	5.36	5.64	0.29	1.15	21.48%	3.00	5.50	7.00
1.A.1.a.4	Written Expression	14	4.79	5.06	0.27	1.37	28.60%	2.00	5.00	7.00
1.A.1.a	Verbal Abilities	56	5.14	5.36	0.22	1.20	23.28%	2.00	5.00	7.00

	Year vs Year	Differences between 2038 - 2018								
	Ability	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.a.1	Oral Comprehension	-	2.29	2.56	0.27	0.14	6.25%	2.00	2.50	3.00
1.A.1.a.2	Written Comprehension	-	2.07	2.11	0.04	0.07	3.42%	2.00	2.50	2.00
1.A.1.a.3	Oral Expression	-	1.71	1.71	0.00	- 0.35	20.32%	2.00	1.50	-
1.A.1.a.4	Written Expression	-	1.79	1.67	- 0.11	- 0.10	5.53%	1.00	2.00	1.00
1.A.1.a	Verbal Abilities	-	1.96	2.01	0.05	- 0.10	4.96%	1.00	2.00	-

Table 29. Verbal Abilities Statistics

Among Verbal Abilities, Oral Comprehension, "the ability to listen to and understand information and ideas presented through spoken words and sentences"[86], was the lowest one evaluated conjointly by the experts in 2018 with solid statistics in the below average range of the scale (mean = 2.64 and median = 2.50) and second lowest in 2038 (mean = 4.93, median = 5.00 and min = 3.00). In other words, it means that respondents assessed this ability as the one that Artificial Intelligence (and related technologies) is less able to execute or emulate in the current state among Verbal Abilities. Moreover, as demonstrated by the lowest standard deviation in 2018 (std. deviation = 0.93) and 2038 (std. deviation = 1.07), Oral Comprehension is the Verbal Ability with less disagreement among experts. According to the expert's comments and justifications, virtual assistants like Apple's Siri[87] and Amazon's Alexa[88], and also solutions from companies like Google and IBM, already display the speech understanding capability for noncomplex activities. They have embedded applications that enable them to perform good oral listening, comprehension, and understanding of natural language. Still, they have several limitations and are very susceptible to errors and misunderstandings, because, according to some specialists, this is a complex task that demands knowledge and context to go beyond just listening. One of the participants supported this view, highlighting that this capability in machines is limited to hearing, processing and transmitting the idea, but never really understanding and comprehending. Some experts also point out that Oral Comprehension is an ability that will improve a lot in the following years, which is confirmed by the statistics depicted.

Written Comprehension, is "the ability to read and understand information and ideas presented in writing"[89]. For this ability, a similar result to Oral Comprehension was expected, since they are related – in fact, experts

[86] O*NET Content Model Reference documentation (2019)
[87] https://www.apple.com/siri/
[88] https://www.alexa.com
[89] O*NET Content Model Reference documentation (2019)

indicated that both abilities have the same technical foundation and that Written Comprehension is usually embedded in Oral Comprehension, once voice is converted into text. Instead, it was the second highest Verbal Ability in 2018 (mean = 3.43 and median = 3.50) and the first in 2038 (mean = 5.50 and median = 6.00), the single one in the high range of the scale and with an acceptable level of homogeneity. These statistics mean that this ability was the most likely of the Verbal Abilities to be emulated by machines in the new twenty years. One of the reasons that could explain this difference is that the written channel is less complex than the oral one and, according to experts, this is an ability that already has some maturity and has improved a lot over the last two decades. Solutions like Ross[90], artificially intelligent tools that enhance lawyers' abilities and allows them to do more and IBM's Watson in Jeopardy![91] were examples shared by the experts to corroborate their opinion about the written comprehension current and future status.

Oral Expression was classified as the highest ability in 2018 (mean = 3.64, median = 4.00 and max = 7.00), meaning that respondents assessed this ability as the one that AI (and related technologies) was already more likely to execute or emulate in the current state among the Verbal Abilities. Oral Expression focus on the ability "to communicate information and ideas in speaking so others will understand"[92]. However, as demonstrated by its deviation in 2018 (std. deviation = 1.50), it is also the Verbal Ability with more disagreement among experts. One of the panelists pointed out that this ability is already performed by machines in its most complex level, which in O*NET's scale would be something as complex as "explain advanced principles of genetics to college freshmen"[93]. A practical example is Waze[94], a community-based traffic and navigation app, which performs the Oral Expression ability already reasonably well (though a set of prerecorded messages). The rationale here is based on the ability's definition: communicate information in speaking so others could understand. On the other hand, other experts believe that in more complex tasks, machines would not be able to perform and emulate human skills, because it takes more than just transmitting – it requires adequate reasoning, comprehension of what is being transmitted and eventually prolonged contact in case of interaction.

Written Expression refers to "the ability to communicate information and ideas in writing so others will understand"[95]. It was the second lowest in 2018 (mean = 3.00 and median = 3.00), but swapped positions with Oral Comprehension in 2038, ranked as the lowest in twenty years from now (mean = 4.79, median = 5.00 and min = 2.00). Unexpectedly and contrary to the comprehension abilities (when Oral appeared more complex that Written), in the expression abilities, Written was evaluated by the experts as more complex than Oral. After some analysis, no convincing rationale was found for this observation. This finding got more peculiar when the examples of Written Expression shared by the experts were evaluated. Besides chatbots, which are artificial intelligence applications that are able to conduct specific conversations via written methods (and more recently, oral too), participants indicated tools like Quill[96], an automation platform that allows organizations to transform

[90] https://rossintelligence.com/
[91] https://www.youtube.com/watch?v=lI-M7O_bRNg
[92] O*NET Content Model Reference documentation (2019)
[93] O*NET Content Model Reference documentation (2019)
[94] https://www.waze.com
[95] O*NET Content Model Reference documentation (2019)
[96] https://narrativescience.com/products/quill/

reporting with natural language generation (NLG), on one side, and SCIgen[97], a program that randomly generated computer-science papers that were selected for conferences, on the other – though these articles were nonsensical and only proved that the review process was poor, not that the technology was good. The complexity in the ability increases when the texts are not previously pre-programmed, questions are not limited to a specific set of contexts and answers are a bit more complex.

As a combined group, Verbal Abilities were evaluated as below average in 2018 (mean = 3.18) and moved to above average in 2038 (mean = 5.14), with one ability in the high range, which was Written Comprehension (mean = 5.50). Therefore, experts believe that Verbal Abilities will not be executed and emulated by Artificial Intelligence, Robotics, and related technologies in the next following years – in fact, it is the group with the lower results in both 2018 and 2038. As already mentioned, Verbal Abilities could be considered as a challenge, if not a bottleneck. Fact is that Verbal Abilities group shows a different result from that of Frey & Osborne (2017), that did not mention any of these abilities or their group as a bottleneck. Nonetheless, there is some space for achievements and improvements, according to experts, who cited Natural Language Processing (NPL) and other fields in AI such as Speech Understanding, Text Understanding, and Dialog Understanding as a research field with ongoing improvement. Several applications were shared by experts, but one that is publicized quite often is IBM's Watson experiences. Watson has already played the role of the advertising legend David Ogilvy in an interview[98], wrote recipes in a cookbook on its own[99], wrote the entire script of a TV commercial[100] and has been used to actively interact with people in museums[101]. Still, these are very low complexity and very restricted applications, specialized solutions that cover and learn about a limited set of scenarios.

Idea Generation and Reasoning Abilities

The second group of Cognitive Abilities in O*NET is Idea Generation and Reasoning Abilities, which are the capabilities that "(…) influence the application and manipulation of information in problem-solving"[102]. This group has 7 abilities: Fluency of Ideas, Originality, Problem Sensitivity, Deductive Reasoning, Inductive Reasoning, Information Ordering, and Category Flexibility. The summarized statistics for the Idea Generation and Reasoning Abilities are presented in Table 30.

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[97] http://news.mit.edu/2015/how-three-mit-students-fooled-scientific-journals-0414
[98] https://www.youtube.com/watch?v=8EGyIpyQCqM
[99] https://www.theguardian.com/lifeandstyle/2015/feb/04/robot-cookbook-watson-supercomputer-recipes-unusual-ingredients-disgusting
[100] https://www.youtube.com/watch?time_continue=15&v=-iaBJ5rqOdg
[101] https://www.youtube.com/watch?v=1rOAgvCnZpw
[102] O*NET Content Model Reference documentation (2019)

	Year	2018								
	Ability	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.b.1	Fluency of Ideas	14	3.36	3.95	0.59	1.78	53.04%	1.00	3.00	7.00
1.A.1.b.2	Originality	13	1.62	1.49	- 0.12	0.96	59.48%	1.00	1.00	4.00
1.A.1.b.3	Problem Sensitivity	14	3.21	3.76	0.54	1.81	56.16%	1.00	3.00	6.00
1.A.1.b.4	Deductive Reasoning	14	4.07	4.35	0.28	1.44	35.35%	2.00	4.00	7.00
1.A.1.b.5	Inductive Reasoning	14	3.86	3.96	0.10	1.70	44.16%	2.00	3.50	7.00
1.A.1.b.6	Information Ordering	14	4.43	4.87	0.44	1.70	38.31%	2.00	4.00	7.00
1.A.1.b.7	Category Flexibility	14	4.64	5.06	0.41	1.74	37.41%	2.00	4.50	7.00
1.A.1.b	Idea Generation and Reasoning A	97	3.60	3.92	0.31	1.82	50.65%	1.00	3.00	7.00

	Year	2038								
	Ability	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.b.1	Fluency of Ideas	14	5.07	5.46	0.39	1.33	26.19%	3.00	5.00	7.00
1.A.1.b.2	Originality	13	3.92	4.03	0.11	1.61	40.92%	1.00	4.00	7.00
1.A.1.b.3	Problem Sensitivity	14	5.14	5.56	0.42	1.79	34.83%	2.00	5.50	7.00
1.A.1.b.4	Deductive Reasoning	14	5.71	5.91	0.20	1.20	21.08%	4.00	6.00	7.00
1.A.1.b.5	Inductive Reasoning	14	5.71	5.50	- 0.21	1.20	21.08%	3.00	6.00	7.00
1.A.1.b.6	Information Ordering	14	5.86	6.10	0.25	1.23	21.02%	4.00	6.00	7.00
1.A.1.b.7	Category Flexibility	14	6.14	6.28	0.13	1.03	16.72%	4.00	6.50	7.00
1.A.1.b	Idea Generation and Reasoning A	97	5.37	5.55	0.09	1.48	27.62%	1.00	6.00	7.00

	Year vs Year	Differences between 2038 - 2018								
	Ability	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.b.1	Fluency of Ideas	-	1.71	1.51	- 0.21	- 0.45	26.39%	2.00	2.00	-
1.A.1.b.2	Originality	-	2.31	2.54	0.23	0.64	27.93%	-	3.00	3.00
1.A.1.b.3	Problem Sensitivity	-	1.93	1.81	- 0.12	- 0.01	0.71%	1.00	2.50	1.00
1.A.1.b.4	Deductive Reasoning	-	1.64	1.56	- 0.08	- 0.23	14.30%	2.00	2.00	-
1.A.1.b.5	Inductive Reasoning	-	1.86	1.54	- 0.31	- 0.50	26.86%	1.00	2.50	-
1.A.1.b.6	Information Ordering	-	1.43	1.24	- 0.19	- 0.47	32.57%	2.00	2.00	-
1.A.1.b.7	Category Flexibility	-	1.50	1.22	- 0.28	- 0.71	47.31%	2.00	2.00	-
1.A.1.b	Idea Generation and Reasoning A	-	1.77	1.63	- 0.22	- 0.34	19.25%	-	3.00	-

Table 30. Idea Generation and Reasoning Abilities Statistics

Fluency of Ideas, "the ability to come up with a number of ideas about a topic (the number of ideas is important, not their quality, correctness, or creativity)"[103] was one of the lowest evaluated abilities in the Idea Generation and Reasoning group both in 2018 (mean = 3.36 and median = 3.00) and 2038 (mean = 5.07, median = 5.00 and min = 3.00). While in 2018, this ability was in the below average range in the opinion of the experts, in 2038 it moved to the above average range. However, there is not much homogeneity in the answers in both years among the experts, especially in 2018 (std. deviation = 1.78). While some experts took into account the orientation in the ability's description quite literally, focusing on the quantity rather than the quality – thus, indicating that machines could emulate this capability in the future (given that a database and ontology is previously set), other experts had a different view. Instead, they focused on the complexities around the ideation capability, the process of coming up and forming new ideas and innovation associated with creativity, clarifying that these are restricted human capabilities. Evaluating the anchor for the highest level of the scale ("name of all the possible strategies for a military battle"), it seems that the ability measures, in fact, are a bit of both domains.

Despite evaluating a completely different aptitude, Problem Sensitivity had a very similar behavior to Fluency of Ideas, both in 2018 (mean = 3.21 and median = 3.00) and 2038 (mean = 5.14 and median = 5.50) and also in regard to heterogeneity of opinions in 2018 (std. deviation = 1.81), moving from below average range to above

[103] O*NET Content Model Reference documentation (2019)

average in terms of the likelihood of being adequately emulated by machines. Problem Sensitivity is about telling "(…) when something is wrong or is likely to go wrong – it does not involve solving the problem, only recognizing there is a problem."[104] In this case, some experts understood this ability as a variation of the standard pattern identification issue, which is one of the key fields in Artificial Intelligence research and already applied in image analysis for suspicious activities[105], including cyber-attack detection. But again, it depends on a dataset and of being previously programmed to find and distinguish problems. The heterogeneity may be explained by the variety of problems in the real world. As one of the experts explains, it is easier to identify a disease than a crime.

Among Idea Generation and Reasoning Abilities and also in the whole set of abilities, Originality was the lowest one evaluated conjointly by the experts in 2018 and 2038. Originality, which means being able "to come up with unusual or clever ideas about a given topic or situation, or to develop creative ways to solve a problem"[106] had solid figures in the low range of the scale in 2018 (mean = 1.62, median = 1.00 and max = 4.00) and in the average range in 2038 (mean = 3.92, median = 4.00 and min = 1.00), meaning that respondents assessed this ability as the one that Artificial Intelligence, Robotics, and related technologies would be less able to execute or emulate in twenty years from now. Moreover, the standard deviation is low in 2018 (std. deviation = 0.96), meaning that is the Idea Generation and Reasoning Ability with less disagreement among panelists, at least in its current state. According to experts, Originality is one of the toughest abilities for machines to replicate, because it involves creativity and innovation, which are essentially human characteristics. Experts sustained that the kind of originality a machine could emulate in the near future are only in eventual evolutions based on the previous history, i.e. pattern recognition, within the boundaries of the system, set by either program, data and/or tutor. Examples are mentioned by experts to clarify this idea: the recreation of the chemistry's periodic table of elements with an AI algorithm[107] or IBM's Watson writing recipes on its own[108] – though something unusual and somewhat intelligent, it is based on the previous knowledge and limited by the program, so it cannot be considered novel or creative per se. This idea was explained in further detail by one of the experts with an example: Machines can only know that a credit card can be used to open a door if taught so – once this is shared with the machine, it may then find out that Visa opens doors more easily than MasterCard. As another specialist explained, machines will perform tasks that they are trained for and will be able to create similar solutions based on analogies (what could be called machine creativity), such as painting portraits[109]. However, it will not be capable of discovering and creating on its own out of the box and innovative solutions (human creativity) – not even in several decades.

Reasoning Abilities had similar behaviors based on the opinion of the experts. Deductive Reasoning, which is "the ability to apply general rules to specific problems to produce answers that make sense"[110], was marked in

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[104] O*NET Content Model Reference documentation (2019)
[105] https://www.youtube.com/watch?time_continue=76&v=E5RkXGiKkDc
[106] O*NET Content Model Reference documentation (2019)
[107] https://news.stanford.edu/2018/06/25/ai-recreates-chemistrys-periodic-table-elements/
[108] https://www.theguardian.com/lifeandstyle/2015/feb/04/robot-cookbook-watson-supercomputer-recipes-unusual-ingredients-disgusting
[109] https://www.youtube.com/watch?v=GrEttzMCneo
[110] O*NET Content Model Reference documentation (2019)

the average range in 2018 (mean = 4.07 and median = 4.00), analogously to Inductive Reasoning (mean = 3.86 and median = 3.50), which means combining "(…) pieces of information to form general rules or conclusions (includes finding a relationship among seemingly unrelated events)"[111]. In 2038, both reasonings moved to the high range and had the same figures (mean = 5.71 and median = 6.00). Deductive and Inductive Reasoning is usually complemented by Abductive Reasoning, which means creating conclusions from incomplete observations. O*NET does not evaluate this ability separately – based on other ability descriptions, it is reasonable to assume that this is embedded in the Inductive Reasoning capability. The similar results found between the two reasonings were not a surprise for the reason that, according to experts, reasoning capabilities are one of the oldest research fields in Artificial Intelligence and there are logical systems that perform inductive, deductive and abductive quite well, although currently, they are usually quite specific and not applicable to complex context – general feeling is that this would improve to excellence in the following two decades. In regard to Deductive Reasoning, experts explain that there are several advanced examples of such algorithms that can produce based on predefined rules, which can be enhanced even further with the application of genetic algorithms[112]. In inductive case, two recent examples are cited, like the aforementioned recreation of the chemistry's periodic table of elements with an AI algorithm[113] and the usage of Artificial Intelligence in the stock market offered by EquBot[114]. The key limitation for Inductive reasoning, as one of the experts sustained, is to have the data available to allow the machine to learn – in other words, the real challenge is to perform good abductive reasoning thru unorthodox AI architectures that are less dependent on huge amounts of data. Finally, one observation worth mentioning was the high results observed for Inductive Reasoning, certainly impacted by the anchors suggested by O*NET. According to experts, the highest anchor for Inductive Reasoning which is to "diagnose a disease using results of many different lab tests"[115], is already being performed and improved by several AI solutions in the Health Care industry[116].

Information Ordering, "the ability to arrange things or actions in a certain order or pattern according to a specific rule or set of rules (e.g. patterns of numbers, letters, words, pictures, mathematical operations)", had similar results to the reasoning abilities. In 2018 the ability was in the average range (mean = 4.43 and median = 4.00), while in 2038 it moved to the high range (mean = 5.86 and median = 6.00), meaning that experts believe this ability is very likely of being emulated by machines in the near future. In this case, most of the experts understand this ability as dealing with a traditional computation problem, the original steps of Artificial Intelligence that have enhanced over the last decades considering the improvements in classification and pattern recognition algorithms. According to experts, Information Ordering is deterministic, methodical, preprogrammed and deliberative, which is exactly the type of problems that machines can perform with more agility, endurance, and quality than humans.

111 O*NET Content Model Reference documentation (2019)
112 https://www.youtube.com/watch?v=CZE86BPDqCI
113 https://news.stanford.edu/2018/06/25/ai-recreates-chemistrys-periodic-table-elements/
114 https://www.youtube.com/watch?v=G3WG9kxbFOY
115 O*NET Content Model Reference documentation (2019)
116 https://www.youtube.com/watch?v=mhEYvrFOP88

The last aptitude in the Idea Generation and Reasoning Abilities is Category Flexibility, which is focused on "generate or use different sets of rules for combining or grouping things in different ways"[117]. According to the combined opinion of the experts, this is an ability that is and would be properly performed by computers in the next two decades. While in 2018 the numbers are already high, placing the ability in the above average range (mean = 4.64 and median = 4.50), in 2038 it moved into the high range with some indicators reaching the very high area (mean = 6.14 and median = 6.50), with acceptable homogeneity (std. deviation = 1.03). According to panelists, in spite of particular limitations, traditional statistical categorization algorithms already perform this ability much better than humans do and, considering machine learning, neural networks, image segmentation, and several other techniques, it is a problem that already has numerous solutions applied in industries.

Overall, Idea Generation and Reasoning Abilities were evaluated as average in 2018 (mean = 3.60) and moved to above average in 2038 (mean = 5.37), ranked as the second lowest among the 15 ability groups. Based on these results, it is possible to assume that experts believe these abilities would only be emulated by Artificial Intelligence, Robotics, and related technologies in the next two decades or so to a limited extent. As explained by experts, some of the aptitudes may already be covered by the original fields of study of Artificial Intelligence and are traditional computational problems, and others have improved consistently over the last decades with the increased computation capability of the supporting hardware and the new techniques - examples in health care, financial market and several others corroborate the experts' opinion. However, there is one undisputable bottleneck and at least two major challenges to overcome. Originality, which was evaluated as average even in twenty years from now, is a coherent outcome similarly to Frey & Osborne (2017)'s bottlenecks, and Fluency of Ideas and Problem Sensitivity are two additional challenges. In fact, by removing Originality from this group of abilities, it would move to the high range. According to experts, Originality is one of the toughest abilities for machines to replicate, because it involves creativity and innovation, which are essentially human characteristics.

Quantitative Abilities

The third group of Cognitive Abilities in O*NET is Quantitative Abilities, which are the capabilities that "(…) influence the solution of problems involving mathematical relationships"[118]. This group has only 2 abilities: Mathematical Reasoning and Number Facility. Their statistics are depicted in Table 31.

[117] O*NET Content Model Reference documentation (2019)
[118] O*NET Content Model Reference documentation (2019)

	Year	2018								
	Ability	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.c.1	Mathematical Reasoning	14	4.21	4.35	0.14	1.72	40.76%	1.00	4.50	7.00
1.A.1.c.2	Number Facility	13	6.23	6.06	- 0.17	1.69	27.14%	2.00	7.00	7.00
1.A.1.c	Quantitative Abilities	27	5.22	5.21	- 0.01	1.96	37.57%	1.00	6.00	7.00

	Year	2038								
	Ability	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.c.1	Mathematical Reasoning	14	5.86	5.80	- 0.06	1.23	21.02%	4.00	6.00	7.00
1.A.1.c.2	Number Facility	13	6.92	6.40	- 0.53	0.28	4.01%	6.00	7.00	7.00
1.A.1.c	Quantitative Abilities	27	6.39	6.10	- 0.29	1.04	16.33%	4.00	7.00	7.00

	Year vs Year	Differences between 2038 - 2018								
	Ability	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.c.1	Mathematical Reasoning	-	1.64	1.44	- 0.20	- 0.49	29.60%	3.00	1.50	-
1.A.1.c.2	Number Facility	-	0.69	0.33	- 0.36	- 1.41	204.17%	4.00	-	-
1.A.1.c	Quantitative Abilities	-	1.17	0.89	- 0.28	- 0.92	78.68%	3.00	1.00	-

Table 31. Quantitative Abilities Statistics

Mathematical Reasoning, which is "the ability to choose the right mathematical methods or formulas to solve a problem"[119], was the lowest of the Quantitative Abilities evaluated, both in 2018 (mean = 4.21 and median = 4.50) and 2038 (mean = 5.86, median = 6.00 and min = 4.00). While in 2018 this ability was in the average range in the opinion of the experts, with some variance in the responses (std. deviation = 1.72), in 2038 it was moved to the high range, yet still with some deviance. The explanation can be found in the comments provided by the experts: while some consider that current technologies are able to apply mathematical methods or formulas to solve a problem quite well, better than humans, supported by proper previous training on each of the cases and solutions, others are doubtful on the capability of machines of adequately performing problem identification and then tool selection. Understanding and identifying a problem requires context and it is a complex task, according to one of the experts, dependent on having the variables pre-mapped and defined. Another expert believes that this part is mostly done by the mentors or developers, while the technologies take care of the application and calculation.

Number Facility is the second ability in the Quantitative Abilities subset, and it measures the capacity "to add, subtract, multiply, or divide quickly and correctly"[120]. It is focused on performing basic mathematical operations rapidly and accurately. According to the combined opinion of the experts, this was the ability that had the highest mean among all evaluated, both in 2018 (mean = 6.23 and median = 7.00) and in 2038 (mean = 6.92 and median = 7.00), meaning it was the ability more likely of being properly performed by computers and related technologies. In 2018, this ability was assessed by participants as high range and in 2038 it moved to the very high range. According to experts, this is an area where machines already perform better than humans, even without artificial intelligence techniques. In fact, specialists explained this ability is one of the basic foundations of computer science and is embedded in most of the applications used today (2018), including but not limited to AI applications.

[119] O*NET Content Model Reference documentation (2019)
[120] O*NET Content Model Reference documentation (2019)

As a combined group, Quantitative Abilities were evaluated as above average in 2018 (mean = 5.22) and moved to high in 2038 (mean = 6.39). Specialists believe that Qualitative Abilities would be executed and emulated in the next following years to a high extent and to the highest levels of complexity. As a matter of fact, it is one of the groups with higher rates, consistent to the comments that point these Mathematical Abilities as aptitudes that are the foundation of computer science and, therefore, the basis for the current developments in Artificial Intelligence.

Memory

The fourth group of Cognitive Abilities in O*NET is Memory Abilities, which are the capabilities "(…) related to the recall of available information"[121]. This is not exactly a group, but one single ability that deals with the "ability to remember information such as words, numbers, pictures, and procedures"[122]. The summarized statistics for the Memory Abilities are in Table 32.

	Year	2018								
	Ability	Answers	$Mean^A$	$Mean^B$	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.d.1	Memorization	13	5.77	6.15	0.38	1.30	22.55%	4.00	6.00	7.00
1.A.1.d	Memory	13	5.77	6.15	0.38	1.30	22.55%	4.00	6.00	7.00

	Year	2038								
	Ability	Answers	$Mean^A$	$Mean^B$	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.d.1	Memorization	13	6.77	6.83	0.06	0.44	6.48%	6.00	7.00	7.00
1.A.1.d	Memory	13	6.77	6.83	0.06	0.44	6.48%	6.00	7.00	7.00

	Year vs Year	Differences between 2038 - 2018								
	Ability	Answers	$Mean^A$	$Mean^B$	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.d.1	Memorization	-	1.00	0.68	- 0.32	- 0.86	86.24%	2.00	1.00	-
1.A.1.d	Memory	-	1.00	0.68	- 0.32	- 0.86	86.24%	2.00	1.00	-

Table 32. Memory Abilities Statistics

According to the combined opinion of the experts, this was the ability that had the second-highest mean among all evaluated, both in 2018 (mean = 5.77 and median = 6.00) and in 2038 (mean = 6.77 and median = 7.00), meaning it is one of the abilities that is most likely of being properly performed by Artificial Intelligence, Robotics, and related technologies. In 2018, this ability was assessed by participants as high range and in 2038 it was moved to the very high range. According to specialists, this is another area where machines already perform better than humans – "once the information is stored, memory is never forgotten" explained one of the panelists. For some time, the key challenge in this ability was indexation for rapid recovery, critical in a scenario where data volume increases in an exponential pace. Nonetheless, this has improved over the last decades to a point that some experts do not see memorization as a concern for Artificial Intelligence whatsoever – actually, processes related to memory are already performed with excellence by machines, without needing AI at all. Comparing it to the other 15 ability type, Memory was evaluated as the first one as the most likely to be executed and emulated in the next following years, almost to its maximum.

[121] O*NET Content Model Reference documentation (2019)
[122] O*NET Content Model Reference documentation (2019)

Perceptual Abilities

The fifth group of Cognitive Abilities in O*NET is Perceptual Abilities, which are aptitudes "(…) related to the acquisition and organization of visual information"[123]. This group has 3 abilities: Speed of Closure, Flexibility of Closure and Perceptual Speed. Based on the answers provided by experts, we summarize statistics for Perceptual Abilities in Table 33.

	Year	2018								
	Ability	Answers	Mean^{A}	Mean^{B}	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.e.1	Speed of Closure	14	4.43	4.78	0.35	1.60	36.21%	2.00	4.00	7.00
1.A.1.e.2	Flexibility of Closure	14	4.36	4.56	0.20	1.45	33.21%	1.00	4.00	6.00
1.A.1.e.3	Perceptual Speed	14	5.57	5.90	0.33	1.09	19.55%	3.00	5.50	7.00
1.A.1.e	Perceptual Abilities	42	4.79	5.08	0.30	1.47	30.80%	1.00	5.00	7.00

	Year	2038								
	Ability	Answers	Mean^{A}	Mean^{B}	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.e.1	Speed of Closure	13	6.08	5.37	- 0.71	1.12	18.35%	4.00	7.00	7.00
1.A.1.e.2	Flexibility of Closure	14	6.36	6.62	0.26	0.84	13.24%	5.00	7.00	7.00
1.A.1.e.3	Perceptual Speed	14	6.86	6.90	0.05	0.36	5.30%	6.00	7.00	7.00
1.A.1.e	Perceptual Abilities	41	6.43	6.30	- 0.13	0.87	13.49%	4.00	7.00	7.00

	Year vs Year	Differences between 2038 - 2018								
	Ability	Answers	Mean^{A}	Mean^{B}	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.e.1	Speed of Closure	- 1.00	1.65	0.59	- 1.06	- 0.49	29.63%	2.00	3.00	-
1.A.1.e.2	Flexibility of Closure	-	2.00	2.05	0.05	- 0.60	30.25%	4.00	3.00	1.00
1.A.1.e.3	Perceptual Speed	-	1.29	1.00	- 0.29	- 0.73	56.49%	3.00	1.50	-
1.A.1.e	Perceptual Abilities	- 1.00	1.64	1.21	- 0.43	- 0.61	36.88%	3.00	2.00	-

Table 33. Perceptual Abilities Statistics

In the Perceptual Ability group, Speed of Closure is "the ability to quickly make sense of, combine, and organize information into meaningful patterns"[124]. It was in the intermediate position of the ranking in 2018, assessed by experts in the average range (mean = 4.43 and median = 4.00), with considerable variance in the responses (std deviation = 1.60). It did not increase as much as Flexibility of Closure in the 20-year window, and therefore, in 2038, despite being in the high range, it was evaluated as the lower of the three abilities in the group, but still high (mean = 6.08, median = 6.00 and min = 4.00). According to specialists, based on O*NET anchors, there are several applications in mobile phones that already perform the Speed of Closure ability in its lower-intermediate level. Examples are SoundHound[125], an app that recognizes songs after hearing some notes (anchor 3) and Microsoft's Surface Pro, a tablet that performs handwriting recognition[126]. Also, several Artificial Intelligence artifacts have been helping to interpret patterns in weather to identify changes and recommend decisions (anchor 6) – practical examples like achieving better accuracy in identifying tropical cyclones, weather fronts and

[123] O*NET Content Model Reference documentation (2019)
[124] O*NET Content Model Reference documentation (2019)
[125] https://soundhound.com
[126] https://www.geek.com/chips/handwriting-recognition-the-unsung-hero-of-the-surface-pro-1541098/

atmospheric rivers already exist, and the topic has been part of the discussion in the World Economic Forum, in its Harnessing Artificial Intelligence for the Earth report[127].

Based on the experts' evaluation, Flexibility of Closure was the lowest of the Perceptual Ability in 2018 in terms of chances of being emulated by computers (mean = 4.36 and median = 4.00) but surpassed Speed of Closure in 2038 (mean = 6.36, median = 7.00 and min = 5.00). The flexibility of Closure is "the ability to identify or detect a known pattern (a figure, object, word, or sound) that is hidden in other distracting material". While in 2018 this ability was in the average range in the opinion of the experts, with medium heterogeneity in responses (std deviation = 1.45), in 2038 it moved to the high range with some reduction in variation. Experts pointed out improvements in the last decades by the scientific community in pattern identification and recognition. Examples of current applications that perform this ability and backed up the opinions of the specialists are end to end solutions for people detection in crowded scenes in the U.S. and China[128], traffic ticketing systems that are able to identify car plates in motion and surgical robots that can perform their deeds no matter the blood – all scenarios with distracting factors. By 2038, experts believe that with improvements in deep learning, one of the fields within Artificial Intelligence, this ability will most likely be completely emulated by machines. It can be even faster, claims one of the experts, if these improvements consider specific sensors, like multispectral, thermal or SAR radars.

Finally, Perceptual Speed refers to "the ability to quickly and accurately compare similarities and differences among sets of letters, numbers, objects, pictures, or patterns. The things to be compared may be presented at the same time or one after the other"[129]. It was the highest of the Perceptual Abilities in both 2018 and 2038 in terms of the predisposition of being emulated by computers, besides being the ability with less variation in the responses in both years. In 2018 this ability was in the high range in the opinion of the experts (mean = 5.57 and median = 5.50), and in 2038 it was moved to the very high range (mean = 6.86, median = 7.00 and min = 6.00). Perceptual Speed was the second-highest ability within the whole group evaluated by experts, which means they understand that, most likely, it would be completely emulated by machines in the next 20 years. Like the other abilities in this group, this evaluation considers the state-of-the-art pattern recognition algorithms to allow quick and accurate comparison of similarities and differences among sets. Two examples of Perceptual Speed are Waymo, the autonomous car that already performs this analysis in real-time to decide its following actions[130] and Google's algorithms in ophthalmology that can find similarities in sets that no human can do based on a deep-learning technique called soft attention[131].

As a combined group, Perceptual Abilities were evaluated as above average in 2018 (mean = 4.79) and moved to high in 2038 (mean = 6.43). Consequently, and combining opinions, experts believe that these abilities will be executed and emulated in the next following years to a high extent. Perceptual Abilities are, in fact, the 3rd group most likely of being emulated by machines according to the specialists. This is a direct result of the great

[127] https://blogs.ei.columbia.edu/2018/06/05/artificial-intelligence-climate-environment/
[128] https://www.youtube.com/watch?v=Nl2fBKxwusQ
[129] O*NET Content Model Reference documentation (2019)
[130] https://www.theverge.com/2018/5/9/17307156/google-waymo-driverless-cars-deep-learning-neural-net-interview
[131] https://medium.com/health-ai/googles-ai-can-see-through-your-eyes-what-doctors-can-t-c1031c0b3df4

achievements of the last few years in pattern recognition algorithms, a major cornerstone for one of the most innovative technologies currently available, the autonomous car[132].

Spatial Abilities

The sixth group of Cognitive Abilities in O*NET is Spatial Abilities, which are the aptitudes "(…) related to the manipulation and organization of spatial information"[133]. This group has 2 abilities: Spatial Orientation and Visualization. Their summarized statistics based on the answers provided by experts are illustrated in Table 34.

	Year	2018								
	Ability	Answers	Mean[A]	Mean[B]	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.f.1	Spatial Orientation	14	4.64	5.11	0.47	1.60	34.43%	1.00	4.50	7.00
1.A.1.f.2	Visualization	14	4.07	4.52	0.45	1.90	46.67%	1.00	4.50	7.00
1.A.1.f	Spatial Abilities	28	4.36	4.82	0.46	1.75	40.10%	1.00	4.50	7.00

	Year	2038								
	Ability	Answers	Mean[A]	Mean[B]	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.f.1	Spatial Orientation	14	6.36	6.56	0.20	1.01	15.86%	4.00	7.00	7.00
1.A.1.f.2	Visualization	13	5.54	5.59	0.05	1.51	27.20%	2.00	6.00	7.00
1.A.1.f	Spatial Abilities	27	5.95	6.07	0.12	1.32	22.11%	2.00	6.00	7.00

	Year vs Year	Differences between 2038 - 2018								
	Ability	Answers	Mean[A]	Mean[B]	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.f.1	Spatial Orientation	-	1.71	1.44	- 0.27	- 0.59	34.43%	3.00	2.50	-
1.A.1.f.2	Visualization	- 1.00	1.47	1.07	- 0.40	- 0.39	26.83%	1.00	1.50	-
1.A.1.f	Spatial Abilities	- 1.00	1.59	1.26	- 0.33	- 0.43	27.17%	1.00	1.50	-

Table 34. Spatial Abilities Statistics

Spatial Orientation is "the ability to know your location in relation to the environment or to know where other objects are in relation to you". It was the highest of the Spatial Abilities evaluated, both in 2018 (mean = 4.64 and median = 4.50) and 2038 (mean = 6.36, median = 7.00 and min = 4.00). While in 2018 this ability was in the above average range in the opinion of the experts, with some variance in the responses (standard deviation = 1.60), in 2038 it was moved to the high range. Considering the acceptable deviation in 2038 (std. deviation = 1.01), experts understand that Spatial Orientation is very likely to be emulated by machines in 2 decades. Spatial Reasoning is an Artificial Intelligence field that focuses on creating logical reasoning systems that recognize entities located in space or that have a spatial structure. Creating machines that can perceive and understand space is a long-lasting dream for researchers, but specialists believe that AI applications will possibly reach excellence in 20 years. Apart from the example of the autonomous car, that, as mentioned before, requires a good perception of the environment, and therefore, a good spatial recognition and orientation, experts highlight the improvements in navigation and location embedded in several different applications in current days, such as vacuum cleaner robots like iRobot's Roomba, that captures images of a room and compares these to gradually

[132] https://medium.com/@teamrework/autonomous-vehicles-need-superhuman-perception-for-success-3fbc9f9710a6
[133] O*NET Content Model Reference documentation (2019)

build up a map of the surroundings and determine its location – and eventually be able to recognize and move objects[134].

Visualization is the other ability in the Spatial Abilities group. It is focused on imagining "(…) how something will look after it is moved around or when its parts are moved or rearranged". More than the vision itself, this ability is about being capable of picturing and simulating how something may look like in a different scenario. In 2018, Visualization was in the average range (mean = 4.07 and median = 4.50) and in 2038 it was moved to high (mean = 5.54, median = 6.00 and min.= 2.00). Nevertheless, evaluating expert's opinion, it is possible to assume that this was an ability tricky to assess – variance in both scenarios was considerable, which shows disagreement on this ability, today and in the future. Some of the experts, more enthusiastic, believe that this scenario simulation is already performed somehow by machines today – Google DeepMind's solutions already deal with simulation scenarios quite well. AlphaPro, for instance, is the machine that mastered the Chinese board game called Go, which requires thinking several steps ahead of the game[135]. Another solution, General Query Network (GQN), is even more relevant to the discussion because it is based on images and claims it can imagine 3D models based on 2D images[136]. Other specialists, however, were bothered by the fact that O*NET's description uses the word imagination in Visualization, which is a unique human aptitude that depends on creativity, a hard-to-emulate ability as already seen in Originality. They were also reluctant about the real capability of simulating without a comprehensive analysis of context and cause and effect, which is still hard to combine in machines.

As a combined group, Spatial Abilities were evaluated as average in 2018 (mean = 4.36) and moved to high in 2038 (mean = 5.54). Therefore, experts believe that these abilities will be executed and emulated in the next following years to some extent. As seen in the comments from experts, Spatial Abilities are closely connected to Vision Abilities, the first being dependent on achievements and progress from the second. Visual Abilities are evaluated later on in the Sensory Abilities category.

Attentiveness

The seventh and final group of Cognitive Abilities in O*NET is Attentiveness Abilities, which are the aptitudes that are "(…) related to the application of attention"[137]. This group has 2 abilities: Selective Attention and Time Sharing. Based on the answers provided by experts, we present in Table 35 their summarized statistics.

[134] https://www.technologyreview.com/s/541326/the-roomba-now-sees-and-maps-a-home/
[135] https://www.youtube.com/watch?v=g-dKXOlsf98
[136] https://www.engadget.com/2018/06/29/google-deepmind-neural-network-gqn-spatial-reasoning
[137] O*NET Content Model Reference documentation (2019)

	Year	2018								
	Ability	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.g.1	Selective Attention	14	5.71	5.97	0.26	1.64	28.66%	2.00	6.50	7.00
1.A.1.g.2	Time Sharing	13	5.08	5.68	0.60	1.44	28.39%	3.00	5.00	7.00
1.A.1.g	Attentiveness	27	5.40	5.82	0.43	1.55	28.74%	2.00	6.00	7.00

	Year	2038								
	Ability	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.g.1	Selective Attention	14	6.57	6.80	0.23	0.85	12.96%	4.00	7.00	7.00
1.A.1.g.2	Time Sharing	12	6.83	7.00	0.17	0.58	8.45%	5.00	7.00	7.00
1.A.1.g	Attentiveness	26	6.70	6.90	0.20	0.74	10.98%	4.00	7.00	7.00

	Year vs Year	Differences between 2038 - 2018								
	Ability	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.1.g.1	Selective Attention	-	0.86	0.83	-0.03	-0.79	91.68%	2.00	0.50	-
1.A.1.g.2	Time Sharing	-1.00	1.76	1.32	-0.43	-0.86	49.18%	2.00	2.00	-
1.A.1.g	Attentiveness	-1.00	1.31	1.08	-0.23	-0.81	62.35%	2.00	1.00	-

Table 35. Attentiveness Abilities Statistics

Selective Attention is "the ability to concentrate on a task over a period of time without being distracted"[138]. It was the highest of the two Attentiveness Abilities evaluated in 2018 – in fact, it was the third-highest among all the abilities, but swapped positions with Time Sharing in 2038. While in 2018 this ability was already in the high range (mean = 5.71 and median = 6.50) in the combined opinion of the experts, with high variance in the responses (std. deviation = 1.64), in 2038 it was moved to the very high range (mean = 6.57, median = 7.00 and min = 4.00), meaning this is an ability very likely to be emulated by machines in the near future. According to experts, the reason is quite straightforward: Selective Attention is pretty much one of the basic characteristics of machines and the specialist systems, including those with Artificial Intelligence. Thus, specialists understand that Selective Attention is already a reality, though systems may suffer to a certain extent with different kinds of interferences – which is why this ability is closely related to Flexibility of Closure. Actually, one could argue that the challenge is in the opposite direction, multitasking, which is evaluated next.

Time Sharing is the other ability in the Attentiveness group, and it measures "the ability to shift back and forth between two or more activities or sources of information (such as speech, sounds, touch, or other sources)"[139] or simply put multitasking. According to experts, in 2018 it was in the above average range (mean = 5.08 and median = 5.00) and in 2038 it was moved to very high (mean = 6.83, median = 7.00 and min.= 5.00) with an acceptable variance in responses. Time Sharing was in top 3 abilities in 2038, almost completely sure of being emulated by machines – a surprise to the researchers, taking into account that multitasking is one of the key challenges in Artificial Intelligence[140]. In our opinion, experts probably considered a simplified perspective of Time Sharing, focusing on computer science variables, like multitasking computers, hardware availability (processors) and integration, parallelism, multicore, GPU and cloud computing.

As a combined group, Attentiveness Abilities were evaluated as above average in 2018 (mean = 5.40) and moved to very high in 2038 (mean = 6.70). Therefore, experts believe that these abilities will be executed and

[138] O*NET Content Model Reference documentation (2019)
[139] O*NET Content Model Reference documentation (2019)
[140] https://www.theverge.com/2016/10/10/13224930/ai-deep-learning-limitations-drawbacks

emulated in the next following years to a high extent – actually, it is the second-highest group out of the 15 evaluated.

Psychomotor Abilities

Psychomotor Abilities are aptitudes that "influence the capacity to manipulate and control objects"[141]. They are mostly related to manipulation, movement, and speed and this category encompasses 10 abilities (out of the 52) divided into 3 ability types.

Fine Manipulative Abilities

The first group of Psychomotor Abilities in O*NET is Fine Manipulative Abilities, which are the capabilities that are "(…) related to the manipulation of objects"[142]. This group has 3 abilities: Arm-Hand Steadiness, Manual Dexterity, and Finger Dexterity. Based on the answers provided by experts, we summarize statistics for Fine Manipulative Abilities in Table 36.

	Year	2018								
	Ability	Answers	Mean[A]	Mean[B]	Dif Means	Deviation	CV	Min	Median	Max
1.A.2.a.1	Arm-Hand Steadiness	14	4.57	5.54	0.96	1.83	39.98%	2.00	4.50	7.00
1.A.2.a.2	Manual Dexterity	14	3.93	4.58	0.65	1.82	46.26%	1.00	4.00	7.00
1.A.2.a.3	Finger Dexterity	14	3.71	4.75	1.03	1.82	48.88%	1.00	4.00	7.00
1.A.2.a	Fine Manipulative Abilities	42	4.07	4.95	0.88	1.81	44.53%	1.00	4.00	7.00

	Year	2038								
	Ability	Answers	Mean[A]	Mean[B]	Dif Means	Deviation	CV	Min	Median	Max
1.A.2.a.1	Arm-Hand Steadiness	14	6.07	6.48	0.41	1.14	18.80%	4.00	6.50	7.00
1.A.2.a.2	Manual Dexterity	14	5.79	6.25	0.46	1.31	22.67%	3.00	6.00	7.00
1.A.2.a.3	Finger Dexterity	14	5.64	6.44	0.80	1.34	23.68%	2.00	6.00	7.00
1.A.2.a	Fine Manipulative Abilities	42	5.83	6.39	0.56	1.25	21.39%	2.00	6.00	7.00

	Year vs Year	Differences between 2038 - 2018								
	Ability	Answers	Mean[A]	Mean[B]	Dif Means	Deviation	CV	Min	Median	Max
1.A.2.a.1	Arm-Hand Steadiness	-	1.50	0.94	- 0.56	- 0.69	45.77%	2.00	2.00	-
1.A.2.a.2	Manual Dexterity	-	1.86	1.67	- 0.19	- 0.51	27.23%	2.00	2.00	-
1.A.2.a.3	Finger Dexterity	-	1.93	1.70	- 0.23	- 0.48	24.86%	1.00	2.00	-
1.A.2.a	Fine Manipulative Abilities	-	1.76	1.44	- 0.33	- 0.57	32.09%	1.00	2.00	-

Table 36. Fine Manipulative Abilities Statistics

Arm-Hand Steadiness is "the ability to keep your hand and arm steady while moving your arm or while holding your arm and hand in one position"[143]. It was the highest evaluated among the Fine Manipulative Abilities both in 2018 and in 2038. While in 2018 this ability was in the above average range (mean = 4.57 and median = 4.50) in the opinion of the experts, in 2038 it was moved to the high range (mean = 6.07, median = 6.50 and min = 4.00), meaning this is an ability that experts believe to be highly probable to be adequately emulated by

[141] O*NET Content Model Reference documentation (2019)
[142] O*NET Content Model Reference documentation (2019)
[143] O*NET Content Model Reference documentation (2019)

machines. Despite this conclusion, the heterogeneity of responses in both cases is considerable and worth mentioning. Nevertheless, according to experts, improvements in automation, more than in AI, have progressed considerably in the last years with precision systems and robotic steadiness that already exceed the human capability. The key example in that sense is Da Vinci Surgical Systems, a medical robot that is able to mimic with precision the surgeon's skill and perform with accuracy semi-autonomous surgeries like prostate cancer[144]. Other examples are available in the medical industry, including in neurosurgery, where precision and steadiness are two important features, which is the case of Neuromate[145].

Manual Dexterity and Finger Dexterity are the other two abilities in the Fine Manipulative Abilities group, focused on the capability of grasp, manipulate, or assemble objects either by hand or by fingers respectively. Since they assess related capabilities and results were similar, they are evaluated simultaneously. According to experts, in 2018, both dexterities were in the average range (mean = 3.93 and median = 4.00 for Manual; mean = 3.71 and median = 4.00 for Finger) and in 2038 they moved to high range (mean = 5.79, median = 6.00 and min. = 3.00 for Manual; mean = 5.64, median = 6.00 and min. = 2.00 for Finger) with a considerable variance in responses in both years, showing quite heterogenous opinions (std. deviation = 1.82 in 2018 and around 1.30 in 2038). In regard to Manual Dexterity, considering the approach of replicating to its best the human capabilities, experts explained that this ability has improved a lot lately in robots, as demonstrated by OceanOne, a humanoid robot that has arms and hands combined with a head with cameras to help it control the movements better[146]. OceanOne is equipped with Artificial Intelligence too so it can do things like avoid obstacles on its own and explore and interact with the environment. It is definitely important progress to the future, in the sense that it can replace humans in hazardous activities. Nonetheless, like the medical robots, it is still semi-autonomous, meaning that a person controls its movements remotely – a good example of the complementarity between machine and humans. Actually, one of the specialists claimed that autonomous dexterity seems to be a challenge to overcome in the long run, not only in twenty years. Experts had similar opinions about Finger Dexterity, a field that has seen some interesting progress, but that has much space to improve in the next decades. There are several interesting improvements in that field, as robotic hands focused on replicating human movements to play the piano independently[147] or Moley Kitchen, a robot that can cook recipes using fine precision motion-capture technology to mimic pre-defined movements[148]. But if we broaden the scope and consider improvements in the prosthetics field, one can see remarkable achievements, like Open Bionics products[149], that combine Manual and Finger Dexterity in alignment with the human mind.

As a combined group, Fine Manipulative Abilities were evaluated as average in 2018 (mean = 4.07) and moved to high in 2038 (mean = 5.83). In other words, these abilities will be executed and emulated in the next following years to a certain extent. Despite the fact of being one of the groups with lower results, though not in the bottom 3, data gathered do not back up Frey & Osborne (2017)'s conclusion to consider both dexterities as bottlenecks

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144 https://electronichealthreporter.com/the-da-vinci-medical-robot-and-ai/
145 https://www.renishaw.com/en/neuromate-robotic-system-for-stereotactic-neurosurgery--10712
146 https://www.nytimes.com/2016/05/09/science/oceanone-a-mer-bot-dive-buddy-with-a-friendly-face.html?_r=0
147 https://www.nytimes.com/2018/12/19/science/piano-robot-hand.html
148 https://www.youtube.com/watch?v=mKCVol2iWcc
149 https://www.youtube.com/watch?v=luHmXHEpF7w

to computerization. Contrary to Originality, individual rates for those abilities were not low enough to confirm them as limitations and examples cited by experts show some achievements in fine precision robotics and mechanics already associated with Artificial Intelligence. Nonetheless, two considerations are worth mentioning. First, the standard deviation in both dexterities is high both in 2018 and 2038, showing opinion heterogeneity among experts. Second, there is a substantial difference between calculated means A and B, which also confirms the heterogeneity just mentioned. If we had to consider the weighted mean of dexterities, the likelihood of these abilities being emulated would be even higher – experts that were more confident with their knowledge on the topic gave higher rates, a significant difference to Frey & Osborne (2017)'s observations, which may suggest these authors considered a different perspective of the ability.

Control Movement Abilities

The second group of Psychomotor Abilities in O*NET is Control Movement Abilities, which are the capabilities necessary to control and handle objects in time and space[150]. This group has 4 abilities: Control Precision, Multilimb Coordination, Response Orientation, and Rate Control. Based on the answers provided by experts, the summarized statistics for the Control Movement Abilities are in Table 37.

	Year	2018								
	Ability	Answers	Mean[A]	Mean[B]	Dif Means	Deviation	CV	Min	Median	Max
1.A.2.b.1	Control Precision	14	4.71	5.66	0.95	1.64	34.73%	2.00	4.00	7.00
1.A.2.b.2	Multilimb Coordination	14	3.93	4.59	0.67	1.54	39.26%	1.00	4.00	6.00
1.A.2.b.3	Response Orientation	14	4.07	4.64	0.57	1.54	37.88%	2.00	4.00	7.00
1.A.2.b.4	Rate Control	14	3.79	4.95	1.16	2.01	53.01%	1.00	4.00	7.00
1.A.2.b	Control Movement Abilities	56	4.13	4.96	0.84	1.68	40.84%	1.00	4.00	7.00

	Year	2038								
	Ability	Answers	Mean[A]	Mean[B]	Dif Means	Deviation	CV	Min	Median	Max
1.A.2.b.1	Control Precision	14	6.21	6.69	0.48	0.97	15.69%	4.00	6.50	7.00
1.A.2.b.2	Multilimb Coordination	14	6.07	6.52	0.44	0.92	15.10%	4.00	6.00	7.00
1.A.2.b.3	Response Orientation	14	6.00	6.28	0.28	0.78	13.07%	5.00	6.00	7.00
1.A.2.b.4	Rate Control	14	5.79	6.38	0.60	1.25	21.63%	3.00	6.00	7.00
1.A.2.b	Control Movement Abilities	56	6.02	6.47	0.45	0.98	16.31%	3.00	6.00	7.00

	Year vs Year	Differences between 2038 - 2018								
	Ability	Answers	Mean[A]	Mean[B]	Dif Means	Deviation	CV	Min	Median	Max
1.A.2.b.1	Control Precision	-	1.50	1.03	- 0.47	- 0.66	44.17%	2.00	2.50	-
1.A.2.b.2	Multilimb Coordination	-	2.14	1.92	- 0.22	- 0.63	29.19%	3.00	2.00	1.00
1.A.2.b.3	Response Orientation	-	1.93	1.64	- 0.29	- 0.76	39.30%	3.00	2.00	-
1.A.2.b.4	Rate Control	-	2.00	1.43	- 0.57	- 0.76	37.77%	2.00	2.00	-
1.A.2.b	Control Movement Abilities	-	1.89	1.51	- 0.39	- 0.70	37.16%	2.00	2.00	-

Table 37. Control Movement Abilities Statistics

Control Precision is "the ability to quickly and repeatedly adjust the controls of a machine or a vehicle to exact positions"[151]. Among Control Movement Abilities, it was the highest one evaluated conjointly by the experts both in 2018, already placed in the below average range of the scale (mean = 4.71 and median = 4.00), and in

[150] O*NET Content Model Reference documentation (2019)
[151] O*NET Content Model Reference documentation (2019)

2038 moved to the high range (mean = 6.21, median = 6.50 and min = 4.00). In other words, it means that respondents assessed this ability as likely to be executed or emulated by AI (and related technologies) in twenty years. According to one of the experts, control systems are already quite precise, and in some cases more than humans, like in the aviation industry, where the fly-by-wire technology helped to support sustainable and safe growth in the market. New systems with embedded Artificial Intelligence, like Maneuvering Characteristics Augmentation System (MCAS), are being developed to increase safety based on flight conditions and not only in flight but also in complex landing situations[152]. Autonomous cars also have to display Control Precision, so that they can quickly and repeatedly adjust their own controls to exact positions.

"The ability to coordinate two or more limbs (for example, two arms, two legs, or one leg and one arm) while sitting, standing, or lying down"[153] is evaluated by Multilimb Coordination. This ability was evaluated by experts in 2018 on the average range (mean = 3.93 and median = 4.00), increasing to high range in 2038 (mean = 6.07 and median = 6.00), also with considerable variance in responses in both years (std. deviation = 1.54). This heterogeneity is backed up by the comments. On one hand, some experts believe this is an area under development and still a huge gap to cover, a major challenge and limited to deliberate and predefined actions. On the other hand, other experts point out several examples of robots that already perform coordination in advance level: Honda's Asimo latest generation has enhanced hand dexterity and can run forward and backward, climb and descend stairs, hop and even jump[154]; though it has been recently decommissioned, Rethink's Baxter[155] was a pioneer in the all-in-one robotic solution, combining camera, arms, grippers and sensing[156]; and finally, Boston Dynamics robots, especially Atlas, a coordinated bipedal humanoid robot that can climb using hands and feet, pick its way through congested spaces and much more[157]. Since one of the highest anchors in this ability was "play the drum set in a jazz band", one of the experts also mentioned Compressorhead, a heavy metal band whose members are all robots[158].

Response Orientation deals with "the ability to choose quickly between two or more movements in response to two or more different signals (lights, sounds, pictures)"[159]. It had similar behavior in the combined opinions to Multilimb Coordination, though they measure different things. It was classified as average in 2018 (mean = 4.07 and median = 4.00) and moved to high in 2038 (mean = 6.00, median = 6.00 and min = 5.00), and it is another ability that is very likely to be emulated by machines in the future. According to experts, systems in planes and cars already choose and respond quickly to two or more different inputs or signals (like lights, sounds, pictures). What others discuss is if it is quick and accurate enough – some claim that the response time is still a limitation in those technologies, but that it is progressing rapidly to a point it could reach excellence in the next 20 years. Other specialists claimed that the main challenge is not about speed, but about accuracy in terms of defining and choosing the more adequate action.

152 https://arstechnica.com/information-technology/2018/12/unite-day1-1/
153 O*NET Content Model Reference documentation (2019)
154 https://www.youtube.com/watch?v=SARB9Ol_Wz4
155 https://www.youtube.com/watch?v=gXOkWuSCkRI
156 https://www.wired.com/story/a-long-goodbye-to-baxter-a-gentle-giant-among-robots/
157 https://www.youtube.com/watch?v=KEMt58ePNDs
158 https://www.youtube.com/watch?v=9gMX_hR-RoM
159 O*NET Content Model Reference documentation (2019)

Rate Control is "the ability to time your movements or the movement of a piece of equipment in anticipation of changes in the speed and/or direction of a moving object or scene"[160]. This aptitude was lowest among Control Movement Abilities in both scenarios (2018 and 2038), which means it is the capability within this group that experts rated as less likely of being performed by machines. In 2018, Rate Control was in the average range (mean = 3.79 and median = 4.00), and in 2038, it moved to high range (mean = 5.79 and median = 6.00). However, it is one of the top 5 abilities in terms of the heterogeneity in the answers, especially in 2018 figures. And as far as practical examples go, not many were shared by specialists – except by the autonomous cars and their necessary obstacle detection systems that help them move safely. Based on one of the top anchors, "shoot a duck in a flight", we could also find military examples, like the EXACTO system[161]. Although is not really Artificial Intelligence, the system combines a maneuverable bullet and a real-time guidance system to track and deliver the projectile to the target, compensate unexpected factors and shooting even the more complex moving targets.

As a combined group, Control Movement Abilities were evaluated as below average in 2018 (mean = 4.13) and moved to high in 2038 (mean = 6.02). Experts believe that these abilities will be executed and emulated in the next following years to a high extent, though there is some heterogeneity in the opinions and a considerable difference in the means. More than Artificial Intelligence itself, Robotics play a major role in defining the future of these abilities. Honda's Asimo, Rethink's Baxter and Boston Dynamics' Atlas are just some of the examples of how robots have improved in the last decades regarding Control Movements.

Reaction Time and Speed Abilities

The third and final group of Psychomotor Abilities in O*NET is Reaction Time and Speed Abilities, which deal with "(…) speed of manipulation of objects"[162]. This group has 3 abilities: Reaction Time, Wrist-Finger Speed and Speed of Limb Movement. Table 38 depicts the key statistics for the Reaction Time and Speed Abilities, based on the combined answers provided by experts.

160 O*NET Content Model Reference documentation (2019)
161 https://www.darpa.mil/program/extreme-accuracy-tasked-ordnance
162 O*NET Content Model Reference documentation (2019)

	Year	2018								
	Ability	Answers	Mean^{A}	Mean^{B}	Dif Means	Deviation	CV	Min	Median	Max
1.A.2.c.1	Reaction Time	14	4.36	5.38	1.02	1.91	43.74%	2.00	4.00	7.00
1.A.2.c.2	Wrist-Finger Speed	14	3.50	4.66	1.16	2.07	59.03%	1.00	3.00	7.00
1.A.2.c.3	Speed of Limb Movement	14	3.86	4.74	0.88	1.75	45.31%	2.00	3.50	7.00
1.A.2.c	Reaction Time and Speed Abilitie	42	3.90	4.93	1.02	1.90	48.59%	1.00	4.00	7.00

	Year	2038								
	Ability	Answers	Mean^{A}	Mean^{B}	Dif Means	Deviation	CV	Min	Median	Max
1.A.2.c.1	Reaction Time	14	6.00	6.33	0.33	1.11	18.49%	4.00	6.00	7.00
1.A.2.c.2	Wrist-Finger Speed	14	5.43	6.32	0.89	1.79	32.88%	2.00	6.00	7.00
1.A.2.c.3	Speed of Limb Movement	14	5.43	6.07	0.64	1.34	24.73%	3.00	5.50	7.00
1.A.2.c	Reaction Time and Speed Abilitie	42	5.62	6.24	0.62	1.43	25.46%	2.00	6.00	7.00

	Year vs Year	Differences between 2038 - 2018								
	Ability	Answers	Mean^{A}	Mean^{B}	Dif Means	Deviation	CV	Min	Median	Max
1.A.2.c.1	Reaction Time	-	1.64	0.95	- 0.69	- 0.80	48.47%	2.00	2.00	-
1.A.2.c.2	Wrist-Finger Speed	-	1.93	1.66	- 0.27	- 0.28	14.57%	1.00	3.00	-
1.A.2.c.3	Speed of Limb Movement	-	1.57	1.33	- 0.24	- 0.41	25.80%	1.00	2.00	-
1.A.2.c	Reaction Time and Speed Abilitie	-	1.71	1.31	- 0.40	- 0.47	27.24%	1.00	2.00	-

Table 38. Reaction Time and Speed Abilities Statistics

Reaction Time is the first of the Reaction Time and Speed Abilities and it evaluates "the ability to quickly respond (with the hand, finger, or foot) to a signal (sound, light, picture) when it appears"[163]. It was the highest-rated by experts within the group. While in 2018 this ability was in the average range (mean = 4.36 and median = 4.00) based on specialists' feedback, in 2038 it was moved to the high range (mean = 6.00, median = 6.00 and min = 4.00), meaning this is an ability very likely to be adequately emulated by machines in the near future. Despite this conclusion, the heterogeneity of responses in both cases, but especially in 2018, is considerable. Nevertheless, according to experts, this is an ability that, again, has improved a lot in recent decades, pushed as a key feature of the autonomous cars. According to recent researches in reaction time while driving, "AI was slightly better in terms of speed and accuracy of detecting objects in rainy conditions (98.3% vs. 97% for humans)"[164], while human volunteers proved significantly slower in recognizing road objects in twilight and blinding sunlight. In other words, for some applications, it is fair to assume that, even nowadays, Reaction Time can be replicated by machines that perform at least as good as human counterparts, as an ultra-fast robotic arm from the École Polytechnique Fédérale de Lausanne in Switzerland[165].

Wrist-Finger Speed and Speed of Limb Movement are the other two abilities in the Fine Reaction Time and Speed group, focused on the ability to quickly and repeatedly (if necessary) move different body parts (arms, legs, hands, wrist, fingers). Since they assess similar capabilities and results were also similar, they are evaluated simultaneously. According to experts, in 2018, both speed abilities were in the average range (mean = 3.50 and median = 3.00 for Wrist-Finger; mean = 3.86 and median = 3.50 for Limb) and in 2038 they moved to above average range (mean = 5.43, median = 6.00 and min. = 2.00 for Wrist-Finger; mean = 5.43, median = 5.50 and min. = 3.00 for Limb) with a considerable variance in responses in both years, showing quite heterogeneous opinions. This issue was particularly abnormal in the Wrist-Finger Speed ability (std deviation = 2.07 in 2018 and 1.79 in 2038), third-highest deviation among abilities in 2018 and second in 2038, which implies a low level

[163] O*NET Content Model Reference documentation (2019)
[164] https://sputniknews.com/science/201711291059543516-human-vs-ai-driving-reaction-time/
[165] https://www.youtube.com/watch?v=EqMPLnIRUvQ

of confidence in this combined evaluation. There are not enough justifications to confirm exactly why this happened, but a possible explanation could be a misinterpretation of how to resolve O*NET's highest-level anchor for Wrist-Finger Speed – "type a document at 90 words a minute". Although there are no robots nowadays that can actually emulate typing in a reasonable way[166], there may be alternative ways of reaching this outcome that could have been considered by experts in their rating. In both Speed abilities, most of the examples were again related to robots (either humanoids or robotic arms) that emulate the dexterity abilities above-mentioned. In fact, it is possible to assume that these robotic solutions aim not only to replicate dexterity but also control and speed to be fully capable of reproducing or enhancing its comparable human competitor. As a consequence, several abilities may have similar statistics and similar explanations or examples, nonetheless, two additional examples that focus on speed too were Kuka's KR Agilus robot, which, marketing aside, is an impressively fast and precise robot[167] and Stäubli's TP80[168], a fast picking and handling robot.

As a combined group, Reaction Time and Speed Abilities were evaluated as average in 2018 (mean = 3.90) and moved to high in 2038 (mean = 5.62). In other words, these abilities will be executed and emulated in the next following years to a certain extent. Despite the fact of being one of the groups with lower results, though not in the bottom 3 in neither of the years, it cannot be considered a bottleneck and it will have some progress in the following years, walking hand in hand with the achievements in dexterity and control. Taking into account this association between the three types of abilities, the results found in this research seem to be consistent and contrary to Frey & Osborne (2017) that only saw limitations in the dexterity. As in other abilities in the Psychomotor family, standard deviations are high in 2018 and 2038, showing opinion heterogeneity among experts and the substantial difference between calculated means A and B.

Physical Abilities

Physical Abilities are those that "influence strength, endurance, flexibility, balance, and coordination"[169]. There are 9 abilities (out of the 52) in this category and they are divided into 3 groups: Physical Strength Abilities, Endurance and Flexibility, Balance, and Coordination.

Physical Strength Abilities

The first group of Physical Abilities in O*NET is Physical Strength Abilities, which are capabilities "(…) related to the capacity to exert force"[170]. This group has 4 abilities: Static Strength, Explosive Strength, Dynamic Strength, and Trunk Strength. Based on the answers provided by experts, we summarize the key statistics found for Physical Strength Abilities in Table 39.

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[166] https://www.youtube.com/watch?v=Z0pkq2CqMhQ
[167] https://www.youtube.com/watch?v=lv6op2HHIuM
[168] https://www.youtube.com/watch?v=Em7C1SlqId8
[169] O*NET Content Model Reference documentation (2019)
[170] O*NET Content Model Reference documentation (2019)

	Year	2018								
	Ability	Answers	Mean^{A}	Mean^{B}	Dif Means	Deviation	CV	Min	Median	Max
1.A.3.a.1	Static Strength	14	5.57	6.34	0.77	1.65	29.63%	2.00	6.00	7.00
1.A.3.a.2	Explosive Strength	14	3.79	4.59	0.81	1.67	44.17%	1.00	4.00	7.00
1.A.3.a.3	Dynamic Strength	14	4.43	5.75	1.32	2.21	49.88%	1.00	5.00	7.00
1.A.3.a.4	Trunk Strength	14	4.50	5.82	1.32	2.24	49.88%	2.00	4.00	7.00
1.A.3.a	Physical Strength Abilities	56	4.57	5.62	1.05	2.02	44.12%	1.00	5.00	7.00

	Year	2038								
	Ability	Answers	Mean^{A}	Mean^{B}	Dif Means	Deviation	CV	Min	Median	Max
1.A.3.a.1	Static Strength	14	6.71	6.86	0.14	0.47	6.98%	6.00	7.00	7.00
1.A.3.a.2	Explosive Strength	14	5.93	6.45	0.53	1.14	19.25%	4.00	6.00	7.00
1.A.3.a.3	Dynamic Strength	14	5.79	6.56	0.77	1.37	23.66%	3.00	6.00	7.00
1.A.3.a.4	Trunk Strength	14	5.64	6.50	0.86	1.65	29.17%	3.00	6.50	7.00
1.A.3.a	Physical Strength Abilities	56	6.02	6.59	0.57	1.27	21.14%	3.00	7.00	7.00

	Year vs Year	Differences between 2038 - 2018								
	Ability	Answers	Mean^{A}	Mean^{B}	Dif Means	Deviation	CV	Min	Median	Max
1.A.3.a.1	Static Strength	-	1.14	0.51	- 0.63	- 1.18	103.43%	4.00	1.00	-
1.A.3.a.2	Explosive Strength	-	2.14	1.86	- 0.28	- 0.53	24.79%	3.00	2.00	-
1.A.3.a.3	Dynamic Strength	-	1.36	0.81	- 0.55	- 0.84	61.90%	2.00	1.00	-
1.A.3.a.4	Trunk Strength	-	1.14	0.68	- 0.46	- 0.60	52.40%	1.00	2.50	-
1.A.3.a	Physical Strength Abilities	-	1.45	0.97	- 0.48	- 0.74	51.50%	2.00	2.00	-

Table 39. Physical Strength Abilities Statistics

Static Strength measures “the ability to exert maximum muscle force to lift, push, pull, or carry objects”[171]. Within the Physical Strength Abilities group, it was evaluated conjointly by the experts as the ability with the highest chances of being emulated by machines both in 2018, already situated in the high range of the scale (mean = 5.57 and median = 6.00), and in 2038, in the very high range (mean = 6.71, median = 7.00 and min = 6.00). Actually, this ability was in the top 5 of the most likely to be emulated in both years and statistics are substantiated by the specialist’s comments. According to experts, robots are already capable of efficient static strength for some years now, though not necessarily in the same way as humans. Actually, they are the major workforce in several heavy industries and two examples are ABB’s automated cranes in ports around the world[172] or Demag’s warehouse automated cranes[173], both working with weights that would be not managed by humans. Evidently, the weight measured by the ability is humanly possible, like “lift 75-pound bags of cement onto a truck”[174], the higher anchor in O*NET. Nonetheless, these examples show that automated robots, some with some degree of intelligence, are already able to go even further of the human capabilities in terms of Static Strength.

Explosive Strength, on the other hand, was the Physical Strength ability that was evaluated as the lowest chance of being emulated by AI, Robotics and related technologies in 2018, assigned to the average range of the scale (mean = 3.79 and median = 4.00). However, in 2038, its likeliness had a strong and solid increase, moving to the high range (mean = 5.93, median = 6.00 and min = 4.00), overpassing Dynamic and Trunk Strength. In this ability, the deviation in the responses, especially in 2018 (std. deviation = 2.21) was considerable, indicating

[171] O*NET Content Model Reference documentation (2019)
[172] https://www.youtube.com/watch?v=8E0-EUdtDF8
[173] https://www.youtube.com/watch?v=iB11n_kV2nY
[174] O*NET Content Model Reference documentation (2019)

heterogeneity of opinions. Considering Explosive Strength description, which is "the ability to use short bursts of muscle force to propel oneself (as in jumping or sprinting), or to throw an object"[175], it is possible to see remarkable achievements already in place, such as Boston Dynamics' Atlas that is able to boost and jump[176]. However, some of the experts believed there are still several challenges yet in place, including the highest anchor in O*NET scale, which is to "throw a shot-put in a track meet"[177]. The justification here is that solutions are still far from emulating human capabilities, especially considering the human's approach, flexibility and adaptability – despite being visually similar in looks and functions, robot muscles are really just servos, hydraulic pumps, or whatever else[178]. Indeed, Ishikawa Komuro Lab's high-speed robot hand is able to throw objects[179], but yet in a simple and predefined way, missing precision and speed, as one of the experts affirms.

The third Physical Strength is Dynamic Strength, which is "the ability to exert muscle force repeatedly or continuously over time (…)", involving "(…) muscular endurance and resistance to muscle fatigue"[180]. Dynamic Strength was evaluated conjointly by the experts in the average range of the scale in 2018 (mean = 4.43 and median = 5.00), and in the high range in 2038 (mean = 5.79, median = 6.00 and min = 4.00). Similarly to Static Strength and other Psychomotor Abilities, some of the experts consider Dynamic Strength as a practical example of the word machine – they never get tired, bored or fatigued, they endure and resist even in restlessly repeatable scenarios.

Trunk Strength is the last of the Physical Strength Abilities. This aptitude is about using "(…) abdominal and lower back muscles to support part of the body repeatedly or continuously over time without 'giving out' or fatiguing"[181]. While in 2018 it was the second higher rate within the group, situated in the above average in 2018 (mean = 4.50 and median = 4.00), in 2038 it was surpassed by other abilities and was evaluated as the lower within the group, though being moved to the high range (mean = 5.64, median = 6.50 and min = 3.00). This means that, according to experts, this ability is likely to be emulated by machines in the near future. Despite the minor differences in statistics that may exist between Trunk Strength and Dynamic Strength and the distinctions between the focus of what they measure, the comments for these two abilities were the same. Actually, it is a very particular type of strength that, as mentioned in other cases, challenges arise from trying to emulate humans, not actually achieving acceptable results with different approaches.

As a combined group, Physical Strength Abilities were evaluated as above average in 2018 (mean = 4.57) and moved to high in 2038 (mean = 6.02), which means that experts believe these abilities will be executed and emulated in the next following years to a high extent, though there is heterogeneity in the opinions in both years and the considerable difference in the means. Again, the major technological component here is Robotics. Apart from the examples pointed out, it is interesting to mention two important innovations in regard to the strength

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175 O*NET Content Model Reference documentation (2019)
176 https://www.youtube.com/watch?v=fRj34o4hN4I
177 O*NET Content Model Reference documentation (2019)
178 https://www.extremetech.com/extreme/173332-super-material-could-create-robot-muscles-with-1000x-human-strength
179 https://www.youtube.com/watch?v=-KxjVlaLBmk
180 O*NET Content Model Reference documentation (2019)
181 O*NET Content Model Reference documentation (2019)

that show how these abilities can progress in the long run. The first case is that of different kinds of robotic exoskeletons and robotic suits already available that are able to cooperate with humans, enhancing their strength[182] or simply aiding disabled people, like Cyberdyne[183]. The second case is that of researchers from U.S. Department of Energy's Berkeley Lab that are looking for a new way to make usefully strong artificial muscles that actually work like real human muscles, but a thousand times stronger[184].

Endurance

The second group of Physical Abilities in O*NET is Endurance Abilities, which are the capabilities "(…) to exert oneself physically over long periods without getting out of breath"[185]. This group has one single ability, which is Stamina and the statistics are summarized in Table 40.

	Year	2018								
	Ability	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.3.b.1	Stamina	14	5.14	5.99	0.84	2.07	40.25%	1.00	5.50	7.00
1.A.3.b	Endurance	14	5.14	5.99	0.84	2.07	40.25%	1.00	5.50	7.00

	Year	2038								
	Ability	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.3.b.1	Stamina	14	6.07	6.36	0.29	1.73	28.50%	1.00	7.00	7.00
1.A.3.b	Endurance	14	6.07	6.36	0.29	1.73	28.50%	1.00	7.00	7.00

	Year vs Year	Differences between 2038 - 2018								
	Ability	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.3.b.1	Stamina	-	0.93	0.38	- 0.55	- 0.34	36.59%	-	1.50	-
1.A.3.b	Endurance	-	0.93	0.38	- 0.55	- 0.34	36.59%	-	1.50	-

Table 40. Endurance Abilities Statistics

Stamina is defined as the "ability to exert yourself physically over long periods of time without getting winded or out of breath"[186]. According to the combined opinion of the experts, this is an ability that is very likely of being emulated by machines both in 2018, already in the above average range (mean = 5.14 and median = 5.50) and in 2038, moving up to the high range (mean = 6.07, median = 7.00 and min = 1.00). According to most of the specialists, and similarly to other abilities already evaluated, this was another aptitude that machines can already perform better than humans. Given energy, endurance is one of the key advantages of the machines since they never get winded. However, a couple of the experts could not see the relationship between stamina, a physical capacity of biological beings, and Artificial Intelligence or Robotics. One of these panelists granted the lower possible rates in the scale for both in 2018 and 2038. This explains why both Stamina (as an individual ability) and Endurance (as a group ability) were in the respective top 5 (2018 and 2038) and top 3 (in 2018 and 2038) in terms of heterogeneity of opinions. Actually, Endurance was the first both in 2018 and 2038 (std.

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182 https://www.youtube.com/watch?v=VSzvVXiWkSg
183 https://www.youtube.com/watch?v=UffBS1uKJdE
184 https://www.extremetech.com/extreme/173332-super-material-could-create-robot-muscles-with-1000x-human-strength
185 O*NET Content Model Reference documentation (2019)
186 O*NET Content Model Reference documentation (2019)

deviation = 1,73) among all groups. Disregarding this particular expert opinion, Stamina and Endurance would increase their means to 5,46 in 2018 and 6,46 in 2038, with an acceptable deviation.

Flexibility, Balance, and Coordination

The third and last group of Physical Abilities in O*NET is Flexibility, Balance, and Coordination Abilities, aptitudes "(…) related to the control of gross body movements"[187]. This group has 4 abilities: Extent Flexibility, Dynamic Flexibility, Gross Body Coordination, and Gross Body Equilibrium. Considering experts opinions, we summarize the key statistics found for Physical Strength Abilities in Table 41.

	Year	2018								
	Ability	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.3.c.1	Extent Flexibility	14	3.93	5.02	1.09	1.86	47.32%	1.00	4.00	7.00
1.A.3.c.2	Dynamic Flexibility	14	3.36	4.42	1.06	1.69	50.40%	1.00	3.00	7.00
1.A.3.c.3	Gross Body Coordination	14	2.86	3.57	0.71	1.35	47.27%	1.00	2.00	6.00
1.A.3.c.4	Gross Body Equilibrium	14	3.14	3.52	0.38	0.86	27.50%	2.00	3.00	4.00
1.A.3.c	Flexibility, Balance, and Coordin	56	3.32	4.13	0.81	1.50	45.25%	1.00	3.00	7.00

	Year	2038								
	Ability	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.3.c.1	Extent Flexibility	14	5.64	6.50	0.86	1.34	23.68%	3.00	6.00	7.00
1.A.3.c.2	Dynamic Flexibility	14	5.29	5.92	0.64	1.38	26.16%	3.00	5.50	7.00
1.A.3.c.3	Gross Body Coordination	14	5.00	5.47	0.47	1.36	27.17%	2.00	5.00	7.00
1.A.3.c.4	Gross Body Equilibrium	14	5.57	6.02	0.45	1.09	19.55%	3.00	6.00	7.00
1.A.3.c	Flexibility, Balance, and Coordin	56	5.38	5.98	0.60	1.29	23.95%	2.00	6.00	7.00

	Year vs Year	Differences between 2038 - 2018								
	Ability	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.3.c.1	Extent Flexibility	-	1.71	1.48	- 0.23	- 0.52	30.49%	2.00	2.00	-
1.A.3.c.2	Dynamic Flexibility	-	1.93	1.51	- 0.42	- 0.31	16.03%	2.00	2.50	-
1.A.3.c.3	Gross Body Coordination	-	2.14	1.91	- 0.24	0.01	0.38%	1.00	3.00	1.00
1.A.3.c.4	Gross Body Equilibrium	-	2.43	2.50	0.07	0.22	9.26%	1.00	3.00	3.00
1.A.3.c	Flexibility, Balance, and Coordin	-	2.05	1.85	- 0.20	- 0.22	10.50%	1.00	3.00	-

Table 41. Flexibility, Balance and Coordination Abilities Statistics

Extent Flexibility measures "the ability to bend, stretch, twist, or reach with your body, arms, and/or legs"[188]. Within the Flexibility, Balance, and Coordination Abilities group, it was evaluated conjointly by the experts as the ability with the highest chances of being emulated by machines both in 2018, situated in the average range of the scale (mean = 3.93 and median = 4.00), and in 2038, in the high range (mean = 5.64, median = 6.00 and min = 3.00). According to experts, flexibility is already possible in current robots, as shown in previous examples and also with emerging technologies such as flexible-joint robots, where elasticity comes from springs in the joints[189]. The emphasis for these robots has been in speed and precision based on predefined and controlled situations, so they still lack genuine flexibility. And, as one of the experts alerted, there is the traditional tradeoff between flexibility and resistance, which is an additional challenge to overcome in the next decades. The

[187] O*NET Content Model Reference documentation (2019)
[188] O*NET Content Model Reference documentation (2019)
[189] https://www.chrismacnab.com/flexible-joint-robots/

authentic revolution here might be another emerging field, that of the soft robots[190]. Harvard scientists have been working on autonomous flexible robots made of silicone rubbers that, apart from being more flexible, are also more resistant than its metallic cousins[191]. Considering this scenario, some experts believe that Robotics, Artificial Intelligence, and related technologies will need more than 20 years to adequately emulate this human capability.

Dynamic Flexibility is "the ability to quickly and repeatedly bend, stretch, twist, or reach out with your body, arms, and/or legs". Thus, it is the combination of Extent Flexibility with speed and recurrence. Despite being two actions that machines usually succeed, the combination affected the overall opinion of the experts that understood that Dynamic Flexibility should be more complicated to achieve than Extent Flexibility, and therefore, less likely to be emulated by machines in the next 20 years. While in 2018 this Dynamic Flexibility was in the below average range of the scale (mean = 3.36 and median = 3.00), in 2038 it moved to the above average range (mean = 5.29, median = 5.50 and min = 3.00). Examples and arguments pointed out by experts are the same as to Extent Flexibility and the opinion is that technology will need more than 20 years of improvement to adequately emulate it.

The third Flexibility, Balance, and Coordination Ability is Gross Body Coordination, which is "the ability to coordinate the movement of your arms, legs, and torso together when the whole body is in motion."[192]. This ability was evaluated conjointly by the experts in the below average range of the scale in 2018 (mean = 2.86 and median = 2.00), and in the above average range in 2038 (mean = 5.00, median = 5.00 and min = 2.00). Apart from being the ability in the Flexibility, Balance, and Coordination group that was less likely to be emulated by machines in both years (2018 and 2038), it was also the third-lowest in 2018 and fourth-lowest in 2038 of the 52 abilities evaluated. These results consider the coordination challenges in Robotics, but opinions are probably mixed with another important feature, which is the integration of the different technologies into a robot that can be truly autonomously coordinated, not just a set of predefined motions as the dancing robot[193]. Despite the low results for coordination, Boston Dynamics has shown some remarkable improvements in that ability in robots that are also adaptable to unfolding situations[194]. Additionally, but not evaluated by this ability, is the coordination between several robots, which has also been an area of interest in the multi-robot coordination and navigation field.

Gross Body Equilibrium is the last of the Flexibility, Balance, and Coordination Ability. While in 2018 it held the second-lower rate within the group, situated in the below average (mean = 3.14 and median = 3.00), in 2038 it surpassed other abilities and was evaluated as the second-higher within the group, in the high range (mean = 5.57, median = 6.00 and min = 3.00). This ability is about being able to "(…) keep or regain your body balance or stay upright when in an unstable position"[195]. According to experts, this ability is still in development,

[190] https://www.youtube.com/watch?v=AI7M-JTC6_w
[191] https://www.popularmechanics.com/technology/robots/a12427/indestructible-starfish-robonots-could-save-your-life-one-day-17190305/
[192] O*NET Content Model Reference documentation (2019)
[193] https://www.youtube.com/watch?v=Q-sK-s_TzN0
[194] https://www.youtube.com/watch?v=op0bhZNUJFE
[195] O*NET Content Model Reference documentation (2019)

especially for robots in challenging situations – unequal paths, extreme weather conditions and other external distresses and unforeseen circumstances. However, interesting achievements were already achieved, which makes it fair to assume the pictured state of 2038. These accomplishments are exemplified by Cassie, a bipedal robot that can walk, run, stand in place and maintain its balance[196] and Boston Dynamics' wheeled handle robot that does outstanding feats without losing its balance[197].

As a combined group, Flexibility, Balance, and Coordination Abilities were evaluated as below average in terms being emulated by machines in 2018 (mean = 3.32) and moved to above average in 2038 (mean = 5.38), which means that experts believe these abilities could not be executed by machines in the next following years. Like other Psychomotor and Physical Abilities groups, there is some heterogeneity in the opinions and a considerable difference in the two means. Flexibility, Balance, and Coordination Abilities is one of the groups less likely to be emulated by machines in both years (2018 and 2038), the second-lowest in 2018 and the third-lowest in 2038 of the 15 groups evaluated. The major technological component here is Robotics and although there are several interesting innovations in the field, experts believe these abilities have much to improve and will not reach perfection by 2038. Contrary to Frey & Osborne (2017), we understand that Flexibility, Balance, and Coordination Abilities could be considered a bottleneck.

Sensory Abilities

Finally, the fourth and last ability category in O*NET is Sensory Abilities, those aptitudes that "(…) influence visual, auditory and speech perception"[198]. There are 12 abilities (out of the 52) in this category and they are divided into 2 groups: Visual Abilities and Auditory and Speech Abilities.

Visual Abilities

The first group of Sensory Abilities in O*NET is Visual Abilities, capabilities "(…) related to visual sensory input"[199]. This group has 7 abilities: Near Vision, Far Vision, Visual Color Determination, Night Vision, Peripherical Vision, Depth Perception, and Glare Sensitivity. Based on the statistics gathered, we share the statistics found for Visual Abilities in Table 42.

[196] https://www.youtube.com/watch?v=Is4JZqhAy-M
[197] https://www.youtube.com/watch?v=uDzz-YLft9k
[198] O*NET Content Model Reference documentation (2019)
[199] O*NET Content Model Reference documentation (2019)

	Year	2018								
	Ability	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.4.a.1	Near Vision	14	5.14	5.73	0.59	1.56	30.37%	2.00	5.00	7.00
1.A.4.a.2	Far Vision	14	5.29	5.82	0.54	1.49	28.19%	2.00	5.00	7.00
1.A.4.a.3	Visual Color Discrimination	14	4.57	4.72	0.14	1.28	28.08%	2.00	5.00	6.00
1.A.4.a.4	Night Vision	14	4.57	5.33	0.76	1.95	42.65%	2.00	4.50	7.00
1.A.4.a.5	Peripheral Vision	14	4.71	5.56	0.85	1.90	40.27%	1.00	4.50	7.00
1.A.4.a.6	Depth Perception	13	4.46	4.59	0.13	1.51	33.76%	2.00	5.00	7.00
1.A.4.a.7	Glare Sensitivity	14	4.21	4.32	0.10	1.72	40.76%	2.00	4.00	7.00
1.A.4.a	Visual Abilities	97	4.71	5.15	0.46	1.63	34.67%	1.00	5.00	7.00

	Year	2038								
	Ability	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.4.a.1	Near Vision	14	6.36	6.60	0.24	0.84	13.24%	5.00	7.00	7.00
1.A.4.a.2	Far Vision	14	6.71	6.82	0.11	0.61	9.10%	5.00	7.00	7.00
1.A.4.a.3	Visual Color Discrimination	14	6.14	6.10	- 0.04	1.10	17.90%	3.00	6.00	7.00
1.A.4.a.4	Night Vision	14	6.07	6.29	0.22	0.83	13.65%	5.00	6.00	7.00
1.A.4.a.5	Peripheral Vision	14	6.14	6.58	0.44	1.17	19.00%	3.00	6.50	7.00
1.A.4.a.6	Depth Perception	13	6.15	6.30	0.15	0.90	14.60%	4.00	6.00	7.00
1.A.4.a.7	Glare Sensitivity	14	5.79	5.77	- 0.01	1.31	22.67%	3.00	6.00	7.00
1.A.4.a	Visual Abilities	97	6.20	6.35	0.20	1.00	16.08%	3.00	6.00	7.00

	Year vs Year	Differences between 2038 - 2018								
	Ability	Answers	Mean^A	Mean^B	Dif Means	Deviation	CV	Min	Median	Max
1.A.4.a.1	Near Vision	-	1.21	0.87	- 0.35	- 0.72	59.30%	3.00	2.00	-
1.A.4.a.2	Far Vision	-	1.43	1.00	- 0.43	- 0.88	61.50%	3.00	2.00	-
1.A.4.a.3	Visual Color Discrimination	-	1.57	1.39	- 0.18	- 0.18	11.74%	1.00	1.00	1.00
1.A.4.a.4	Night Vision	-	1.50	0.95	- 0.55	- 1.12	74.75%	3.00	1.50	-
1.A.4.a.5	Peripheral Vision	-	1.43	1.02	- 0.41	- 0.73	51.18%	2.00	2.00	-
1.A.4.a.6	Depth Perception	-	1.69	1.71	0.02	- 0.61	35.91%	2.00	1.00	-
1.A.4.a.7	Glare Sensitivity	-	1.57	1.46	- 0.12	- 0.41	25.86%	1.00	2.00	-
1.A.4.a	Visual Abilities	-	1.49	1.20	- 0.26	- 0.64	42.81%	2.00	1.00	-

Table 42. Visual Abilities Statistics

First two abilities in the Visual Abilities group are those that focus on vision and distance. Near Vision is "the ability to see details at close range (within a few feet of the observer)"[200], while Far Vision is "the ability to see details at a distance"[201]. Despite the slight differences in statistics for these two types of vision, we evaluate them together since they both use the same technologies to be performed and because experts that assessed them with diverse rates did not provide any remarks or reasons to support their differing opinions. Within the Visual Abilities group, Near and Far Vision were evaluated as the two aptitudes with the highest chances of being emulated by machines both in 2018 and 2038, with intermediate homogeneity in the responses. In 2018 both visions were in the above average range of the scale (mean = 5.14 and median = 5.00 for Near Vision; mean = 5.29 and median = 5.00 for Far Vision), and in 2038, Near Vision was in the high range (mean = 6.36, median = 7.00 and min = 5.00) and Far Vision in the very high range (mean = 6.71, median = 7.00 and min = 5.00). According to experts, vision is a capability quite advanced in machines thanks to the Artificial Intelligence field of Computer Vision. The combination of power lenses with a broader range of vision and zoom (broader than human beings), high definition cameras and video systems and enhanced and powerful recognition algorithms, motivated experts to rate these abilities as very likely to be emulated by machines in the next twenty years. The examples on Visual Abilities go beyond just seeing, but they apply it to perform more complex tasks, like

[200] O*NET Content Model Reference documentation (2019)
[201] O*NET Content Model Reference documentation (2019)

Waymo, the autonomous car[202] and IPI's robot[203], that combines Vision with dexterity and strength, two other abilities already discussed. However, some critics explain that there is still a major challenge, a difference between just seeing and understanding and making sense of what is seen[204].

Additionally to Near and Far Vision, Visual Abilities also consider another complementary optical capability which is Peripheral Vision, that presented similar results to the two just mentioned, as the third with a high likelihood of being emulated by machines. In 2018 it was already in the above average (mean = 4.71 and median = 4.50) and in 2038 it moved to the high range (mean = 6.14, median = 6.50 and min = 3.00). This ability is about being able to "(…) see objects or movement of objects to one's side when the eyes are looking ahead"[205]. According to experts, machines are not limited by hardware like humans are (only two eyes), so currently it is possible to use several sensors, cameras and such to allow the machine to have omnidirectional 360 degrees view of its surroundings. Even simple vacuum cleaners robots such as Dyson 360 Eye have these technologies embedded in them[206]. Peripheral Vision limitations are, in fact, the same ones from the other visions and will improve along with them.

Visual Color Discrimination is "the ability to match or detect differences between colors, including shades of color and brightness"[207]. This aptitude was evaluated conjointly by the experts in the above average range of the scale in 2018 (mean = 4.57 and median = 5.00), and in the high range in 2038 (mean = 6.14, median = 6.00 and min = 3.00) with an average homogeneity in opinions. Experts understood that there are current technologies that already perform this ability, like distinguishing traffic lights and take action upon this information. They also saw no great challenges that could block its complete emulation by machines in the near future, at least with similar results, even with shades and brightness variance that add some complexity to the problem or with a completely different approach than humans.

The fourth Visual Ability is Night Vision, which is "the ability to see under low light conditions"[208]. This ability was evaluated conjointly by the experts in the above average range of the scale in 2018 (mean = 4.57 and median = 4.50), and in the high range in 2038 (mean = 6.07, median = 6.00 and min = 3.00), which means that experts evaluate that Night Vision is very likely to be emulated by Artificial Intelligence, Robotics or related technologies in the next twenty years. There is, however, some heterogeneity in the opinions, especially in 2018 (std. deviation = 1.95). Nevertheless, according to experts, this is another aptitude already performed by current technologies, with great success because machines can overcome potential challenges by complementing the basic vision with infrared and thermal functionalities, what makes them perfect for the surveillance and defense

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202 https://www.theverge.com/2018/5/9/17307156/google-waymo-driverless-cars-deep-learning-neural-net-interview
203 https://www.youtube.com/watch?v=Plo7SH9aBgg
204 https://www.youtube.com/watch?v=40riCqvRoMs
205 O*NET Content Model Reference documentation (2019)
206 https://www.dyson.com/vacuum-cleaners/robot-vacuum.html
207 O*NET Content Model Reference documentation (2019)
208 O*NET Content Model Reference documentation (2019)

industry. An example is Knightscope K5, an autonomous security robot that, among several features, has embedded night vision combined with other visual capabilities[209].

Depth Perception, “the ability to judge which of several objects is closer or farther away from you, or to judge the distance between you and an object”[210] was the second-lowest rated ability within the Visual Abilities group in 2018. While in 2018 it was in the average range (mean = 4.46 and median = 5.00) and moved to high range (mean = 6.15, median = 6.00 and min = 4.00). Some of the experts believe this ability could be emulated in the near future by machines, pointing out that this capability is already executed by different appliances, as in autonomous cars, or that it is not a complex problem since lasers are already able to tell distances with extreme precision. However, in both cases, the approach to perceive distance and depth is quite different from the human one, using either lasers or radar systems rather than vision[211] – nonetheless, the outcomes are remarkable.

The last of the Visual Abilities and the one that had the lowest rate, meaning that it is less likely to be emulated by Artificial Intelligence, Robotics, and related technologies in 2018 and 2038 was Glare Sensitivity, which is the “ability to see objects in the presence of glare or bright lighting”. Based on experts’ opinions and rates, it was assigned to the average range of the scale (mean = 4.21 and median = 4.00) and moved to high range (mean = 5.79, median = 6.00 and min = 3.00). In this ability, there was also some degree of deviation in the responses, especially in 2018 (std. deviation = 1.72). Despite the advanced camera systems and the application of filters, as well as researches that showed that human volunteers proved significantly slower in recognizing road objects in blinding sunlight[212], experts understand that Glare Sensitivity needs more time to be totally emulated, especially because illumination is a critical component in machine vision systems to perform consistently and reliably[213]. Again, there is a flexibility and adaptability issue, which the human vision can handle without much problem.

As a combined group, Visual Abilities were evaluated as above average in terms of replication likelihood in 2018 (mean = 4.71) and moved to high in 2038 (mean = 6.20), which means that experts believe these abilities will be executed and emulated in the next following years to a considerable extent. In this group, it is possible to see integration among several of the abilities as well as their application in several different solutions. Maybe Waymo is the best example of how advance Vision Abilities currently are. It has a combination of high-resolution cameras to detect visual information like traffic lights, laser beams to build a detailed 360 degrees picture of the world surrounding it and a series of radars to detect how far away objects are and their speed[214]. Robots that perform the most amazing deeds also require a complex system of visualization, like MIT Cheetah Robot[215] or many of the robots that take part every year of Amazon Picking Challenge[216]. However, there are several challenges to overcome too[217], one of them being the occlusion problem – when part of an object may be

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209 https://www.businesswire.com/news/home/20181009005816/en/Knightscope-K5-Featured-Robot-Wired25-San-Francisco
210 O*NET Content Model Reference documentation (2019)
211 https://physicsworld.com/a/machine-vision-with-depth/
212 https://sputniknews.com/science/201711291059543516-human-vs-ai-driving-reaction-time/
213 https://blog.robotiq.com/robot-vision-lighting-why-theres-no-perfect-setup
214 https://www.youtube.com/watch?time_continue=3&v=B8R148hFxPw
215 https://www.youtube.com/watch?v=_luhn7TLfWU
216 https://www.youtube.com/watch?v=AljePt7Mh6U
217 https://blog.robotiq.com/top-10-challenges-for-robot-vision

partially covered up, making it hard for the computer to recognize it, an issue in Computer Vision mentioned by one of the experts.

Auditory and Speech Abilities

The second and final group of Sensory Abilities in O*NET is Auditory and Speech Abilities, which are the capabilities that are "(…) related to auditory and oral input"[218]. This group has 5 abilities: Hearing Sensitivity, Auditory Attention, Sound Localization, Speech Recognition, and Speech Clarity. Based on the answers provided by experts, we present the key statistics in Table 43.

	Year	2018								
	Ability	Answers	Mean[A]	Mean[B]	Dif Means	Deviation	CV	Min	Median	Max
1.A.4.b.1	Hearing Sensitivity	14	4.57	4.87	0.30	1.74	38.10%	2.00	4.50	7.00
1.A.4.b.2	Auditory Attention	13	4.15	4.36	0.20	1.77	42.67%	2.00	4.00	7.00
1.A.4.b.3	Sound Localization	13	4.23	4.54	0.31	1.79	42.23%	2.00	4.00	7.00
1.A.4.b.4	Speech Recognition	14	4.00	4.09	0.09	0.88	21.93%	2.00	4.00	5.00
1.A.4.b.5	Speech Clarity	14	3.79	3.65	- 0.14	1.58	41.67%	2.00	4.00	7.00
1.A.4.b	Auditory and Speech Abilities	68	4.15	4.30	0.12	1.56	37.55%	2.00	4.00	7.00

	Year	2038								
	Ability	Answers	Mean[A]	Mean[B]	Dif Means	Deviation	CV	Min	Median	Max
1.A.4.b.1	Hearing Sensitivity	14	6.21	6.29	0.08	0.80	12.90%	5.00	6.00	7.00
1.A.4.b.2	Auditory Attention	13	6.15	6.36	0.20	0.90	14.60%	4.00	6.00	7.00
1.A.4.b.3	Sound Localization	13	6.15	6.27	0.12	0.99	16.04%	4.00	6.00	7.00
1.A.4.b.4	Speech Recognition	14	6.14	6.37	0.23	0.77	12.54%	5.00	6.00	7.00
1.A.4.b.5	Speech Clarity	14	5.57	5.52	- 0.06	1.45	26.07%	2.00	6.00	7.00
1.A.4.b	Auditory and Speech Abilities	68	6.05	6.16	0.12	1.01	16.77%	2.00	6.00	7.00

	Year vs Year	Differences between 2038 - 2018								
	Ability	Answers	Mean[A]	Mean[B]	Dif Means	Deviation	CV	Min	Median	Max
1.A.4.b.1	Hearing Sensitivity	-	1.64	1.42	- 0.22	- 0.94	57.20%	3.00	1.50	-
1.A.4.b.2	Auditory Attention	-	2.00	2.00	-	- 0.87	43.68%	2.00	2.00	-
1.A.4.b.3	Sound Localization	-	1.92	1.73	- 0.19	- 0.80	41.58%	2.00	2.00	-
1.A.4.b.4	Speech Recognition	-	2.14	2.28	0.13	- 0.11	4.98%	3.00	2.00	2.00
1.A.4.b.5	Speech Clarity	-	1.79	1.87	0.09	- 0.13	7.01%	-	2.00	-
1.A.4.b	Auditory and Speech Abilities	-	1.90	1.86	0.01	- 0.54	28.63%	-	2.00	-

Table 43. Auditory and Speech Abilities Statistics

Hearing Sensitivity measures "the ability to detect or tell the differences between sounds that vary in pitch and loudness"[219]. Within the Auditory and Speech Abilities group, it was evaluated conjointly by the experts as the ability with the highest chances of being emulated by machines both in 2018, already situated in the above high range of the scale (mean = 4.57 and median = 4.50), and in 2038, in the high range (mean = 6.21, median = 6.00 and min = 5.00). According to experts, the sound analysis is quite evolved in current applications, as a consequence of traditional methods, such as the Fourier Series, and modern computational models and algorithms that are able to isolate tracks for better analysis and understanding. Artificial Intelligence has been introduced to this area and applied, for instance, in hearing aids, to improve people's experience with products

[218] O*NET Content Model Reference documentation (2019)
[219] O*NET Content Model Reference documentation (2019)

that can learn from the behavior and particularities of its user[220]. In spite of eventual noises and technical difficulties, this ability is not perceived by the experts as a complex capability to be emulated by Artificial Intelligence and related technologies in the near future. However, as in Vision Abilities, machines may be able to listen, but that does not mean they are able to hear and make sense of it.

The following abilities in the Auditory and Speech Abilities group are Auditory Attention, "the ability to focus on a single source of sound in the presence of other distracting sounds"[221] and Sound Localization, "the ability to tell the direction from which a sound originated"[222]. We evaluate these two aptitudes together since they have some interface that is detailed next. In 2018 both abilities were in the average range of the scale (mean = 4.15 and median = 4.00 for Auditory Attention; mean = 4.23 and median = 4.00 for Sound Location), and in 2038, both were in the high range (mean = 6.15, median = 6.00 and min = 4.00 for both). According to experts, Auditory Attention to machines is about being able to filter and separate the different sounds, tones, frequencies that are listened, but this approach has some limitations. More recently, solutions that combine hearing and vision have been able to improve the quality of separation by simply looking and focusing on the right individual[223]. This software has several restrictions but can be an important achievement for complementary approaches in the following years. For adequate results, this solution requires adequate interfaces with clear source identification capabilities. To perform Sound Localization, experts mentioned additional technologies in progress such as microphone matrixes. Overall, experts considered that adequate emulation of both abilities by Artificial Intelligence, Robotics, and related technologies is very likely in the near future.

The two last abilities in this group are related to Speech: Speech Recognition and Speech Clarity, that, according to experts, had the lowest chances of being emulated by AI, Robotics and related technologies both in 2018 and 2038. They were both assigned to the average range of the scale in 2018 (mean = 4.00 and median = 4.00 for Recognition; mean = 3.79 and median = 4.00 for Clarity). In 2038 they both increase their rates, moving to the high range (mean = 6.14, median = 6.00 and min. = 5.00 for Recognition; mean = 5.57, median = 6.00 and min = 2.00 for Clarity). Opinions about Speech Recognition were also the most homogeneous of the Auditory and Speech Abilities. Considering Speech Recognition description, which is "the ability to identify and understand the speech of another person"[224], experts recognize that there has been great progress in the last decades with chatbots and personal assistants that are good in transcribing what is said, such as Apple Siri, Amazon Alexa, and Echo or Google Assistant, improving the ability to interact with computers to a point of reaching human parity in conversational Speech Recognition[225]. There are still some mistakes, misunderstandings and several linguist variants that are complicated to deal, but again, the key missing part is understanding what was recognized[226]. Speech Clarity, "the ability to speak clearly so others can understand you" has been a challenge

[220] https://www.youtube.com/watch?v=CVFvI_DzRno
[221] O*NET Content Model Reference documentation (2019)
[222] O*NET Content Model Reference documentation (2019)
[223] https://www.youtube.com/watch?v=IFbVOcZFZys
[224] O*NET Content Model Reference documentation (2019)
[225] https://blogs.microsoft.com/ai/historic-achievement-microsoft-researchers-reach-human-parity-conversational-speech-recognition/
[226] https://www.youtube.com/watch?v=yxxRAHVtafI

for machines for a long time. Although it has improved in the last years[227], some experts claimed it still needs further developments that can enable computers to speak with a wider variance of intonations, accents, languages, etc, which are currently hard to achieve.

As a combined group, Auditory and Speech Abilities were evaluated as average in 2018 (mean = 4.15) and moved to high in 2038 (mean = 6.05), which means that experts believe these abilities will be executed and emulated in the next following years to a considerable extent. Researchers alert to the fact that there is still much work to be done, but remarkable progress has already been done, such as Google's virtual assistant emulating a human voice to book an appointment by phone[228]. Important to mention that these abilities are very connected to those in Verbal Abilities, Oral Comprehension and Written Comprehension, including with some overlap and deep integration.

6.4. Considerations, Limitations and Future Improvements

Based on the analysis from the previous sections, the first consideration worth mentioning is that all abilities, without exceptions, had their likelihood of being emulated by machines increased in the timeframe proposed. In other words, data from the survey confirmed that Artificial Intelligence, Robotics, and related technologies will all continue to advance, and in doing so, the complexity level of their applications will improve. The direct implication of this phenomena is that the possibility of having different technologies emulating more and better human abilities over the next twenty years will also increase significantly, which ties back to some of the comments of distinguished authors and leaders seen in previous chapters. Considering the current trend of innovations in these areas, this fact was already expected, but it turned into an alarming apprehension when statistics confirmed that the growth in the overall likelihood average was substantial, increasing almost 1.70 points in a scale that varies from 1 to 7, and widespread, affecting even those abilities considered bottlenecks in previous researches.

According to experts, Number Facility, Perceptual Speed, Time Sharing, Memorization, and Static Strength were the top 5 individual abilities rated as very likely to be emulated by Artificial Intelligence, Robotics, and related technologies in 20 years. Actually, considering the combined opinions of the specialists, some of these abilities could already be adequately emulated by machines in 2018 – they were also rated as very likely in that year. Considering ability groups, which are groups of related abilities from O*NET, Memory, Attentiveness, and Perceptual Abilities were rated as the top 3 in terms of emulation likelihood. Despite some heterogeneity in the opinions, these were considered as acceptable results.

In practical terms, the interpretation of the results is that individual abilities that were marked by the specialists as very likely to be emulated could partially use machines and thus replace humans in occupations that require or are highly dependable of them. Partially is an important word in this observation because, as seen in Chapter 5,

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[227] https://www.youtube.com/watch?v=wQjTgvUEOrY
[228] https://www.theguardian.com/technology/video/2018/may/09/new-google-assistant-mimics-human-voice-video

an occupation is comprised of a combination of several competencies, which means that replacement is more complex than it seems. In other words, no matter how advanced technology might be in Number Facility, for instance, it will take more than that for machines to successfully replace human Mathematical Technicians – the occupation in O*NET where this ability is more relevant.

On the other hand, Originality, Written Expression, Oral Comprehension, Gross Body Coordination and Fluency of Ideas were the bottom 5 individual abilities in 2038, which means that in the combined opinion of the experts, these abilities were evaluated as the less likely of being emulated by Artificial Intelligence, Robotics, and related technologies in twenty years. In spite of being the lower abilities, they were all in the average and above average ranges of the scale, confirming the previous observation that technologies will progress in the next two decades impacting even those abilities. Considering ability groups, Verbal Abilities, Idea Generation and Reasoning Abilities and Flexibility, Balance and Coordination Abilities were rated as the bottom 3 types in terms of emulation likelihood in 2038.

During the analysis, we noticed that the hard statistics were only a part of the picture. The qualitative data gathered in the survey, comprised of comments, justifications, and feedback from experts, was an additional source of information that allowed to cross-check the quantitative findings and, therefore, understand and interpret some of the results and the logics supporting them. It also showed that the figures should not be evaluated absolutely, but rather relatively among the abilities. This process of combining qualitative and quantitative data and make sense of it was not easy in the individual level, nor in the group level – conclusions by ability types were a challenge because they combined abilities quite different and in opposite directions, like Originality, less likely, with Category Flexibility, more likely. Extrapolating this combined analysis to the major Ability Categories (Cognitive, Psychomotor, Physical and Sensory Abilities) was an initial objective, but no solid conclusions were yielded in that sense. For instance, we expected that Physical Abilities would show higher likeliness of being emulated than Cognitive, considering developments in Robotics, but according to experts, there are still several challenges to overcome.

By comparing findings from this survey with those from Frey & Osborne (2017), we also had some remarkable conclusions. First of all, based on the experts' opinions, Originality was the ability less likely to be adequately executed or emulated by Artificial Intelligence, Robotics, and related technologies. It is, therefore, confirmed as a bottleneck for computerization, confirming Frey & Osborne (2017)'s outcomes. In the opposite direction to these authors' observations, however, experts that participated in this survey did not perceive Manual Dexterity and Finger Dexterity as key bottlenecks for Artificial Intelligence, Robotics, and related technologies. Other abilities not mentioned by Frey & Osborne (2017)'s research did surface from the combined opinion analysis as bottlenecks, such as Written Expression, Oral Comprehension, Gross Body Coordination and Fluency of Ideas. Additionally, there were other abilities that, if not bottlenecks, could be evaluated as challenges to overcome in the next years. Considering the differences from this research to that of Frey & Osborne (2017)'s, we believe that complementary investigation on abilities bottlenecks would be an important effort.

Another important observation is that, based on the combined opinions, we can conjecture that specialists do not perceive technical plateaus that could indefinitely block technological progress to perform abilities – like happen to Artificial Intelligence in the past, as seen in Chapter 3. Bottlenecks and challenges may exist, as mentioned, but experts believe in new developments, approaches, and achievements to gradually overcome them. This could be partially explained by the enthusiastic bias of most of the respondents. However, there seems to be a non-technical plateau in the opinion of most of the experts, which is related to several capabilities that are intrinsically human, most of them intellectual. As much as machines could mimic abilities like Originality and Fluency of Ideas, for instance, according to experts they could never do it spontaneously, autonomously and adaptively as humans do. More than bottlenecks, these areas can be considered as indefinite barriers, corroborating the idea of the Narrow Artificial Intelligence.

Despite eventual disadvantages and inadequacy to the purpose of this research (negative feedback from one of the experts), we believe that leveraging O*NET's framework, definitions and even questionnaires worked as an accelerator and a powerful tool to achieve these conclusions. In our opinion, taking one step back and evaluating one of the building blocks of occupations (abilities), instead of the direct occupations like Frey and Osborne did, allowed us to have a more sensible and fair measure of the real susceptibility of occupations – seen in more detail in Chapter 7, even if limited to only one building block. Also, it allowed us to illustrate the complexity of this topic and to uncover an important construct in the occupation's discussion, which is integration. Technologies may emulate individual abilities to a higher extent, but more important than that is being able to harmonically combinate them and make them work together to achieve even basic tasks of occupations. This is hard for humans that want to be successful in their jobs, but it is a great challenge for machines, that still today are very specific in content and application. This integration challenge corroborates the fact that, as previously mentioned, no matter how advanced technology might be in a specific ability, it takes more than that for machines to successfully replace humans in occupation. Again, we believe that Frey & Osborne (2017) ignored this important bottleneck and oversimplified a very complex model – probably because O*NET itself is not concerned with the integration factor. Moreover, considering all the information abovementioned, we interpret this integration challenge as a confirmation and solidification of the complementary scenario and point of view mentioned in Chapter 3, where instead of complete replacement, we'll actually see the increase of symbiotic relationships between man and machines (either Artificial Intelligence, Robotics or any technology), a collaborative connection as illustrated by the Cobots[229].

An important lesson learned in this analytical process was that all conclusions, considerations, and interpretations derived from this survey should be taken with parsimony. They are based on a mediated combination of personal opinions, experiences, and impressions of what could happen in the future, and in that sense, cannot be confirmed and verified. Therefore, they should not be used indiscriminately as facts. We believe that this survey and its discussion collaborates with a complementary view from that of Frey and Osborne's recent study and, if not conclusive, it shows at least that further studies and alternative approaches are important to challenge the impactful conclusions from these authors. After all, the uneasiness mentioned at the beginning

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[229] https://www.forbes.com/sites/bernardmarr/2018/08/29/the-future-of-work-are-you-ready-for-smart-cobots/#abc9f97522b3

of this section and at the beginning of this work was gradually reduced taking into account all the interpretations mentioned so far. In spite of the increasing likelihoods, there are several indications that the future may not be so harsh as some believe. Instead, we see the increase of symbiotic relationships between humans and machines, a collaborative relationship where the best of each creates a powerful synergy in the marketplace. Finally, emulating individual abilities may be conceivable, but recreating the perfection intricacy of humans in machines, is a mission for gods or nature.

As part of scientific research, we understand that the abilities survey has some limitations, that directly or not affect its findings. Two limitations already mentioned are: (a) using only one of the building blocks of occupations model (abilities) for the analysis, which is also an oversimplification, and (b) considering only opinions from Brazilian experts, which may represent some bias. We list and detail other limitations and possible ideas to overcome them in future studies.

- Sample size: As previously stated, 14 participants answered the abilities survey, which obviously limited observations and interpretations. However, it was not the researchers' intention to have an inferential statistics study, nor to deduce population conclusions from this sample. Instead, we evaluated and combined the opinions of a particular group of experts considering the benefits of using a reduced but capable team of participants as part of a customized Delphi method.

- Expert's background: Despite the efforts to gather a mixed group of experts, there could be an eventual bias due to an unintentional inclination on the background. In spite of most of them having international experience, all participants that took part of the survey were from Brazil – so considerations are based on the knowledge of Brazilian experts. Additionally, the aim was to balance between scholar and market specialists, but the final ratio was 85% scholar vs 15% market. Also, another limitation was uncovered during the data analysis. Despite the fact that all of the specialists had a solid technical background in Computer Science, Mathematics, Engineering and were enthusiastic about the theme of the research, few had the full knowledge on all the diverse technologies required to evaluate if emulation of abilities was feasible or not. This is a weakness of the research, not of the experts. Artificial Intelligence and Robotics, just to name the two key areas of the study, are broad areas of knowledge. In that sense, the sample could have been complemented by Robotics experts – as shown by the statistics, abilities related to Robotics had higher heterogeneity in the opinions (lower quality, maybe), an effect of the different levels of knowledge in that topic.

- Questionnaire size: The size and duration of the questionnaire was also an issue that had implications. Replying a long-form with four questions (rating in 2018, rating in 2038, justification and competence) per each of the 52 abilities took more around 90 minutes to answer and some claimed even more. This demanded a high level of concentration, commitment, and interest from experts, which cannot be granted and affects the instrument reliability. Therefore, the instrument could have affected the quality and consistency of opinions. Besides, since justifications and competence levels were optional, several experts did not share that information. The direct consequences were that the qualitative analysis was not as rich as could be and also that the weighted mean, an alternative solution to balance the opinions from those with higher confidence and knowledge, was not reliable enough to be used with consistency.

- Abilities definitions: As explained in Chapter 5, we decided to leverage O*NET's framework and questionnaire, including abilities definitions. In spite of sharing them, experts commented that several abilities seemed to measure very similar aptitudes, having a hard time to distinguish them, especially when answering from a machine perspective (like the four types of strength available). This was also noted in the analysis performed by the authors of this research. Besides this issue, experts mentioned that some abilities were hard to evaluate because they were focused on intrinsic capabilities to biological beings, like stamina, which do not make much sense for machines – endurance, for instance, is one of the undisputed capabilities from machines. Also, according to one of the experts, some questions required more information than shared to decide and mixed different things that were not necessarily Artificial Intelligence and Robotics topics. According to this panelist, the questionnaire had several technical and also scientific limitations that could jeopardize later conclusions derived from the answers. Considering these issues, two specialists shared their discontent in replying a survey they understood was not fit for the purpose of the research. But they did it anyway.

- Abilities anchors: We also used the complexity anchors and scales from O*NET to help experts in understanding what the ability was about and how technology could emulate it. However, in some cases, it had the opposite effect, because some scales confused participants even more. That happened because anchors from the complexity scales presented can be completely different for Artificial Intelligence, Robotics, and related technologies. In other words, something that is complex to humans, like finding an unhidden pattern in a dataset, can be trivial to machines, and vice versa. This contributes to the previous limitation, clearly indicating that using the questionnaire focused on humans and how they perform the abilities had some disadvantages.

- Combining opinions: The overall results were obtained thru a process of combining opinions, using mathematical indicators such as means and medians and complementing them with interpretations of the qualitative data gathered. In the course of this analysis, we faced situations were experts could have quite distinct positions, but the combined opinions created a forced consensus that some may argue, does not represent either of the opinions collected. We tried to indicate this disagreement thru the homogeneity discussion using standard deviation and coefficient of variation. Ideally, this part of the research should also have undergone thru the interactive feedback processes of Delphi to reach a true consensus, but this was not possible due to time constraints.

To overcome some of the limitations previously mentioned, we provide some suggestions for improvements or future complementary studies to this one. Future researches should increase the number of participants and background to ensure a broader group of experts and a richer discussion, evaluating opinions of experts from other countries and from other areas, technical (like Robotics) and non-technical (like Business and Economy). Also, they should simplify the questionnaire and combine those abilities that have some overlap. To really ensure a combined view of the participants, a Delphi could be performed with further interaction and discussion. Finally, as mentioned, occupations are a combination of several components, abilities being one of them. In that sense, it would be important for a more comprehensive view on the susceptibility matter (which is covered in Chapter 7) to evaluate types of skills and other O*NET variables. We also believe that more studies using different approaches should be proposed, tested and analyzed in other to continue to evaluate either Frey & Osborne (2017)'s and this research findings and conclusions.

7. Occupation Susceptibility Analysis

Based on the outputs from Chapter 6, where the impacts of technology in abilities were evaluated, we now focus on the occupational analysis, designing and discussing occupational susceptibility rankings, similar to that of Frey & Osborne (2017). First, we share our preliminary considerations, including the basic preparations for the calculations. Then, we present two different rankings of susceptibility, detailing how the results were achieved as we gradually improve them in seeking for what we believe is a better representation of reality and context. We also compare our findings to those of Frey & Osborne (2017) and finally, we use one of the rankings to evaluate the overall impact of Artificial Intelligence, Robotics, and related technologies in the U.S. job market. In the final section of this chapter, we present key considerations, conclusions, and limitations.

7.1. Preliminary Considerations

The Ability Survey had as its key objective to evaluate the likelihood of capabilities being properly emulated by Artificial Intelligence, Robotics, and related technologies, currently and in twenty years from now. With this data, we can now try to fulfill one more goal of this research, which is to generate alternative occupation susceptibility rankings, comparable to that from Frey & Osborne (2017) and, if possible, evaluate the impact on the job market, as these authors did. Since we use Frey & Osborne (2017)'s research as a reference, it is important to state that we consider Computerization and Automatization, words used by the authors in their work, the process in which abilities can be emulated, performed or replaced by Artificial Intelligence, Robotics, and related technologies.

In the following sections, we present, analyze and discuss these alternative rankings, we compare the procedures, logics, and results. We first start with the preliminary considerations, which are focused on understanding the data and preparing it for further calculations, as well as, detailing the preparatory discussions and decisions.

Based on the analysis done in Chapter 6, we managed to build Table 44 and Table 45 which summarize the findings of the ability survey ran with the experts. Basically, these lists depict to what extent or complexity level experts believe that Artificial Intelligence, Robotics, and related technologies are and will be able to emulate abilities, that is, perform as good as humans do. If able to execute abilities in those levels of complexity, indirectly and without considering external factors, we can derive that it also illustrates the likelihood of the ability being executed by machines, therefore, replacing humans. Thus Table 44 presents the 2018 state, while Table 45 the 2038 state.

2018	Ability	Mean^	Mean^ Std	2018	Ability	Mean^	Mean^ Std
		1 - 7	0 - 100			1 - 7	0 - 100
1.A.1.a.1	Oral Comprehension	2.64	27.38	1.A.2.b.3	Response Orientation	4.07	51.19
1.A.1.a.2	Written Comprehension	3.43	40.48	1.A.2.b.4	Rate Control	3.79	46.43
1.A.1.a.3	Oral Expression	3.64	44.05	1.A.2.c.1	Reaction Time	4.36	55.95
1.A.1.a.4	Written Expression	3.00	33.33	1.A.2.c.2	Wrist-Finger Speed	3.50	41.67
1.A.1.b.1	Fluency of Ideas	3.36	39.29	1.A.2.c.3	Speed of Limb Movement	3.86	47.62
1.A.1.b.2	Originality	1.62	10.26	1.A.3.a.1	Static Strength	5.57	76.19
1.A.1.b.3	Problem Sensitivity	3.21	36.90	1.A.3.a.2	Explosive Strength	3.79	46.43
1.A.1.b.4	Deductive Reasoning	4.07	51.19	1.A.3.a.3	Dynamic Strength	4.43	57.14
1.A.1.b.5	Inductive Reasoning	3.86	47.62	1.A.3.a.4	Trunk Strength	4.50	58.33
1.A.1.b.6	Information Ordering	4.43	57.14	1.A.3.b.1	Stamina	5.14	69.05
1.A.1.b.7	Category Flexibility	4.64	60.71	1.A.3.c.1	Extent Flexibility	3.93	48.81
1.A.1.c.1	Mathematical Reasoning	4.21	53.57	1.A.3.c.2	Dynamic Flexibility	3.36	39.29
1.A.1.c.2	Number Facility	6.23	87.18	1.A.3.c.3	Gross Body Coordination	2.86	30.95
1.A.1.d.1	Memorization	5.77	79.49	1.A.3.c.4	Gross Body Equilibrium	3.14	35.71
1.A.1.e.1	Speed of Closure	4.43	57.14	1.A.4.a.1	Near Vision	5.14	69.05
1.A.1.e.2	Flexibility of Closure	4.36	55.95	1.A.4.a.2	Far Vision	5.29	71.43
1.A.1.e.3	Perceptual Speed	5.57	76.19	1.A.4.a.3	Visual Color Discrimination	4.57	59.52
1.A.1.f.1	Spatial Orientation	4.64	60.71	1.A.4.a.4	Night Vision	4.57	59.52
1.A.1.f.2	Visualization	4.07	51.19	1.A.4.a.5	Peripheral Vision	4.71	61.90
1.A.1.g.1	Selective Attention	5.71	78.57	1.A.4.a.6	Depth Perception	4.46	57.69
1.A.1.g.2	Time Sharing	5.08	67.95	1.A.4.a.7	Glare Sensitivity	4.21	53.57
1.A.2.a.1	Arm-Hand Steadiness	4.57	59.52	1.A.4.b.1	Hearing Sensitivity	4.57	59.52
1.A.2.a.2	Manual Dexterity	3.93	48.81	1.A.4.b.2	Auditory Attention	4.15	52.56
1.A.2.a.3	Finger Dexterity	3.71	45.24	1.A.4.b.3	Sound Localization	4.23	53.85
1.A.2.b.1	Control Precision	4.71	61.90	1.A.4.b.4	Speech Recognition	4.00	50.00
1.A.2.b.2	Multilimb Coordination	3.93	48.81	1.A.4.b.5	Speech Clarity	3.79	46.43

Table 44. Ability's Complexity Level Reached by Machines – 2018

2038	Ability	Mean^	Mean^ Std	2038	Ability	Mean^	Mean^ Std
		1 - 7	0 - 100			1 - 7	0 - 100
1.A.1.a.1	Oral Comprehension	4.93	65.48	1.A.2.b.3	Response Orientation	6.00	83.33
1.A.1.a.2	Written Comprehension	5.50	75.00	1.A.2.b.4	Rate Control	5.79	79.76
1.A.1.a.3	Oral Expression	5.36	72.62	1.A.2.c.1	Reaction Time	6.00	83.33
1.A.1.a.4	Written Expression	4.79	63.10	1.A.2.c.2	Wrist-Finger Speed	5.43	73.81
1.A.1.b.1	Fluency of Ideas	5.07	67.86	1.A.2.c.3	Speed of Limb Movement	5.43	73.81
1.A.1.b.2	Originality	3.92	48.72	1.A.3.a.1	Static Strength	6.71	95.24
1.A.1.b.3	Problem Sensitivity	5.14	69.05	1.A.3.a.2	Explosive Strength	5.93	82.14
1.A.1.b.4	Deductive Reasoning	5.71	78.57	1.A.3.a.3	Dynamic Strength	5.79	79.76
1.A.1.b.5	Inductive Reasoning	5.71	78.57	1.A.3.a.4	Trunk Strength	5.64	77.38
1.A.1.b.6	Information Ordering	5.86	80.95	1.A.3.b.1	Stamina	6.07	84.52
1.A.1.b.7	Category Flexibility	6.14	85.71	1.A.3.c.1	Extent Flexibility	5.64	77.38
1.A.1.c.1	Mathematical Reasoning	5.86	80.95	1.A.3.c.2	Dynamic Flexibility	5.29	71.43
1.A.1.c.2	Number Facility	6.92	98.72	1.A.3.c.3	Gross Body Coordination	5.00	66.67
1.A.1.d.1	Memorization	6.77	96.15	1.A.3.c.4	Gross Body Equilibrium	5.57	76.19
1.A.1.e.1	Speed of Closure	6.08	84.62	1.A.4.a.1	Near Vision	6.36	89.29
1.A.1.e.2	Flexibility of Closure	6.36	89.29	1.A.4.a.2	Far Vision	6.71	95.24
1.A.1.e.3	Perceptual Speed	6.86	97.62	1.A.4.a.3	Visual Color Discrimination	6.14	85.71
1.A.1.f.1	Spatial Orientation	6.36	89.29	1.A.4.a.4	Night Vision	6.07	84.52
1.A.1.f.2	Visualization	5.54	75.64	1.A.4.a.5	Peripheral Vision	6.14	85.71
1.A.1.g.1	Selective Attention	6.57	92.86	1.A.4.a.6	Depth Perception	6.15	85.90
1.A.1.g.2	Time Sharing	6.83	97.22	1.A.4.a.7	Glare Sensitivity	5.79	79.76
1.A.2.a.1	Arm-Hand Steadiness	6.07	84.52	1.A.4.b.1	Hearing Sensitivity	6.21	86.90
1.A.2.a.2	Manual Dexterity	5.79	79.76	1.A.4.b.2	Auditory Attention	6.15	85.90
1.A.2.a.3	Finger Dexterity	5.64	77.38	1.A.4.b.3	Sound Localization	6.15	85.90
1.A.2.b.1	Control Precision	6.21	86.90	1.A.4.b.4	Speech Recognition	6.14	85.71
1.A.2.b.2	Multilimb Coordination	6.07	84.52	1.A.4.b.5	Speech Clarity	5.57	76.19

Table 45. Ability's Complexity Level Reached by Machines – 2038

As previously justified, the chosen database to perform all calculations was O*NET's abilities database, which was used in its version 23.1 with latest updates from March 2018[230]. This database considers both the Level and Importance scales for each of one of 52 abilities and for each one of the 967 occupations available, complemented with statistics on these scales (such as standard error, sample size, etc.)[231]. Before using the database, we had to perform some checks and simple treatments in the data, which are explained next.

- The total number of entries in the database was 100,568, half of them are Level values (and additional statistics) and the other half are Importance values, thus, 50,284 entries each. When the total number of entries for each scale was divided by the number of abilities (52), the resulting value was the 967 occupations expected (967 occupations * 52 abilities * 2 variables = 100,568).

- According to O*NET, the Importance scale varies from 1-5[232], with 1 meaning that the ability is not relevant at all for the occupation and 5, extremely relevant. The general rule is that if Importance is 1, Level values should all be zero (or blank). The rule was partially verified, the only exception was Mathematical Technicians. In spite of having 14 abilities marked as non-relevant, they all had values for the Level scale. Since these abilities are not relevant, they were ignored.

- Also, according to O*NET, the Level scale varies from 0-7[233]. The general rule is that if Level is 0 (or blank), Importance values should all be 1 (not relevant). The rule was fully verified, and no exceptions were found, thus no treatment was required.

- In O*NET's questionnaire, the Level scale and its anchors varied from 1-7, and so did our findings from the experts' survey explained in Chapter 6. However, in the database, values from the Level scale varied from 0-7 – more precisely, between 0.12 and 6.38. This was an unexpected issue that required treatment. O*NET itself provided the solution for this problem with the standardized scores approach, explained next.

- According to O*NET, since different scales could have different ranges of possible scores, to make reports more intuitive and understandable to users, descriptor average ratings are standardized to a scale ranging from 0 to 100. The equation used by O*NET for converting original ratings to standardized scores is $S = ((O - L) / (H - L)) * 100$, where O is the original rating score on the scales, L is the lowest possible score on the rating scale used, and H is the highest possible score on the rating scale used. Performing such transformation in this research to all values ensures that variables are measured in the same scale (from 0 to 100), making it easier to compare the information.

[230] https://www.onetcenter.org/database.html#overview
[231] https://www.onetcenter.org/dictionary/23.1/excel/abilities.html
[232] https://www.onetonline.org/help/online/scales
[233] https://www.onetonline.org/help/online/scales

- Therefore, such conversion was executed to the ratings in the final lists of the ability's complexity level reached by machines from Chapter 6, depicted in Table 44 and Table 45, where Mean^{A} is the level in the original scale (from 1 to 7) and Mean^{A} Std (from 0 to 100) is the result of the standardization. It was also executed to all of the values in the O*NET database (both Level and Importance scales) as illustrated in Table 46, using Chief Executives occupation as a sample, where Level and Importance are in the original scale (from 0 to 7 and 1 to 5, respectively) and Level Std and Importance Std are the results of standardization (from 0 to 100). Two cases were chosen randomly, Surgeons[234] and Economists[235] were used to validate the transformation and were successfully confirmed – we crosschecked the details presented in the webpage with the results of the calculation using the figures available in the database. From this point on, we use only the standardized scores.

SOC Code	Occupation	Ability	Level	Level Std	Import.	Import. Std
			0 - 7	0 - 100	1 - 5	0 - 100
11-1011.00	Chief Executives	Oral Comprehension	4.88	69.71	4.50	87.50
11-1011.00	Chief Executives	Written Comprehension	4.62	66.00	4.25	81.25
11-1011.00	Chief Executives	Oral Expression	5.00	71.43	4.38	84.50
11-1011.00	Chief Executives	Written Expression	4.62	66.00	4.12	78.00
11-1011.00	Chief Executives	Fluency of Ideas	4.62	66.00	3.88	72.00
11-1011.00	Chief Executives	Originality	4.25	60.71	3.88	72.00
11-1011.00	Chief Executives	Problem Sensitivity	5.00	71.43	4.00	75.00
11-1011.00	Chief Executives	Deductive Reasoning	5.00	71.43	4.12	78.00
11-1011.00	Chief Executives	Inductive Reasoning	5.00	71.43	4.00	75.00
11-1011.00	Chief Executives	Information Ordering	4.00	57.14	3.62	65.50
11-1011.00	Chief Executives	Category Flexibility	4.12	58.86	3.50	62.50
11-1011.00	Chief Executives	Mathematical Reasoning	3.88	55.43	3.38	59.50
11-1011.00	Chief Executives	Number Facility	4.12	58.86	3.25	56.25
11-1011.00	Chief Executives	Memorization	3.12	44.57	3.00	50.00
11-1011.00	Chief Executives	Speed of Closure	3.38	48.29	3.12	53.00
11-1011.00	Chief Executives	Flexibility of Closure	3.50	50.00	3.38	59.50
11-1011.00	Chief Executives	Perceptual Speed	2.88	41.14	3.12	53.00
11-1011.00	Chief Executives	Spatial Orientation	0.12	1.71	1.12	3.00
11-1011.00	Chief Executives	Visualization	3.88	55.43	3.12	53.00
11-1011.00	Chief Executives	Selective Attention	3.12	44.57	3.00	50.00
11-1011.00	Chief Executives	Time Sharing	2.88	41.14	3.00	50.00
11-1011.00	Chief Executives	Finger Dexterity	2.00	28.57	2.25	31.25
11-1011.00	Chief Executives	Control Precision	1.12	16.00	1.75	18.75
11-1011.00	Chief Executives	Multilimb Coordination	0.88	12.57	1.75	18.75
11-1011.00	Chief Executives	Near Vision	4.50	64.29	3.88	72.00
11-1011.00	Chief Executives	Far Vision	3.12	44.57	3.00	50.00
11-1011.00	Chief Executives	Visual Color Discrimination	1.62	23.14	1.88	22.00
11-1011.00	Chief Executives	Depth Perception	1.50	21.43	1.75	18.75
11-1011.00	Chief Executives	Hearing Sensitivity	1.50	21.43	1.75	18.75
11-1011.00	Chief Executives	Auditory Attention	2.12	30.29	2.12	28.00
11-1011.00	Chief Executives	Speech Recognition	4.62	66.00	4.12	78.00
11-1011.00	Chief Executives	Speech Clarity	4.88	69.71	4.12	78.00

Table 46. Score Standardization for Level and Importance

Once the basic checks and treatments were performed, we moved to set up the essential calculations for testing the rankings. An explanation of the calculations comes next.

- As mentioned in Chapter 5, Frey & Osborne (2017)'s ranking did not consider in its development the Importance scale. In our research, Importance plays a major role from the start, so the initial step was to create the Level vs Importance variable, which is the simple product of the two standardized scores for

[234] https://www.onetonline.org/link/details/29-1067.00#Abilities
[235] https://www.onetonline.org/link/details/19-3011.00#Abilities

each of the abilities and each of the occupations, column L*I in Table 47. The minimum is 0 (the lowest level possible, 0, multiplied by the lowest importance possible, 0) and the maximum is 10,000 (the highest level possible, 100, multiplied by the highest importance possible, 100). This action ensured that the Level scale was properly qualified and weighted according to the relevance of each ability for each occupation.

SOC Code	Occupation	Ability	Level Std	Import. Std	L*I Std
			0 - 100	0 - 100	0 - 10,000
11-1011.00	Chief Executives	Oral Comprehension	69.71	87.50	6,100.00
11-1011.00	Chief Executives	Written Comprehension	66.00	81.25	5,362.50
11-1011.00	Chief Executives	Oral Expression	71.43	84.50	6,035.71
11-1011.00	Chief Executives	Written Expression	66.00	78.00	5,148.00
11-1011.00	Chief Executives	Fluency of Ideas	66.00	72.00	4,752.00
11-1011.00	Chief Executives	Originality	60.71	72.00	4,371.43
11-1011.00	Chief Executives	Problem Sensitivity	71.43	75.00	5,357.14
11-1011.00	Chief Executives	Deductive Reasoning	71.43	78.00	5,571.43
11-1011.00	Chief Executives	Inductive Reasoning	71.43	75.00	5,357.14
11-1011.00	Chief Executives	Information Ordering	57.14	65.50	3,742.86
11-1011.00	Chief Executives	Category Flexibility	58.86	62.50	3,678.57
11-1011.00	Chief Executives	Mathematical Reasoning	55.43	59.50	3,298.00
11-1011.00	Chief Executives	Number Facility	58.86	56.25	3,310.71
11-1011.00	Chief Executives	Memorization	44.57	50.00	2,228.57
11-1011.00	Chief Executives	Speed of Closure	48.29	53.00	2,559.14
11-1011.00	Chief Executives	Flexibility of Closure	50.00	59.50	2,975.00
11-1011.00	Chief Executives	Perceptual Speed	41.14	53.00	2,180.57
11-1011.00	Chief Executives	Spatial Orientation	1.71	3.00	5.14
11-1011.00	Chief Executives	Visualization	55.43	53.00	2,937.71
11-1011.00	Chief Executives	Selective Attention	44.57	50.00	2,228.57
11-1011.00	Chief Executives	Time Sharing	41.14	50.00	2,057.14
11-1011.00	Chief Executives	Finger Dexterity	28.57	31.25	892.86
11-1011.00	Chief Executives	Control Precision	16.00	18.75	300.00
11-1011.00	Chief Executives	Multilimb Coordination	12.57	18.75	235.71
11-1011.00	Chief Executives	Near Vision	64.29	72.00	4,628.57
11-1011.00	Chief Executives	Far Vision	44.57	50.00	2,228.57
11-1011.00	Chief Executives	Visual Color Discrimination	23.14	22.00	509.14
11-1011.00	Chief Executives	Depth Perception	21.43	18.75	401.79
11-1011.00	Chief Executives	Hearing Sensitivity	21.43	18.75	401.79
11-1011.00	Chief Executives	Auditory Attention	30.29	28.00	848.00
11-1011.00	Chief Executives	Speech Recognition	66.00	78.00	5,148.00
11-1011.00	Chief Executives	Speech Clarity	69.71	78.00	5,437.71

Table 47. Standardized Level * Importance Variable based on O*NET

- Next, we fetched the scores from the ability's complexity level reached by machines (column Mean^{A} Std) from Table 44 and Table 45. and used them as a reference. A simple Boolean logic was applied, comparing the level required of each ability with the experts' level, by occupation. Results are presented in Table 48. If the experts' score of complexity is higher than or equal to the level score required for a particular occupation, we assumed this ability can be emulated or performed by Artificial Intelligence, Robotics or related technologies – in this case, we flagged column If Std as a Yes (equals to 1.00). Chief Executive occupation, for instance, requires Category Flexibility at a level 58.86 and according to experts, this ability can be already emulated by machines up to level 60.71 – thus, this row is marked as Yes.

- On the other hand, if the experts' score of complexity is lower than the level score required for that particular occupation, we assumed that technology cannot emulate or perform the ability - in this other case, we flagged column If Std as a No (equals to 0.00). Chief Executive occupation requires Oral

Comprehension at a level 69.71, but according to experts, this ability cannot be emulated by machines in this level (only up to 27.38) – thus, this row is marked as No. Both cases are illustrated in Table 48.

SOC Code	Occupation	Ability	Level Std	Import. Std	L*I Std	Mean^ Std	If Std	AI L*I Std
			0 - 100	0 - 100	0 - 10,000	0 - 100	Y=1 / N=0	0 - 10,000
11-1011.00	Chief Executives	Oral Comprehension	69.71	87.50	6,100.00	27.38	-	-
11-1011.00	Chief Executives	Written Comprehension	66.00	81.25	5,362.50	40.48	-	-
11-1011.00	Chief Executives	Oral Expression	71.43	84.50	6,035.71	44.05	-	-
11-1011.00	Chief Executives	Written Expression	66.00	78.00	5,148.00	33.33	-	-
11-1011.00	Chief Executives	Fluency of Ideas	66.00	72.00	4,752.00	39.29	-	-
11-1011.00	Chief Executives	Originality	60.71	72.00	4,371.43	10.26	-	-
11-1011.00	Chief Executives	Problem Sensitivity	71.43	75.00	5,357.14	36.90	-	-
11-1011.00	Chief Executives	Deductive Reasoning	71.43	78.00	5,571.43	51.19	-	-
11-1011.00	Chief Executives	Inductive Reasoning	71.43	75.00	5,357.14	47.62	-	-
11-1011.00	Chief Executives	Information Ordering	57.14	65.50	3,742.86	57.14	1.00	3,742.86
11-1011.00	Chief Executives	Category Flexibility	58.86	62.50	3,678.57	60.71	1.00	3,678.57
11-1011.00	Chief Executives	Mathematical Reasoning	55.43	59.50	3,298.00	53.57	-	-
11-1011.00	Chief Executives	Number Facility	58.86	56.25	3,310.71	87.18	1.00	3,310.71
11-1011.00	Chief Executives	Memorization	44.57	50.00	2,228.57	79.49	1.00	2,228.57
11-1011.00	Chief Executives	Speed of Closure	48.29	53.00	2,559.14	57.14	1.00	2,559.14
11-1011.00	Chief Executives	Flexibility of Closure	50.00	59.50	2,975.00	55.95	1.00	2,975.00
11-1011.00	Chief Executives	Perceptual Speed	41.14	53.00	2,180.57	76.19	1.00	2,180.57
11-1011.00	Chief Executives	Spatial Orientation	1.71	3.00	5.14	60.71	1.00	5.14
11-1011.00	Chief Executives	Visualization	55.43	53.00	2,937.71	51.19	-	-
11-1011.00	Chief Executives	Selective Attention	44.57	50.00	2,228.57	78.57	1.00	2,228.57
11-1011.00	Chief Executives	Time Sharing	41.14	50.00	2,057.14	67.95	1.00	2,057.14
11-1011.00	Chief Executives	Finger Dexterity	28.57	31.25	892.86	45.24	1.00	892.86
11-1011.00	Chief Executives	Control Precision	16.00	18.75	300.00	61.90	1.00	300.00
11-1011.00	Chief Executives	Multilimb Coordination	12.57	18.75	235.71	48.81	1.00	235.71
11-1011.00	Chief Executives	Near Vision	64.29	72.00	4,628.57	69.05	1.00	4,628.57
11-1011.00	Chief Executives	Far Vision	44.57	50.00	2,228.57	71.43	1.00	2,228.57
11-1011.00	Chief Executives	Visual Color Discrimination	23.14	22.00	509.14	59.52	1.00	509.14
11-1011.00	Chief Executives	Depth Perception	21.43	18.75	401.79	57.69	1.00	401.79
11-1011.00	Chief Executives	Hearing Sensitivity	21.43	18.75	401.79	59.52	1.00	401.79
11-1011.00	Chief Executives	Auditory Attention	30.29	28.00	848.00	52.56	1.00	848.00
11-1011.00	Chief Executives	Speech Recognition	66.00	78.00	5,148.00	50.00	-	-
11-1011.00	Chief Executives	Speech Clarity	69.71	78.00	5,437.71	46.43	-	-

Table 48. Emulation Boolean Flag Results

- Considering this emulation Boolean flag, we calculated the product of the two standardized scores (Level and Importance) again into column AI L*I, but only for those abilities that were considered emulative (flag equal to Yes). This is illustrated in Table 48 in column AI L*I Std. As in the previous L*I Std variable, the minimum is 0 and the maximum is 10,000, since both work with the standardized scores.

- This procedure was executed for all 52 abilities of all the 967 occupations. It was done twice, considering the two states (2018 and 2038). For 2018, we used the ability's complexity level reached by machines in 2018 and for 2038, the analogous results in 2038. They were individually crosschecked against O*NET's database, which focus is based on the current situation – O*NET does not work with future scenarios. Executing calculations and rankings for 2018 gave us a baseline and reference to evaluate the outcomes, check their representativeness of reality and then eventually perform fine-tuning, if necessary.

7.2. Susceptibility Rankings

Once all the previous calculations were performed, we started exploring different susceptibility rankings for both states (2018 and 2038), increasing in complexity but also improving in terms of representativeness of situation and context. As previously mentioned, 2018 rankings were important to validate and calibrate the findings in 2038, so we present both in the following analysis.

Simple Standard Ranking

The first ranking explored, called Simple Standard Ranking (SSR), was based on a simple division of the sums of AI L*I Std (Level vs Importance multiplication with Emulation Flag Yes, meaning abilities covered by AI) by LxI Std (Level vs Importance multiplication, all abilities required) per occupation. By doing so, we were able to evaluate to what extent could Artificial Intelligence, Robotics, and related technologies perform each particular occupation. Indirectly, we assume that this percentage also describes the susceptibility of that particular occupation being replaced by technology – the higher the emulation percentage, the higher the susceptibility. Results for 2018 and 2038 are presented in the following tables, where we highlight the top 15 and bottom 15 ordered by susceptibility ranking.

SOC Code	Title	SOC Major Group	L*I Std	AI L*I Std	Susceptibility	Ranking
			0 - 520,000	0 - 520,000	0 - 100%	1 - 967
51-6021.00	Pressers, Textile, Garment, and Related Mater	51	52,075.29	50,611.00	97.19%	1
51-6041.00	Shoe and Leather Workers and Repairers	51	53,295.64	51,163.93	96.00%	2
51-3023.00	Slaughterers and Meat Packers	51	53,874.00	51,633.14	95.84%	3
53-7081.00	Refuse and Recyclable Material Collectors	53	76,715.39	73,504.68	95.81%	4
45-2041.00	Graders and Sorters, Agricultural Products	45	39,199.32	37,142.18	94.75%	5
35-2021.00	Food Preparation Workers	35	50,185.46	47,414.04	94.48%	6
51-9192.00	Cleaning, Washing, and Metal Pickling Equip	51	63,636.86	59,929.93	94.17%	7
53-7061.00	Cleaners of Vehicles and Equipment	53	46,841.96	43,881.25	93.68%	8
51-7041.00	Sawing Machine Setters, Operators, and Tend	51	75,030.61	70,152.04	93.50%	9
51-9198.00	Helpers--Production Workers	51	71,489.29	66,840.86	93.50%	10
51-4052.00	Pourers and Casters, Metal	51	79,077.96	73,567.25	93.03%	11
49-3022.00	Automotive Glass Installers and Repairers	49	67,458.50	62,722.79	92.98%	12
39-5093.00	Shampooers	39	43,132.57	40,102.43	92.97%	13
43-5053.00	Postal Service Mail Sorters, Processors, and P	43	64,165.43	59,642.00	92.95%	14
35-3021.00	Combined Food Preparation and Serving Wo	35	47,804.46	44,333.04	92.74%	15
…	…	…	…	…	…	…
17-1011.00	Architects, Except Landscape and Naval	17	108,227.46	35,064.75	32.40%	953
29-1067.00	Surgeons	29	137,364.54	44,458.96	32.37%	954
25-1064.00	Geography Teachers, Postsecondary	25	71,033.25	22,968.07	32.33%	955
25-1066.00	Psychology Teachers, Postsecondary	25	70,960.93	22,453.36	31.64%	956
25-1122.00	Communications Teachers, Postsecondary	25	67,823.25	21,312.32	31.42%	957
25-1081.00	Education Teachers, Postsecondary	25	68,730.86	21,476.14	31.25%	958
25-1113.00	Social Work Teachers, Postsecondary	25	71,310.29	22,162.29	31.08%	959
25-1124.00	Foreign Language and Literature Teachers, P	25	71,204.93	22,051.36	30.97%	960
19-3041.00	Sociologists	19	69,800.86	21,579.68	30.92%	961
25-1123.00	English Language and Literature Teachers, P	25	72,550.00	21,551.57	29.71%	962
29-1069.04	Neurologists	29	105,289.75	31,043.11	29.48%	963
25-1067.00	Sociology Teachers, Postsecondary	25	64,407.82	18,170.11	28.21%	964
19-2012.00	Physicists	19	126,569.29	35,444.71	28.00%	965
25-1112.00	Law Teachers, Postsecondary	25	73,785.71	20,602.00	27.92%	966
29-1069.09	Preventive Medicine Physicians	29	99,507.61	27,578.82	27.72%	967
Total			**82,289.39**	**50,718.65**	**62.09%**	

Table 49. Simple Standard Ranking (SSR) Scores – 2018

Similarly to findings in the abilities survey, Table 49 shows that resulting scores in 2018 for the Simple Standard Ranking were already quite high, with susceptibility index reaching a mean of 62.09% (std. deviation = 17.07%) and some positions already reaching susceptibilities scores close to 100.00%. Pressers, Textile, Garment, and Related Materials was the occupation with the highest susceptibility index, indicating that 97.19% of the abilities (considering their level of complexity and relevance) required by this occupation could be performed by the current state of technologies. In an opposite direction, Preventive Medicine Physicians was the occupation with the lower susceptibility index in 2018, indicating that only 27.72% of the abilities required by this occupation could be performed by the current state of technologies. Another similarity to previous observations is that, based on the figures, it is possible to say that all occupations would be affected (with more or less intensity) by these new technologies already in 2018, as demonstrated by the susceptibility in Preventive Medicine Physicians.

SOC Code	SOC Major Group	Total	Qty > 90%	% > 90%	Qty > 75%	% > 75%
11	Management Occupations	56	-	0.00%	-	0.00%
13	Business and Financial Operations Occupatio	50	-	0.00%	1	2.00%
15	Computer and Mathematical Occupations	33	-	0.00%	-	0.00%
17	Architecture and Engineering Occupations	70	-	0.00%	1	1.43%
19	Life, Physical, and Social Science Occupation	60	-	0.00%	-	0.00%
21	Community and Social Service Occupations	14	-	0.00%	-	0.00%
23	Legal Occupations	8	-	0.00%	-	0.00%
25	Educational Instruction and Library Occupati	60	-	0.00%	-	0.00%
27	Arts, Design, Entertainment, Sports, and Med	43	-	0.00%	1	2.33%
29	Healthcare Practitioners and Technical Occup	86	-	0.00%	2	2.33%
31	Healthcare Support Occupations	18	-	0.00%	8	44.44%
33	Protective Service Occupations	29	-	0.00%	4	13.79%
35	Food Preparation and Serving Related Occup	17	4	23.53%	14	82.35%
37	Building and Grounds Cleaning and Mainten	8	2	25.00%	7	87.50%
39	Personal Care and Service Occupations	32	2	6.25%	10	31.25%
41	Sales and Related Occupations	24	-	0.00%	3	12.50%
43	Office and Administrative Support Occupatio	63	1	1.59%	14	22.22%
45	Farming, Fishing, and Forestry Occupations	17	3	17.65%	12	70.59%
47	Construction and Extraction Occupations	61	3	4.92%	48	78.69%
49	Installation, Maintenance, and Repair Occupa	54	1	1.85%	22	40.74%
51	Production Occupations	111	15	13.51%	94	84.68%
53	Transportation and Material Moving Occupat	53	2	3.77%	31	58.49%
Total		**967**	**33**	**3.41%**	**272**	**28.13%**

Table 50. Highest Susceptibility by Major Group of Occupations – 2018

Table 50 illustrates which major groups of occupations[236] were more affected by Artificial Intelligence, Robotics, and related technologies in 2018. For those occupation groups with very high susceptibility (higher than 90%), Building and Grounds Cleaning and Maintenance (25.00%) and Food Preparation and Serving Related Occupations (23.53%), relatively, and Production Occupations (15), absolutely, were the most affected groups. For those with high susceptibility (higher than 75%), Building and Grounds Cleaning and Maintenance (87.50%), Production Occupations (84.68%) and Food Preparation and Serving Related Occupations (82.35%) were the most affected, and, overall 28.13% of occupations are in high range (higher than 75%). Based on these statistics, it is possible to interpret that occupations more labor-intensive seem to be more affected than those more intellectual intensive. Several occupations in Business, Management, Legal, Healthcare, Education, Arts, however, seem to be less affected by technologies in 2018 evaluation – occupations with a preponderant human /

[236] https://www.bls.gov/soc/2018/#classification

social factor, heavily dependable in characteristics such as creativity, empathy, and interaction. Another expected observation that was confirmed is that the more complex the occupations are – abilities with higher complexity requirements, the lesser technologies are able to emulate. L*I Std average of the top 15 (58,900) occupations is 30% less than the bottom 15 (85,200), and top 50 (65,500) is 23% less than the bottom 50 (85,000).

As expected, in 2038, statistics were even higher, but they moved to extreme results reaching an average index of 96.60% (std deviation = 6.61%) among all occupations, as shown in Table 51. Actually, 666 out of the 967 occupations (close to 2/3 of the total number) were marked as top 1, reaching 100.00% of susceptibility – meaning that all these occupations could be fairly emulated by Artificial Intelligence, Robotics, and related technologies in 2038. On the other side are Physicists, with a score of 60.03% – even the lowest occupation in terms of susceptibility has a significant score.

SOC Code	Title	SOC Major Group	L*I Std	AI L*I Std	Susceptibility	Ranking
			0 - 520,000	0 - 520,000	0 - 100%	1 - 967
11-1021.00	General and Operations Managers	11	72,402.68	72,402.68	100.00%	1
11-3011.00	Administrative Services Managers	11	71,970.14	71,970.14	100.00%	1
11-3031.01	Treasurers and Controllers	11	83,295.79	83,295.79	100.00%	1
11-3051.01	Quality Control Systems Managers	11	93,851.32	93,851.32	100.00%	1
11-3051.02	Geothermal Production Managers	11	88,397.11	88,397.11	100.00%	1
11-3051.06	Hydroelectric Production Managers	11	100,280.79	100,280.79	100.00%	1
11-3071.02	Storage and Distribution Managers	11	76,970.75	76,970.75	100.00%	1
11-3071.03	Logistics Managers	11	73,081.93	73,081.93	100.00%	1
11-3111.00	Compensation and Benefits Managers	11	58,938.86	58,938.86	100.00%	1
11-9013.01	Nursery and Greenhouse Managers	11	85,984.32	85,984.32	100.00%	1
11-9013.02	Farm and Ranch Managers	11	96,021.93	96,021.93	100.00%	1
11-9013.03	Aquacultural Managers	11	95,071.00	95,071.00	100.00%	1
11-9051.00	Food Service Managers	11	77,183.46	77,183.46	100.00%	1
11-9061.00	Funeral Service Managers	11	72,222.75	72,222.75	100.00%	1
11-9071.00	Gaming Managers	11	82,397.11	82,397.11	100.00%	1
…	…	…	…	…	…	…
29-1069.04	Neurologists	29	105,289.75	78,211.39	74.28%	953
19-1029.02	Molecular and Cellular Biologists	19	114,677.93	84,674.14	73.84%	954
25-1041.00	Agricultural Sciences Teachers, Postsecondary	25	80,881.29	59,577.71	73.66%	955
25-1054.00	Physics Teachers, Postsecondary	25	82,016.75	60,161.82	73.35%	956
25-1113.00	Social Work Teachers, Postsecondary	25	71,310.29	51,646.00	72.42%	957
25-1042.00	Biological Science Teachers, Postsecondary	25	77,437.07	55,994.89	72.31%	958
15-2021.00	Mathematicians	15	90,146.21	64,018.54	71.02%	959
29-1067.00	Surgeons	29	137,364.54	97,065.21	70.66%	960
29-1069.07	Pathologists	29	104,411.86	70,765.43	67.78%	961
29-1063.00	Internists, General	29	95,530.11	63,672.75	66.65%	962
29-1069.09	Preventive Medicine Physicians	29	99,507.61	65,227.04	65.55%	963
25-1011.00	Business Teachers, Postsecondary	25	75,683.50	49,587.07	65.52%	964
19-3039.01	Neuropsychologists and Clinical Neuropsych	19	104,881.96	68,617.68	65.42%	965
25-1112.00	Law Teachers, Postsecondary	25	73,785.71	45,858.93	62.15%	966
19-2012.00	Physicists	19	126,569.29	75,976.43	60.03%	967
Total			**82,289.39**	**79,270.78**	**96.60%**	

Table 51. Simple Standard Ranking (SSR) Scores – 2038

Not much can be said about the upper part of the ranking - within these 666 occupations we can find all types of professions: from workers, operators, attendants, and technicians to engineers, managers, and executives. However, when we evaluate which occupations were less affected with the help of Table 52, we clearly note that Life, Physical, and Social Science Occupations (55.00%), Educational Instruction and Library Occupations (55.00%), Legal Occupations (50.00%), followed by Healthcare Practitioners and Technical Occupations (38.37%), Community and Social Service Occupations (21.43%), Architecture and Engineering Occupations (20.00%), Computer and Mathematical Occupations (18.18%) and Management Occupations (14.29%) are the groups with more occupations that would still need humans to be performed, more difficult to be entirely replaced by machines. Again, it is possible to interpret that more labor-intensive occupations seem to be more affected, while occupations with a preponderant human and social factor, heavily dependable in characteristics such as creativity, empathy, and interaction are less.

SOC Code	SOC Major Group	Total	Qty < 75%	% < 75%	Qty < 90%	% < 90%
11	Management Occupations	56	-	0.00%	8	14.29%
13	Business and Financial Operations Occupatior	50	-	0.00%	3	6.00%
15	Computer and Mathematical Occupations	33	1	3.03%	6	18.18%
17	Architecture and Engineering Occupations	70	-	0.00%	14	20.00%
19	Life, Physical, and Social Science Occupation	60	3	5.00%	33	55.00%
21	Community and Social Service Occupations	14	-	0.00%	3	21.43%
23	Legal Occupations	8	-	0.00%	4	50.00%
25	Educational Instruction and Library Occupati	60	7	11.67%	33	55.00%
27	Arts, Design, Entertainment, Sports, and Med	43	-	0.00%	3	6.98%
29	Healthcare Practitioners and Technical Occup	86	5	5.81%	33	38.37%
31	Healthcare Support Occupations	18	-	0.00%	-	0.00%
33	Protective Service Occupations	29	-	0.00%	1	3.45%
35	Food Preparation and Serving Related Occupa	17	-	0.00%	-	0.00%
37	Building and Grounds Cleaning and Maintena	8	-	0.00%	-	0.00%
39	Personal Care and Service Occupations	32	-	0.00%	-	0.00%
41	Sales and Related Occupations	24	-	0.00%	-	0.00%
43	Office and Administrative Support Occupatio	63	-	0.00%	-	0.00%
45	Farming, Fishing, and Forestry Occupations	17	-	0.00%	-	0.00%
47	Construction and Extraction Occupations	61	-	0.00%	-	0.00%
49	Installation, Maintenance, and Repair Occupa	54	-	0.00%	-	0.00%
51	Production Occupations	111	-	0.00%	-	0.00%
53	Transportation and Material Moving Occupat	53	-	0.00%	-	0.00%
Total		**967**	**16**	**1.65%**	**141**	**14.58%**

Table 52. Lowest Susceptibility by Major Group of Occupations – 2038

On first sight, results were again quite alarming and the differences in behavior between 2018 and 2038 were significant, as shown in Figure 12.

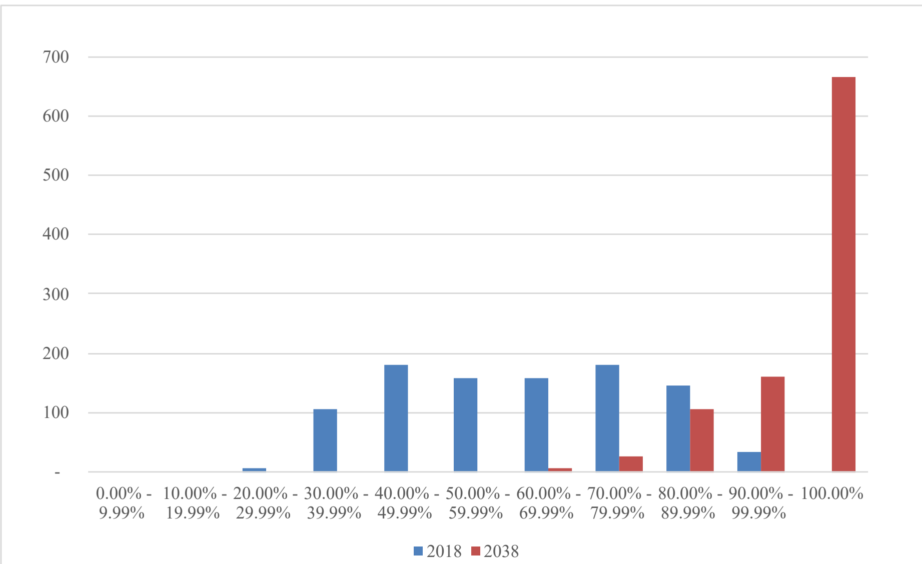

Figure 12. Simple Standard Ranking Comparison – 2018 vs 2038

However, these outcomes are a direct consequence of the equally high evaluation performed by experts on the ability survey. Recalling the overall results, most of the abilities in 2038 were conjointly classified in the high range (mean = 5.88 and median = 6.00), meaning that in the combined opinion of the experts in regard to 2038, abilities would be emulated to a high extent from a complexity point of view by Artificial Intelligence, Robotics, and related technologies.

When checking for the bottlenecks applied into the occupation context, that is, considering the complexity requirements, Originality, Oral Comprehension, and Written Comprehension were confirmed as the top 3 bottlenecks, in line with the findings from Chapter 6. Table 53 confirms this statement. Taking Originality as an example, all 967 available occupations require this ability in a higher or lesser level. Based on the combined opinion of experts, Originality could be emulated in 2018 up to a level 1.62 (out of 7.00) by Artificial Intelligence, Robotics, and related technologies. Considering the level required of Originality among the 967 occupations, machines would not be able to perform the minimum requirements in 965 of them (or 99.79% of the occupations). Likewise, Originality could be emulated in 2038 up to a level 3.92 (out of 7.00). Considering the level required of Originality among the 967 occupations, the future level of Artificial Intelligence, Robotics, and related technologies would not be able to emulate 251 (or 25.96% of the occupations).

Ability	Total	Required	No Emul '18	%	No Emul '38	%
Originality	967	967	965	99.79%	251	25.96%
Oral Comprehension	967	967	967	100.00%	164	16.96%
Written Expression	967	967	826	85.42%	117	12.10%
Problem Sensitivity	967	967	937	96.90%	48	4.96%
Oral Expression	967	967	824	85.21%	27	2.79%
Inductive Reasoning	967	967	505	52.22%	5	0.52%
Written Comprehension	967	967	864	89.35%	4	0.41%
Mathematical Reasoning	967	964	95	9.85%	3	0.31%
Fluency of Ideas	967	967	598	61.84%	2	0.21%
Speech Clarity	967	967	386	39.92%	2	0.21%
Gross Body Coordination	967	664	195	29.37%	2	0.30%
Finger Dexterity	967	965	182	18.86%	1	0.10%
Manual Dexterity	967	866	62	7.16%	1	0.12%
Deductive Reasoning	967	967	493	50.98%	-	0.00%
Speech Recognition	967	967	292	30.20%	-	0.00%
Visualization	967	967	171	17.68%	-	0.00%
Multilimb Coordination	967	779	80	10.27%	-	0.00%
Extent Flexibility	967	679	79	11.63%	-	0.00%
Gross Body Equilibrium	967	648	71	10.96%	-	0.00%

Table 53. Abilities Not Emulated in 2018 and 2038

There are several explanations for these extremely high results. First, which was negative feedback from some experts that replied to the survey, could be that the instrument used was not fit for this type of research or for the problem at hand. In other words, eventual difficulties and misunderstandings about the questionnaire, including O*NET's definitions and anchors, but also about the size, method, and research itself could have pushed these high results. Second, could be that experts showed more enthusiasm about technologies or more pessimism about the future of occupations than we anticipated, besides the other limitations already mentioned in Chapter 6 about knowledge of a wide variety of technologies. As a matter of fact, the questionnaire had a query to test experts' position towards technology and most of them (8 out of 14) said that they were favorable or enthusiasts of Artificial Intelligence, Robotics, and related technologies, meaning that they believed there are few barriers that hinder these technologies of emulating human abilities. Third possible explanation is that since this research is a simplification of a very complex problem, an experimental trial with its focus on the technical variables, it does not take into account several other important exogenous variables that would have a lessening effect, such as social, economic and political bottlenecks yet to be unfold – these are evaluated in Chapter 0. Forth is that this evaluation considers only the outcome of emulating isolated abilities but does not cover the remaining occupation descriptors, nor integration challenge exposed in Chapter 6. As mentioned, an occupation is more about combining the different abilities in synergy, than performing individual abilities.

Actually, after some thought, we conclude that the inflated outcomes in this first ranking are a combination of these four explanations, and probably others not uncovered. Moreover, we believe 2018 figures are a confirmation of these outcomes because scores were already very high in that year, and yet, none of the occupations in top 15 has been replaced by machines nor is close of being so. Therefore, we believe that the Simple Standard Ranking (both 2018 and 2038) does not fit the reality both current and future and adjustments are required wherever possible. We evaluate next, how to manage at least the integration challenge since the other factors are more complex to manage and overcome.

Integration Enhanced Ranking

As previously mentioned, technologies may emulate individual abilities to a higher extent, but more important than that is being able to harmonically combine them and make them work together with synergy to achieve even basic tasks of occupations. This is hard for humans that want to be successful in their jobs, but it is a great challenge for machines, that still today are very specific in content and application. This integration challenge corroborates the fact that, no matter how advanced technology might be in a specific ability, it takes more than that for machines to successfully replace humans in an occupation. As mentioned by several experts in the Delphi research, which is covered in Chapter 0, machines are very specialized in specific tasks or abilities, in some cases overpowering their human counterparts, as for instance, in Pattern Recognition of hidden datasets. However, integrating this capability with Oral Expression and Manual Dexterity, that are also performed by machines, demands a higher level of development that cannot be seen in the current state – and for all that is known, will also be challenging in twenty years from now.

We understand, thus, that the integration of these different technologies to perform occupations is an essential variable in the discussion and that it has been overlooked. Thus, we understand that to overcome this downside, based on the integration complexity of abilities within an occupation, a reduction factor should be defined, designed and combined in the rankings, however complex this task may be.

To define the Integration Reduction Factor, the first decision was determining the inputs. Based on findings from previous chapters and sections, we believe that integration complexity is dependable of the number of abilities and/or abilities types required by an occupation. Hence, if an occupation requires 29 abilities or 10 abilities types, it is fair to assume that this profession is less complex to integrate than another that requires all 52 abilities and 15 abilities types, no matter the complexity level on each case. Therefore, two additional calculations were performed in the database to support the next steps: for each occupation, we checked the total amount of distinct abilities required to perform it (from 0 up to 52) and the total amount of distinct ability types required to perform it (from 0 up to 15).

Table 54 illustrates the database with these two new variables. Robotics Technicians, Dancers, Recreational Therapists, and 227 other occupations are very complex in terms of integration – they require all 52 abilities and 15 types of abilities working together in harmony. On the other hand, Climate Change Analysts, Counseling Psychologists, and Investment Fund Managers are less complex in terms of integration. At this point, an important consideration is needed. These indicators reflect the complexity of the integration of the abilities and ability types, not how complex an occupation is. In other words, these results do not mean that Climate Change Analysts, Counseling Psychologists and Investment Fund Managers are easy professions – this is measured by the Level scale in combination with the relevance. They only have fewer abilities to integrate.

SOC Code	Title	SOC Major Group	Abilities	Abilities Std	Types	Types Std
			0 - 52	0 - 100	0 - 15	0 - 100
11-3051.02	Geothermal Production Managers	11	52	100.00	15	100.00
17-3024.01	Robotics Technicians	17	52	100.00	15	100.00
17-3029.01	Non-Destructive Testing Specialists	17	52	100.00	15	100.00
17-3029.07	Mechanical Engineering Technologists	17	52	100.00	15	100.00
19-1032.00	Foresters	19	52	100.00	15	100.00
19-4041.02	Geological Sample Test Technicians	19	52	100.00	15	100.00
19-4093.00	Forest and Conservation Technicians	19	52	100.00	15	100.00
27-2021.00	Athletes and Sports Competitors	27	52	100.00	15	100.00
27-2023.00	Umpires, Referees, and Other Sports Officials	27	52	100.00	15	100.00
27-2031.00	Dancers	27	52	100.00	15	100.00
27-3012.00	Public Address System and Other Announcer	27	52	100.00	15	100.00
29-1125.00	Recreational Therapists	29	52	100.00	15	100.00
29-2034.00	Radiologic Technologists	29	52	100.00	15	100.00
29-2041.00	Emergency Medical Technicians and Parame	29	52	100.00	15	100.00
31-9093.00	Medical Equipment Preparers	31	52	100.00	15	100.00
…	…	…	…	…	…	…
25-1111.00	Criminal Justice and Law Enforcement Teach	25	30	57.69	11	73.33
25-1113.00	Social Work Teachers, Postsecondary	25	30	57.69	11	73.33
25-1126.00	Philosophy and Religion Teachers, Postsecon	25	30	57.69	11	73.33
25-1192.00	Home Economics Teachers, Postsecondary	25	30	57.69	11	73.33
13-1071.00	Human Resources Specialists	13	29	55.77	11	73.33
19-3031.03	Counseling Psychologists	19	29	55.77	11	73.33
25-1065.00	Political Science Teachers, Postsecondary	25	29	55.77	11	73.33
25-1067.00	Sociology Teachers, Postsecondary	25	29	55.77	11	73.33
25-1112.00	Law Teachers, Postsecondary	25	29	55.77	11	73.33
25-1123.00	English Language and Literature Teachers, P	25	29	55.77	11	73.33
25-1124.00	Foreign Language and Literature Teachers, P	25	29	55.77	11	73.33
25-3011.00	Adult Basic and Secondary Education and Lit	25	29	55.77	11	73.33
11-9199.03	Investment Fund Managers	11	29	55.77	10	66.67
13-1199.05	Sustainability Specialists	13	29	55.77	10	66.67
19-2041.01	Climate Change Analysts	19	29	55.77	10	66.67

Table 54. Integration Complexity of Occupations

As can be seen in Figure 13, there are 230 occupations that require full integration on the 52 abilities. Around 55% of the occupations require at least 47 abilities (out of 52) and the minimum requirements is 29 abilities.

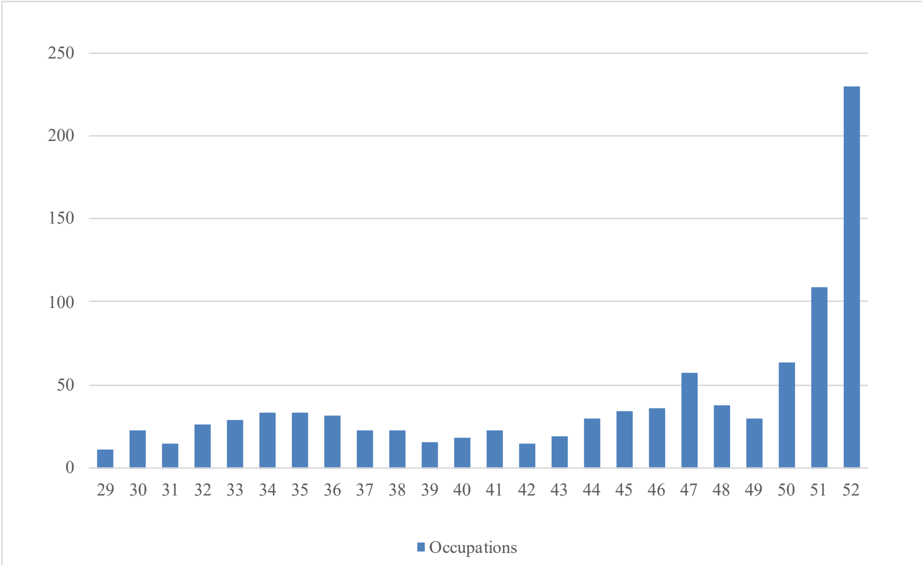

Figure 13. Occupations by Number of Occupations

The second decision on the Integration Reduction Factor – and the most complex one – was to define how should this integration complexity behave. Our initial assumption is that as the number of abilities and ability types increase, the more complex is the occupation, and the harder it is to integrate the abilities. Based on this assumption, we discussed and evaluated possible functions that could represent expected behaviors and their appropriateness to the problem at hand. The functions are presented next and are plotted in Figure 14, just for illustration. Functions are represented by equations where Y is the integration complexity and X is the number of abilities or types of abilities that need to be integrated.

- Linear Function: is a function ruled by the general equation $y = f(x) = a + bx$. Its graph is a straight line, with a constant increase rate, similar to an arithmetic sequence (in blue).

- Power Function: is a function ruled by the general equation $y = f(x) = x^a$. Its graph is a curved line, with a rising increase rate (in red).

- Exponential Function: is a function ruled by the general equation $y = f(x) = a^x$. Its graph is a curved line too, but much steeper than the Power Function, with a rising increase rate (in green).

- Metcalfe's Function: is a function ruled by the general equation $y = f(x) = (x * (x - 1)) / 2$. Its graph is a curved line, but less steep than the Power Function, with a rising increase rate (in purple).

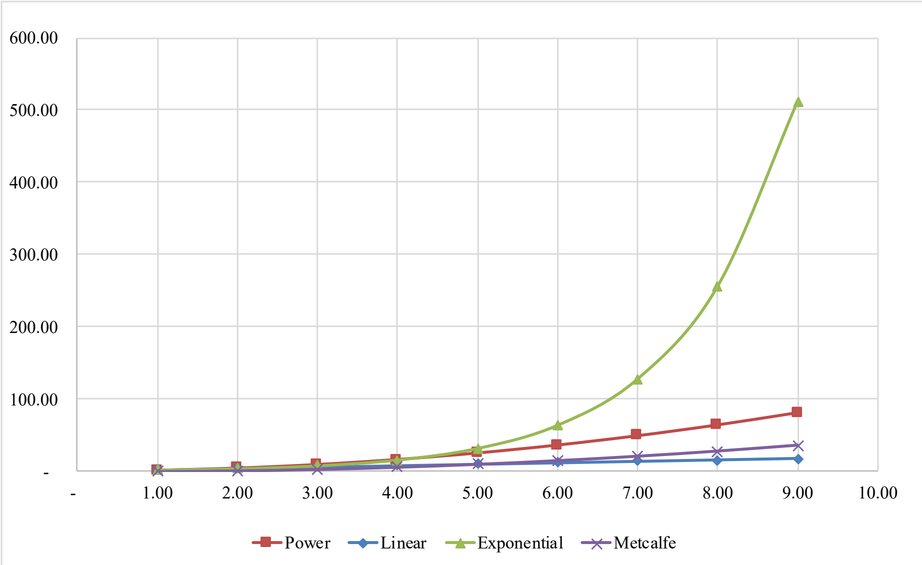

Figure 14. Functions Evaluated

Experiments were executed with all these functions and outcomes were evaluated, except with the Linear Function, because in the researchers' opinion, it failed to represent the increasing change rate of including more abilities to the occupations. In other words, the Linear Function does not differentiate between adding 1 to 2 and adding 1 to 14. The experiments also showed that the Exponential Function was too sharp in the researchers' opinion, presenting an opposite effect to that of the Linear Function. When reaching elevated scores, i.e. the complete set of 52 abilities, the Exponential Function practically represents integration as an impossible task – which could be closer to the truth. However, it demands further transformations and jeopardizes the overall understanding of the model. Nonetheless, some theoretical background could be used to support this decision, based on Reed's Law (Tongia & Wilson III, 2011).

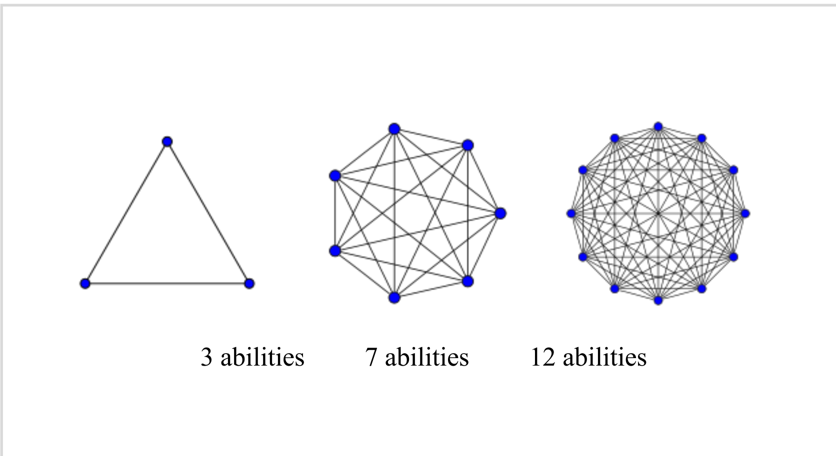

Figure 15. Increasing Integration Complexity

As mentioned, an important assumption for these experiments is that we believe that adding abilities or ability types to the model intensifies and increases the integration complexity challenge. When one ability is included, it must integrate with all the remaining capabilities, working as a network of abilities rather than a simple set of them. This network-like behavior is illustrated in Figure 15, with an increasing number of abilities.

Networks like the ones in Figure 15 are known as Complete Graphs and are covered by Graph Theory, a field within Discrete Mathematics and by Network Theory, which is the application of Graph Theory to network contexts. Graphs are structures corresponding to a set of objects in which some pairs of them are somehow related. According to West (2001), a Graph G is a combination of three elements consisting of a vertex set V(G), represented by points, an edge set E(G), represented by linking curves or lines, and a relation that associates with each edge two vertices called endpoints. Complete Graphs are one specific type of Graphs, more specifically "(…) simple graphs whose vertices are pairwise adjacent" (West, 2001) and where every pair of distinct vertices is connected by a unique edge, undirected.

It is beyond the scope of this research to detail the Graph Theory or the Network Theory, but it is important to explain that they have been used for many different purposes and in many different fields, including in Social Sciences, especially Economy, and Computer Science, just to name a few. According to König & Battiston (2009), there are several applications of network models in economics, such as Corporate Ownership and Boards of Directors, Labor Markets, Diffusion in Networks, Formal and Informal Organizations and R&D Collaborations. The cause is that "(…) Graph Theory has allowed economic network theory to improve our understanding of those economic phenomena in which the embeddedness of individuals in their social inter-relations cannot be neglected" (König & Battiston, 2009). In Computer Science, Graph and Network Theories also had different applications and one of them is the notorious Metcalfe's Law. This law states that the effect (and later the value) of a Telecommunications Networks (telephones, cell phones, faxes and later internet and social networks), which are Complete Graphs, is proportional to the square of the number of connected users of the system (Hendler, 2008). According to Tongia & Wilson III (2011), "Metcalfe's law has become synonymous with connectivity, stating that, as more people join a network, they add to the value of the network nonlinearly."

The square of the number of connected system users is the Power Function which was also pointed out at the beginning of the discussion as a possible behavior for the Integration Factor. However, Metcalfe proposed a proportional behavior to the Power Function, because in a network of 3 elements, the total number of links should be 3 (2 + 1) and not 9. Metcalfe's reasoning led to an equation that is the sum of all possible pairings between nodes, which means that the value of the network of size n is given by the formula in Figure 16, which is proportional to n^2 (Tongia & Wilson III, 2011). This formula is an asymptotical proportion of the Power Function when n tends towards a high valued or infinity, it becomes close to n^2 (actually, ½ of n^2).

$$\frac{(n)(n-1)}{2}$$

Figure 16. Metcalfe's Law Equation

After some internal debate, we understood that the abilities and ability types network that rules the integration complexity had similar form and behavior to that of Telecommunications Networks. In that sense, we assumed we could derive Metcalfe's Law not to calculate the network's value – its original use, but to estimate the integration complexity of the Ability Network. Unfortunately, we lack referenceable studies that can support and justify this decision, which is a limitation later recalled. Nonetheless, as a major postulation of this work and for the following analysis, we considered that Metcalfe's Law is the function that better represents this difficult challenge of integrating technologies to emulate abilities within occupations contexts. Mathematical confirmation of this assumption is a work for a future study.

With the behavior defined, we turned our focus to the third decision: determining the output, meaning the Integration Reduction Factor. Table 55 helps to understand the procedure for this task, first for Abilities. We primary applied Melcalfe's equation, where column X is the number of abilities in an occupation (varying from 1 to 52) and column Y is the complexity of integrations (varying from 0 to 1,326.00). The higher the number of abilities required by occupation, the higher its integration complexity in a nonlinear increase rate, which is illustrated by column Y Increase. Then, we calculated the reduction factor. We performed the same standardization applied to previous variables using formula S = ((O - L) / (H - L)) * 100, resulting a variable measured in a 0 – 100 scale, illustrated by column Y Std, where 0 means no integration complexity (when there is only one ability) and 100 means the highest integration complexity (when there are all 52 abilities are required). We called this Integration Reduction Factor A, related to the number of abilities.

X	Y	Y Increase	Y Std	Y Std Incr.
1.00	-	-	-	-
2.00	1.00	1.00	0.08	0.08
3.00	3.00	2.00	0.23	0.15
4.00	6.00	3.00	0.45	0.23
5.00	10.00	4.00	0.75	0.30
6.00	15.00	5.00	1.13	0.38
...	...	...	...	...
47.00	1,081.00	46.00	81.52	3.47
48.00	1,128.00	47.00	85.07	3.54
49.00	1,176.00	48.00	88.69	3.62
50.00	1,225.00	49.00	92.38	3.70
51.00	1,275.00	50.00	96.15	3.77
52.00	1,326.00	51.00	100.00	3.85

Table 55. Integration Reduction Factor A – Abilities

We applied this same logic to Ability Types and calculated a separated reduction factor, which can be evaluated in Table 56. Again, we had another variable measured in a 0 – 100 scale, illustrated by column Y Std, where 0 means no integration complexity (when there is only one ability type) and 100 means the highest integration complexity (when there are all 15 abilities types). We named this Integration Reduction Factor B, related to the number of ability types. The development of this second reduction factor considered some findings from the Delphi research and comments from experts when responding to the survey, previously explained in Chapter 6. They indicated that several abilities were very similar and hard to distinguish, and some use the same principles, technologies and should not the evaluated separately – e.g., according to experts, the same systems that perform

Inductive Reasoning are able to perform Deductive Reasoning. Therefore, the integration complexity behavior also has to consider the effect of adding a group of abilities, not only abilities.

X	Y	Y Increase	Y Std	Y Std Incr.
1.00	-	-	-	-
2.00	1.00	1.00	0.95	0.95
3.00	3.00	2.00	2.86	1.90
4.00	6.00	3.00	5.71	2.86
5.00	10.00	4.00	9.52	3.81
6.00	15.00	5.00	14.29	4.76
7.00	21.00	6.00	20.00	5.71
8.00	28.00	7.00	26.67	6.67
9.00	36.00	8.00	34.29	7.62
10.00	45.00	9.00	42.86	8.57
11.00	55.00	10.00	52.38	9.52
12.00	66.00	11.00	62.86	10.48
13.00	78.00	12.00	74.29	11.43
14.00	91.00	13.00	86.67	12.38
15.00	105.00	14.00	100.00	13.33

Table 56. Integration Reduction Factor B – Ability Types

Finally, complexity level must also be considered in the integration, because doing it with 52 abilities in their higher complexity level is much tougher than integrating 52 abilities in their lower complexity level. For this, we use as base input the average complexity of the occupation. Airline Pilots, Copilots, and Flight Engineers is the occupation that requires the highest standardized complexity Level scale (2,551.71 points out of 5,200), but the highest average score was from Surgeons (51.18 out of 100), which is the maximum that the Integration Reduction Factor should reach. We had a third variable measured in a 0 – 100 scale, illustrated by column Y Std in Table 57, where 0 means no integration complexity (when the level of the complexity is low) and 100 means the highest integration complexity (when the level of the complexity is very high). We named this Integration Reduction Factor C, related to the complexity level of abilities and, contrary to the other two factors, this is a continuous variable, not a discrete one.

X	Y	Y Increase	Y Std	Y Std Incr.
1.00	-	-	-	-
5.00	10.00	10.00	0.78	0.78
10.00	45.00	35.00	3.53	2.74
15.00	105.00	60.00	8.23	4.70
20.00	190.00	85.00	14.88	6.66
25.00	300.00	110.00	23.50	8.62
30.00	435.00	135.00	34.08	10.58
35.00	595.00	160.00	46.61	12.53
40.00	780.00	185.00	61.10	14.49
45.00	990.00	210.00	77.55	16.45
51.03	1,276.52	286.52	100.00	22.45

Table 57. Integration Reduction Factor C – Complexity

As shown in Table 58, to apply the Integration Reduction Factors in occupations, we consider the number of abilities (column Abilities), the number of ability types (column Abil. Type) and also the complexity level (column Comp. Avg) thru a combination (simple multiplication) of the three respective reduction factors into a Combined Integration Reduction Factor (column Comb Factor), that varies from 0 to 100. The higher this factor, the higher the complexity of integrating abilities to perform this occupation, and therefore, the lower its susceptibility of being emulated. In the same table, we illustrate the outcome of the calculation, with the bottom 15 and top 15 occupations in terms of the Integration Reduction Factor.

SOC Code	Title	SOC Major Group	Abilities	Red Factor A	Abil. Type	Red Factor B	Comp. Avg	Red Factor C	Comb Factor
			0 - 52	0 - 100	0 - 15	0 - 100	0 - 100	0 - 100	0 - 100
41-9041.00	Telemarketers	41	33.00	39.82	13.00	74.29	24.16	21.80	6.45
43-4041.02	Credit Checkers	43	31.00	35.07	12.00	62.86	30.69	35.48	7.82
43-4051.00	Customer Service Representatives	43	31.00	35.07	11.00	52.38	35.76	48.41	8.89
43-9081.00	Proofreaders and Copy Markers	43	35.00	44.87	13.00	74.29	27.20	27.76	9.25
13-1199.05	Sustainability Specialists	13	29.00	30.62	10.00	42.86	43.28	71.25	9.35
19-2041.01	Climate Change Analysts	19	29.00	30.62	10.00	42.86	43.53	72.09	9.46
25-1067.00	Sociology Teachers, Postsecondary	25	29.00	30.62	11.00	52.38	39.87	60.35	9.68
43-6013.00	Medical Secretaries	43	33.00	39.82	12.00	62.86	32.17	39.04	9.77
13-1071.00	Human Resources Specialists	13	29.00	30.62	11.00	52.38	40.20	61.37	9.84
43-4161.00	Human Resources Assistants, Except Payroll a	43	32.00	37.41	12.00	62.86	33.82	43.21	10.16
43-3061.00	Procurement Clerks	43	34.00	42.31	13.00	74.29	29.36	32.42	10.19
43-3021.01	Statement Clerks	43	36.00	47.51	13.00	74.29	27.76	28.92	10.21
25-1065.00	Political Science Teachers, Postsecondary	25	29.00	30.62	11.00	52.38	40.94	63.67	10.21
27-3031.00	Public Relations Specialists	27	32.00	37.41	11.00	52.38	37.67	53.80	10.54
43-4031.02	Municipal Clerks	43	34.00	42.31	13.00	74.29	30.04	33.97	10.68
…	…	…	…	…	…	…	…	…	…
47-2221.00	Structural Iron and Steel Workers	47	52.00	100.00	15.00	100.00	43.20	71.00	71.00
49-9044.00	Millwrights	49	52.00	100.00	15.00	100.00	43.27	71.22	71.22
33-1021.02	Forest Fire Fighting and Prevention Supervis	33	51.00	96.15	15.00	100.00	44.38	74.97	72.08
49-3042.00	Mobile Heavy Equipment Mechanics, Except	49	52.00	100.00	15.00	100.00	43.69	72.63	72.63
53-5021.01	Ship and Boat Captains	53	51.00	96.15	15.00	100.00	44.90	76.74	73.79
29-1067.00	Surgeons	29	45.00	74.66	15.00	100.00	51.18	100.00	74.66
29-2041.00	Emergency Medical Technicians and Parame	29	52.00	100.00	15.00	100.00	44.40	75.03	75.03
33-3051.01	Police Patrol Officers	33	52.00	100.00	15.00	100.00	44.44	75.17	75.17
49-9095.00	Manufactured Building and Mobile Home Ins	49	52.00	100.00	15.00	100.00	44.65	75.87	75.87
53-5021.03	Pilots, Ship	53	51.00	96.15	15.00	100.00	45.83	80.01	76.93
53-2012.00	Commercial Pilots	53	52.00	100.00	15.00	100.00	45.02	77.16	77.16
33-2011.01	Municipal Firefighters	33	52.00	100.00	15.00	100.00	46.80	83.48	83.48
33-1021.01	Municipal Fire Fighting and Prevention Supe	33	52.00	100.00	15.00	100.00	47.05	84.36	84.36
33-2011.02	Forest Firefighters	33	52.00	100.00	15.00	100.00	47.14	84.70	84.70
53-2011.00	Airline Pilots, Copilots, and Flight Engineers	53	50.00	92.38	15.00	100.00	51.03	99.43	91.85

Table 58. Combined Integration Reduction Factor – Bottom 15 and Top 15

Most of the occupations with less integration complexity are clerks and assistant positions. Interestingly, telemarketers, which has been used as an example in previous rounds, it the lowest complexity occupation, which explains the risk that it is currently facing. On the other side, pilots in general, firefighters and medical careers such surgeons are the ones with higher integration requirements, harder to perform.

Based on the Simple Standard Ranking (SSR), we can now apply the Combined Reduction Factor, and generate the Integration Enhanced Ranking (IER), finding out the new susceptibility and the new ranking, as illustrated in Table 59.

SOC Code	Title	SOC Major Group	L*I Std	AI L*I Std	Susceptibility	SRR Ranking	Red. Factor	Susceptibility	IER Ranking
			0 - 520,000	0 - 520,000	0 - 100%	1 - 967	0 - 100	0 - 100%	1 - 967
39-5092.00	Manicurists and Pedicurists	39	40,788.64	37,715.64	92.47%	17	13.24	80.22%	1
45-2041.00	Graders and Sorters, Agricultural Products	45	39,199.32	37,142.18	94.75%	5	16.82	78.81%	2
39-5093.00	Shampooers	39	43,132.57	40,102.43	92.97%	13	17.98	76.25%	3
35-3041.00	Food Servers, Nonrestaurant	35	44,964.32	41,494.89	92.28%	18	20.56	73.31%	4
53-7061.00	Cleaners of Vehicles and Equipment	53	46,841.96	43,881.25	93.68%	8	22.54	72.57%	5
37-2012.00	Maids and Housekeeping Cleaners	37	46,446.18	42,562.25	91.64%	21	20.91	72.47%	6
51-6021.00	Pressers, Textile, Garment, and Related Mater	51	52,075.29	50,611.00	97.19%	1	25.47	72.43%	7
43-5081.04	Order Fillers, Wholesale and Retail Sales	43	45,211.64	40,658.07	89.93%	34	19.69	72.22%	8
51-3023.00	Slaughterers and Meat Packers	51	53,874.00	51,633.14	95.84%	3	25.00	71.88%	9
41-9012.00	Models	41	32,643.64	26,773.54	82.02%	144	13.39	71.03%	10
35-3021.00	Combined Food Preparation and Serving Wo	35	47,804.46	44,333.04	92.74%	15	23.67	70.78%	11
51-6041.00	Shoe and Leather Workers and Repairers	51	53,295.64	51,163.93	96.00%	2	26.30	70.75%	12
35-2021.00	Food Preparation Workers	35	50,185.46	47,414.04	94.48%	6	25.26	70.61%	13
35-9011.00	Dining Room and Cafeteria Attendants and B	35	51,301.39	47,537.32	92.66%	16	24.43	70.02%	14
39-3031.00	Ushers, Lobby Attendants, and Ticket Takers	39	46,093.07	40,828.79	88.58%	49	21.73	69.33%	15
...	...	...	...	...	...	...	...	...	...
53-5021.01	Ship and Boat Captains	53	133,335.54	87,627.93	65.72%	428	73.79	17.23%	953
17-2199.04	Manufacturing Engineers	17	112,899.57	43,705.14	38.71%	881	57.47	16.46%	954
49-3042.00	Mobile Heavy Equipment Mechanics, Except	49	120,719.25	72,367.04	59.95%	518	72.63	16.41%	955
33-3051.01	Police Patrol Officers	33	126,299.39	78,063.00	61.81%	490	75.17	15.35%	956
29-2041.00	Emergency Medical Technicians and Paramed	29	125,800.68	74,732.82	59.41%	525	75.03	14.83%	957
49-9095.00	Manufactured Building and Mobile Home Ins	49	136,880.29	79,077.11	57.77%	551	75.87	13.94%	958
53-2012.00	Commercial Pilots	53	140,699.32	77,744.64	55.26%	591	77.16	12.62%	959
29-1022.00	Oral and Maxillofacial Surgeons	29	128,417.00	47,442.64	36.94%	912	65.92	12.59%	960
29-1021.00	Dentists, General	29	133,318.11	51,191.57	38.40%	888	67.83	12.35%	961
53-5021.03	Pilots, Ship	53	135,969.21	64,645.54	47.54%	722	76.93	10.97%	962
33-2011.01	Municipal Firefighters	33	140,898.04	87,664.75	62.22%	482	83.48	10.28%	963
33-1021.01	Municipal Fire Fighting and Prevention Supe	33	140,671.64	82,011.61	58.30%	543	84.36	9.12%	964
33-2011.02	Forest Firefighters	33	141,829.07	83,468.32	58.85%	535	84.70	9.00%	965
29-1067.00	Surgeons	29	137,364.54	44,458.96	32.37%	954	74.66	8.20%	966
53-2011.00	Airline Pilots, Copilots, and Flight Engineers	53	170,342.64	74,332.82	43.64%	785	91.85	3.56%	967
Total			**82,289.39**	**50,718.65**	**62.09%**		**36.08**	**38.51%**	

Table 59. Integration Enhanced Ranking (IER) Scores – 2018

Table 59 shows that resulting scores in 2018 for the Integration Enhanced Ranking were significantly reduced, with susceptibility index reaching an average of 38.51% (a reduction of almost 25 points) and no positions surpassing susceptibilities scores higher than 80% (except Manicurists and Pedicurists). Pressers, Textile, Garment, and Related Materials was moved to 6th position and the highest susceptibility occupation was Manicurists and Pedicurists (80.22%). In the opposite direction, Airline Pilots, Copilots and Flight Engineers (3.56%) was the occupation with the lower susceptibility index in 2018, followed by Surgeons (8.20%).

Table 60 illustrates the major groups of occupations[237] more affected by Artificial Intelligence, Robotics, and related technologies in 2018, considering the integration reduction factor. Only Personal Care and Service Occupations and Farming, Fishing, and Forestry Occupations had professions in the high susceptibility range (higher than 75%) and Food Preparation and Serving Related Occupations (52.94%), Building and Grounds Cleaning and Maintenance Occupations (25.00%) and Personal Care and Service Occupations (21.88%) were in the above average (higher than 60%) susceptibility. Again, based on these statistics, it is possible to interpret that occupations more labor-intensive and with less complexity in terms of level and integration seem to be more affected than those more intellectual intensive, more complex and that require more integration.

[237] https://www.bls.gov/soc/2018/#classification

SOC Code	SOC Major Group	Total	Qty > 75%	% > 75%	Qty > 60%	% > 60%
11	Management Occupations	56	-	0.00%	-	0.00%
13	Business and Financial Operations Occupatior	50	-	0.00%	-	0.00%
15	Computer and Mathematical Occupations	33	-	0.00%	-	0.00%
17	Architecture and Engineering Occupations	70	-	0.00%	-	0.00%
19	Life, Physical, and Social Science Occupation	60	-	0.00%	-	0.00%
21	Community and Social Service Occupations	14	-	0.00%	-	0.00%
23	Legal Occupations	8	-	0.00%	-	0.00%
25	Educational Instruction and Library Occupati	60	-	0.00%	-	0.00%
27	Arts, Design, Entertainment, Sports, and Med	43	-	0.00%	-	0.00%
29	Healthcare Practitioners and Technical Occup	86	-	0.00%	-	0.00%
31	Healthcare Support Occupations	18	-	0.00%	-	0.00%
33	Protective Service Occupations	29	-	0.00%	2	6.90%
35	Food Preparation and Serving Related Occup	17	-	0.00%	9	52.94%
37	Building and Grounds Cleaning and Mainten	8	-	0.00%	2	25.00%
39	Personal Care and Service Occupations	32	2	6.25%	7	21.88%
41	Sales and Related Occupations	24	-	0.00%	1	4.17%
43	Office and Administrative Support Occupatio	63	-	0.00%	7	11.11%
45	Farming, Fishing, and Forestry Occupations	17	1	5.88%	1	5.88%
47	Construction and Extraction Occupations	61	-	0.00%	1	1.64%
49	Installation, Maintenance, and Repair Occupa	54	-	0.00%	-	0.00%
51	Production Occupations	111	-	0.00%	9	8.11%
53	Transportation and Material Moving Occupat	53	-	0.00%	2	3.77%
Total		**967**	**3**	**0.31%**	**41**	**4.24%**

Table 60. Highest Susceptibility by Major Group of Occupations in IER – 2018

In 2038, the figures were higher than 2018, but the Integration Reduction Factor balanced occupations, not only equalizing the integration challenge just mentioned but also making the analysis of the results easier to evaluate and interpret, especially the professions that are more or less susceptible, as shown in Table 61. Resulting scores in 2038 for the Integration Enhanced Ranking were significantly reduced, the susceptibility index reached an average of 61.48% (a reduction of more than 35 points) and no occupations reaching the 100% susceptibility – though six higher than 90%. In the top positions, as the most susceptible to be emulated by machines, consequently replacing humans, are Telemarketers, Credit Checkers, Customer Service Representatives, Proofreaders and Copy Markers, Medical Secretaries and Human Resources Specialists, all above 90%. On the opposite side, occupations less susceptible are similar to those evaluated in 2018 and Airline Pilots, Copilots and Flight Engineers (7.63%) was the occupation with the lower susceptibility index. The complete list of the 967 occupations, their susceptibility index, and the ranking are in Appendix 5.

SOC Code	Title	SOC Major Group	L*I Std	AI L*I Std	Susceptibility	SRR Ranking	Red. Factor	Susceptibility	IER Ranking
			0 - 520,000	0 - 520,000	0 - 100%	1 - 967	0 - 100	0 - 100%	1 - 967
41-9041.00	Telemarketers	41	34,243.57	34,243.57	100.00%	1	6.45	93.55%	1
43-4041.02	Credit Checkers	43	45,046.29	45,046.29	100.00%	1	7.82	92.18%	2
43-4051.00	Customer Service Representatives	43	53,841.32	53,841.32	100.00%	1	8.89	91.11%	3
43-9081.00	Proofreaders and Copy Markers	43	44,804.93	44,804.93	100.00%	1	9.25	90.75%	4
43-6013.00	Medical Secretaries	43	49,022.82	49,022.82	100.00%	1	9.77	90.23%	5
13-1071.00	Human Resources Specialists	13	61,278.14	61,278.14	100.00%	1	9.84	90.16%	6
43-4161.00	Human Resources Assistants, Except Payroll a	43	54,062.96	54,062.96	100.00%	1	10.16	89.84%	7
43-3061.00	Procurement Clerks	43	51,301.11	51,301.11	100.00%	1	10.19	89.81%	8
43-3021.01	Statement Clerks	43	43,201.61	43,201.61	100.00%	1	10.21	89.79%	9
43-4031.02	Municipal Clerks	43	48,871.00	48,871.00	100.00%	1	10.68	89.32%	10
25-3011.00	Adult Basic and Secondary Education and Lit	25	66,307.39	66,307.39	100.00%	1	10.81	89.19%	11
11-9199.01	Regulatory Affairs Managers	11	70,377.29	70,377.29	100.00%	1	10.85	89.15%	12
41-9091.00	Door-To-Door Sales Workers, News and Stre	41	42,264.32	42,264.32	100.00%	1	10.90	89.10%	13
43-4041.01	Credit Authorizers	43	59,954.54	59,954.54	100.00%	1	11.05	88.95%	14
13-2072.00	Loan Officers	13	60,247.79	60,247.79	100.00%	1	11.17	88.83%	15
…	…	…	…	…	…	…	…	…	…
49-9044.00	Millwrights	49	123,298.71	123,298.71	100.00%	1	71.22	28.78%	953
29-1021.00	Dentists, General	29	133,318.11	119,080.39	89.32%	830	67.83	28.73%	954
33-1021.02	Forest Fire Fighting and Prevention Supervis	33	121,530.82	121,530.82	100.00%	1	72.08	27.92%	955
49-3042.00	Mobile Heavy Equipment Mechanics, Except	49	120,719.25	120,719.25	100.00%	1	72.63	27.37%	956
53-5021.01	Ship and Boat Captains	53	133,335.54	133,335.54	100.00%	1	73.79	26.21%	957
29-2041.00	Emergency Medical Technicians and Parame	29	125,800.68	125,800.68	100.00%	1	75.03	24.97%	958
33-3051.01	Police Patrol Officers	33	126,299.39	126,299.39	100.00%	1	75.17	24.83%	959
49-9095.00	Manufactured Building and Mobile Home Ins	49	136,880.29	136,880.29	100.00%	1	75.87	24.13%	960
53-5021.03	Pilots, Ship	53	135,969.21	135,969.21	100.00%	1	76.93	23.07%	961
53-2012.00	Commercial Pilots	53	140,699.32	140,699.32	100.00%	1	77.16	22.84%	962
29-1067.00	Surgeons	29	137,364.54	97,065.21	70.66%	960	74.66	17.90%	963
33-2011.01	Municipal Firefighters	33	140,898.04	140,898.04	100.00%	1	83.48	16.52%	964
33-1021.01	Municipal Fire Fighting and Prevention Supe	33	140,671.64	137,658.25	97.86%	667	84.36	15.30%	965
33-2011.02	Forest Firefighters	33	141,829.07	141,829.07	100.00%	1	84.70	15.30%	966
53-2011.00	Airline Pilots, Copilots, and Flight Engineers	53	170,342.64	159,490.64	93.63%	795	91.85	7.63%	967
Total			**82,289.39**	**79,270.78**	**96.60%**		**36.11**	**61.48%**	

Table 61. Integration Enhanced Ranking (IER) Scores – 2038

In terms of occupation groups, the Integration Reduction Factor works as a distributing influence, because it seems that now susceptibility is wider and affects more groups than the previous ranking, as can be seen in Table 62.

SOC Code	SOC Major Group	Total	Qty > 90%	% > 90%	Qty > 75%	% > 75%
11	Management Occupations	56	-	0.00%	21	37.50%
13	Business and Financial Operations Occupatior	50	1	2.00%	35	70.00%
15	Computer and Mathematical Occupations	33	-	0.00%	15	45.45%
17	Architecture and Engineering Occupations	70	-	0.00%	7	10.00%
19	Life, Physical, and Social Science Occupation	60	-	0.00%	7	11.67%
21	Community and Social Service Occupations	14	-	0.00%	2	14.29%
23	Legal Occupations	8	-	0.00%	4	50.00%
25	Educational Instruction and Library Occupati	60	-	0.00%	10	16.67%
27	Arts, Design, Entertainment, Sports, and Med	43	-	0.00%	11	25.58%
29	Healthcare Practitioners and Technical Occup	86	-	0.00%	2	2.33%
31	Healthcare Support Occupations	18	-	0.00%	2	11.11%
33	Protective Service Occupations	29	-	0.00%	2	6.90%
35	Food Preparation and Serving Related Occup	17	-	0.00%	6	35.29%
37	Building and Grounds Cleaning and Mainten	8	-	0.00%	2	25.00%
39	Personal Care and Service Occupations	32	-	0.00%	11	34.38%
41	Sales and Related Occupations	24	1	4.17%	14	58.33%
43	Office and Administrative Support Occupatio	63	4	6.35%	44	69.84%
45	Farming, Fishing, and Forestry Occupations	17	-	0.00%	1	5.88%
47	Construction and Extraction Occupations	61	-	0.00%	-	0.00%
49	Installation, Maintenance, and Repair Occupa	54	-	0.00%	-	0.00%
51	Production Occupations	111	-	0.00%	4	3.60%
53	Transportation and Material Moving Occupat	53	-	0.00%	2	3.77%
Total		**967**	**6**	**0.62%**	**202**	**20.89%**

Table 62. Highest Susceptibility by Major Group of Occupations in IER – 2038

Business and Financial Operations Occupations (70.00%), Office and Administrative Support Occupations (69.84%), Sales and Related Occupations (58.33%) and Legal Occupations (50.00%) are the top susceptible areas in 2038, a different picture than in 2018 in both rankings. On the opposite direction, Construction and Extraction Occupations (0.00%) and Installation, Maintenance, and Repair Occupations (0.00%) had no occupations marked in the high susceptibility, and Healthcare Practitioners and Technical Occupations (2.33%), Production Occupations (3.60%) and Transportation and Material Moving Occupations (3.77%) were also quite low.

Comparing results between 2018 and 2038 with the Integrated Enhanced Ranking show similar distributions, but obviously, with 2038 offset to the right, as a demonstration that the capabilities of machines will improve and will be added to the occupations, as shown in Figure 17.

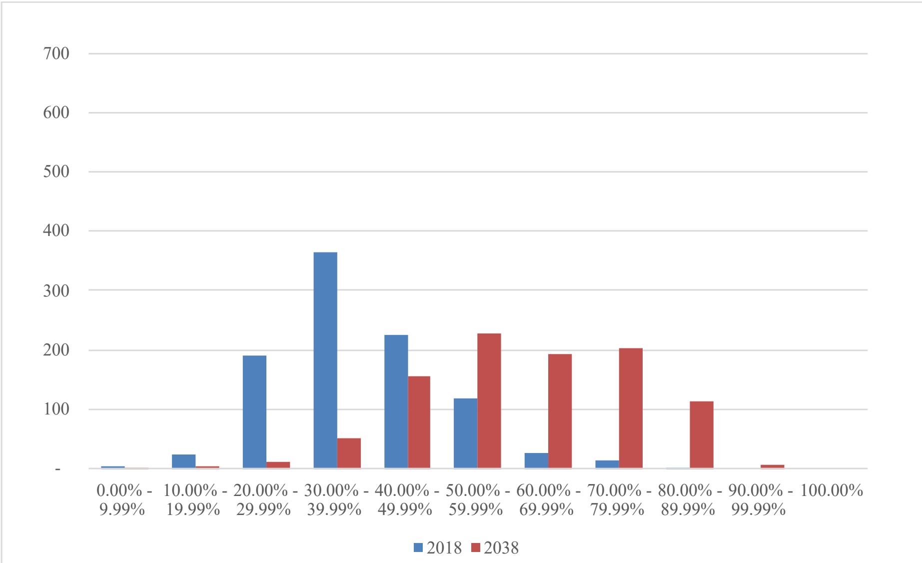

Figure 17. Integration Enhanced Ranking Comparison – 2018 vs 2038

7.3. Comparison with Frey & Osborne (2017)'s Ranking

At this point, we understand that a comparison between our Integration Enhanced Ranking (IER) with Frey & Osborne (2017)'s Ranking – henceforward F&OR – results is an important discussion. Nonetheless, it is critical to highlight that this evaluation is a complicated chore because, apart from using a different method, F&OR is broader than IER in terms of characteristics considered (we evaluated only Abilities), however, it is more superficial than IER in terms of analysis depth (we assessed in further detail Abilities). Therefore, we expected some significant differences between the two rankings, which were confirmed. The complete list of the 967 occupations, their susceptibility, and ranking comparison are in Appendix 5.

When analyzing the highest differences in susceptibility between the two rankings, we noticed several disparities, as shown in Table 63. First were the cases where F&OR found a great susceptibility, while IER did not. In F&OR, some Transportation and Material Moving Occupations (SOC Major Group 53) such as Locomotive Engineers, Locomotive Firers, Sailors and Marine Oilers were flagged as highly susceptible to computerization. In that sense, one of Frey & Osborne (2017)'s key conclusions was that "(…) most workers in transportation and logistics occupations (…) are likely to be substituted by computer capital" – the authors took into account the autonomous cars and its increasing cost-effectiveness in their judgment. Yet, these occupations were below the average in IER and Pilots, for instance, were among the lowest level of susceptibility. When investigating the rationale, we observed that the integration factor was of great influence for these professions, because they require several abilities, ability types and a high average of complexity level. Only those with a low level of integration, like Packers and Packagers and Cleaners of Vehicles and Equipment were classified as high susceptibility in IER. While Frey & Osborne (2017)'s argument may be a valid one, in line with our argument of this chapter, we believe that the integration challenge may create difficulties of automating these occupations as predicted by the authors. It could be that Frey & Osborne (2017) considered a different way of performing the activities related to these occupations.

SOC Code	Title	SOC Major Group	Red. Factor	IER Susc.	IER	F&OR Susc.	F&OR	Suscep. Diff.
			0 - 100	0 - 100%	1 - 967	0 - 100%	1 - 702	-100 - 100%
53-4011.00	Locomotive Engineers	53	64.43	35.57%	930	96.00%	65	-60.43%
53-7032.00	Excavating and Loading Machine and Dragli	53	65.82	34.18%	939	94.00%	101	-59.82%
47-2221.00	Structural Iron and Steel Workers	47	71.00	29.00%	952	83.00%	246	-54.00%
51-9021.00	Crushing, Grinding, and Polishing Machine S	51	56.79	43.21%	850	97.00%	51	-53.79%
47-5013.00	Service Unit Operators, Oil, Gas, and Mining	47	60.45	39.55%	902	93.00%	127	-53.45%
53-5011.00	Sailors and Marine Oilers	53	70.31	29.69%	951	83.00%	242	-53.31%
51-4011.00	Computer-Controlled Machine Tool Operator	51	65.92	34.08%	940	86.00%	205	-51.92%
53-4012.00	Locomotive Firers	53	57.74	42.26%	865	93.00%	124	-50.74%
17-3031.01	Surveying Technicians	17	54.69	45.31%	820	96.00%	68	-50.69%
49-9097.00	Signal and Track Switch Repairers	49	60.68	39.32%	904	90.00%	160	-50.68%
51-8099.01	Biofuels Processing Technicians	51	64.52	35.48%	932	86.00%	212	-50.52%
53-4013.00	Rail Yard Engineers, Dinkey Operators, and I	53	58.88	41.12%	882	91.00%	150	-49.88%
47-5011.00	Derrick Operators, Oil and Gas	47	68.62	31.38%	946	80.00%	263	-48.62%
49-3043.00	Rail Car Repairers	49	60.24	39.76%	900	88.00%	182	-48.24%
51-9111.00	Packaging and Filling Machine Operators anc	51	49.79	50.21%	740	98.00%	22	-47.79%
…	…	…	…	…	…	…	…	…
27-3043.04	Copy Writers	27	17.23	78.13%	141	3.80%	580	74.33%
11-2022.00	Sales Managers	11	20.39	75.81%	184	1.30%	644	74.51%
41-1012.00	First-Line Supervisors of Non-Retail Sales Wo	41	14.17	82.34%	96	7.50%	547	74.84%
21-2021.00	Directors, Religious Activities and Education	21	22.38	77.62%	148	2.50%	606	75.12%
41-3041.00	Travel Agents	41	14.55	85.45%	62	9.90%	535	75.55%
13-1151.00	Training and Development Specialists	13	17.99	77.90%	142	1.40%	639	76.50%
11-3121.00	Human Resources Managers	11	19.38	77.27%	156	0.55%	675	76.72%
11-9111.00	Medical and Health Services Managers	11	19.64	77.62%	149	0.73%	667	76.89%
11-3061.00	Purchasing Managers	11	15.02	80.73%	111	3.00%	592	77.73%
11-2021.00	Marketing Managers	11	16.60	79.44%	126	1.40%	642	78.04%
13-1081.00	Logisticians	13	16.14	80.18%	117	1.20%	648	78.98%
11-3031.01	Treasurers and Controllers	11	13.60	86.40%	47	6.90%	551	79.50%
41-3031.01	Sales Agents, Securities and Commodities	41	18.37	81.63%	103	1.60%	629	80.03%
13-2071.00	Credit Counselors	13	11.60	88.40%	18	4.00%	577	84.40%
25-3099.02	Tutors	25	12.68	87.32%	35	0.95%	655	86.37%

Table 63. Differences between IER and F&OR – Higher Differences

The second group of disparities are the cases where F&OR found a low susceptibility, instead IER found them high. A key group here for discussion was that of Management Occupations (11), pointed out as low susceptibility in F&OR. Actually, the authors explain that "(…) most management, business, and finance occupations, which are intensive in generalist tasks requiring social intelligence, are largely confined to the low-risk category" (Frey & Osborne, 2017). In IER, however, several occupations within this group, like Sales Managers, Marketing Managers, Purchasing Managers had high susceptibilities for the reason that they did not require high levels of complexity and integration is reduced in terms of abilities and ability types. But the key difference here is that in F&OR, Skills like Social Perceptiveness, Negotiation and Persuasion, indicated as bottlenecks were taken into account, while in IER we did not – our scope was limited to abilities.

Another interesting difference is the one seen in Production Occupations (51). According to Frey & Osborne (2017), labor in these occupations is also likely to be substituted by computers, suggesting "(…) a continuation of a trend that has been observed over the past decades, with industrial robots taking on the routine tasks of most operatives in manufacturing." Though most of the Production Occupations are in the above the average in terms of susceptibility in IER, at least from an Abilities perspective, it is not one of the groups that seemed to be more affected by Artificial Intelligence, Robotics, and related technologies. Again, direct explanation is the integration complexity factor, but we could also interpret it may reflect, indirectly, the fact that most of these occupations are already quite robotized and what remains is not so easy to replace, especially in a country like the U.S. where production processes are quite advanced in terms of technology applied.

SOC Code	Title	SOC Major Group	Red. Factor	IER Susc.	IER	F&OR Susc.	F&OR	Suscep. Diff.
			0 - 100	0 - 100%	1 - 967	0 - 100%	1 - 702	-100 - 100%
19-4099.01	Quality Control Analysts	19	41.27	58.73%	530	61.00%	363	-2.27%
33-2021.01	Fire Inspectors	33	54.20	45.80%	812	48.00%	414	-2.20%
19-4031.00	Chemical Technicians	19	45.16	54.84%	624	57.00%	384	-2.16%
51-4071.00	Foundry Mold and Coremakers	51	35.01	64.99%	407	67.00%	333	-2.01%
19-4093.00	Forest and Conservation Technicians	19	59.96	40.04%	898	42.00%	425	-1.96%
35-1012.00	First-Line Supervisors of Food Preparation an	35	38.91	61.09%	487	63.00%	354	-1.91%
39-9021.00	Personal Care Aides	39	27.65	72.35%	268	74.00%	297	-1.65%
25-4013.00	Museum Technicians and Conservators	25	42.57	57.43%	567	59.00%	377	-1.57%
53-5021.01	Ship and Boat Captains	53	73.79	26.21%	957	27.00%	473	-0.79%
27-3012.00	Public Address System and Other Announcer	27	28.61	71.39%	291	72.00%	304	-0.61%
33-2011.01	Municipal Firefighters	33	83.48	16.52%	964	17.00%	506	-0.48%
11-9131.00	Postmasters and Mail Superintendents	11	25.37	74.63%	214	75.00%	294	-0.37%
17-1022.00	Surveyors	17	62.24	37.76%	917	38.00%	441	-0.24%
43-4161.00	Human Resources Assistants, Except Payroll a	43	10.16	89.84%	7	90.00%	171	-0.16%
43-4021.00	Correspondence Clerks	43	14.01	85.99%	50	86.00%	203	-0.01%
17-3022.00	Civil Engineering Technicians	17	24.95	75.05%	200	75.00%	290	0.05%
49-9052.00	Telecommunications Line Installers and Repa	49	50.85	49.15%	757	49.00%	406	0.15%
27-4011.00	Audio and Video Equipment Technicians	27	44.41	55.59%	609	55.00%	387	0.59%
29-2081.00	Opticians, Dispensing	29	27.76	72.24%	271	71.00%	312	1.24%
51-6011.00	Laundry and Dry-Cleaning Workers	51	27.76	72.24%	270	71.00%	311	1.24%
49-2022.00	Telecommunications Equipment Installers and	49	62.69	37.31%	922	36.00%	449	1.31%
17-3012.01	Electronic Drafters	17	17.66	82.34%	97	81.00%	260	1.34%
31-9095.00	Pharmacy Aides	31	25.83	74.17%	225	72.00%	309	2.17%
25-4011.00	Archivists	25	21.76	78.24%	139	76.00%	288	2.24%
19-2021.00	Atmospheric and Space Scientists	19	20.19	69.73%	328	67.00%	332	2.73%
11-9141.00	Property, Real Estate, and Community Associ	11	16.26	83.74%	77	81.00%	257	2.74%
53-7033.00	Loading Machine Operators, Underground M	53	47.04	52.96%	668	50.00%	404	2.96%
39-5093.00	Shampooers	39	17.98	82.02%	99	79.00%	271	3.02%
47-5081.00	Helpers--Extraction Workers	47	59.83	40.17%	897	37.00%	445	3.17%
31-2022.00	Physical Therapist Aides	31	35.31	64.69%	415	61.00%	368	3.69%

Table 64. Differences between IER and F&OR – Lower Differences

In regard to similarities, some were identified, as plotted in Table 64, both in high and in mid ends – in low ends, it was not possible to evaluated because the lower susceptibility in IER was higher than 20.00%. As previously mentioned, in Table 62 we identified that Business and Financial Operations Occupations (70.00%), Office and Administrative Support Occupations (69.84%), Sales and Related Occupations (58.33%) and Legal Occupations (50.00%) were the ones with more occupations in the high susceptibility areas in 2038. Office and Administrative Support Occupations and Sales and Related Occupations had similar behaviors in F&OR – authors pointed out to a bulk of office and administrative support workers and even services and sales with high susceptibility. As the Frey & Osborne (2017) explained, though it might be counterintuitive that these occupations could be subject to a wave of computerization, several high-risk occupations are included, Cashiers, Counter and Rental Clerks, and Telemarketers. In that sense, it is worth mentioning that Telemarketer was the number one occupation in terms of susceptibility both in F&OR and in IER rankings.

7.4. Impact on U.S. Job Market

After reaching their ranking, Frey & Osborne (2017) crossed their findings with the total volume of positions in the U.S. job market per occupation. First, they distinguished between high, medium and low-risk occupations, depending on their probability of computerization with thresholds at probabilities of 0.7 and 0.3. Based on this rationale, according to their estimate, 47% of total the U.S. employment was in the high-risk category, "(…) meaning that associated occupations are potentially automatable over some unspecified number of years, perhaps a decade or two" (Frey & Osborne, 2017).

We executed this same procedure and as in Frey & Osborne (2017), we made no attempt to forecast future changes in the occupational composition of the labor market – instead, we focus our analysis on the mix of jobs that existed in 2016 and its projection to 2026, both provided by BLS – Bureau of Labor Statistics, and our analysis is limited only to the effects of Artificial Intelligence, Robotics, and related technologies. We believe that this considers a worst-case scenario because it fails to consider several non-technical challenges and bottlenecks explained before that will have a hindering effect to computerization.

The outcomes found were, to the authors' surprise, exactly the same as those of Frey & Osborne (2017). Based on the calculations, which are summarized in Table 65, 47% to 51% of the job positions in U.S. both in 2016 and 2026 are in the high-risk category, meaning that occupations are potentially replaceable by Artificial Intelligence, Robotics, and related technologies in two decades or so. Similarities between 2016 and 2026 can be overlooked because, as a projection based on historical results, the job positions are simply proportional.

	2016		2026	
Total Employment (in thousands)	156,063.20		167,580.90	
Occupations in high-risk	323		323	
Positions in high-risk (lower)	73,733.00	47.25%	78,762.10	47.00%
Positions in high-risk (higher)	79,661.30	51.04%	85,139.60	50.81%
Occupations not in high-risk	644		644	
Positions not in high-risk (lower)	76,401.90	48.96%	82,441.30	49.19%
Positions not in high-risk (higher)	82,330.20	52.75%	88,818.80	53.00%

Table 65. Impact on the U.S. Job Market

We considered this a surprise because of three different reasons. First, method and inputs (part of them) were different – we based our ranking in only one occupation characteristic (Abilities) but in higher detail and we considered Importance scale and a Reduction Factor for the integration challenge. Second, the results of the new ranking were quite different from those of Frey and Osborne, already explained in the previous section, with significant discrepancies. Third, the number of occupations in the high-risk category in IER was lower than F&OR – our ranking had 33.4% of the occupations (323 out of 967) in the high susceptibility area (higher than 70%), while Frey & Osborne (2017) had 45% (318 out of 702).

We interpret, therefore, that the key reason to explain such a scenario is that the IER ranking had more impact in occupations that have a higher volume of job positions, which, in most cases, are characterized with less complexity and that require less integration of abilities. This is confirmed by the averages of the most and the less susceptible groups against the combined mean (191,000 positions per occupation). While in the most susceptible the average is higher than the mean (301,000 positions per occupation), the less susceptible second is lower than the mean (149,000 positions per occupation). In regard to the range presented, between 47% and 51%, it reflects eventual cases where one group occupation in BLS has one or more occupations in O*NET, like Chief Executives – O*NET has split this in two Chief Executives and Chief Sustainability Officers.

Our major consideration regarding to this job market impact is that it is far from conclusive and should not be used indiscriminately as irrefutable. As mentioned, there are several other technical and non-technical variables that were not considered and that, most certainly, would have a reducing effect on the statistics just shared. Nonetheless, when evaluated in combination with Frey & Osborne (2017)'s findings, which have also several limitations, it is an important result to create awareness of the problem at hand, which is that Artificial Intelligence, Robotics, and related technologies can severely impact occupations and the job markets, though not necessarily replacing humans. This is also a concern that was clearly highlighted by experts in the Delphi research, which is evaluated next in Chapter 0.

It was our initial intention to execute this same analysis for the Brazilian job market, and evaluate the potential impact of Artificial Intelligence, Robotics, and related technologies in a developing country and compare it to the findings in the U.S.. We expect that the impacts would be even higher – though the cost/benefit equation may be quite averse to machines in a country where the cost of human labor is still cheaper. However, we faced two challenges that could not be dealt in time: (a) having the Brazilian job market database detailed by occupations, like BLS in the U.S., and (b) mapping the occupations between American SOC and Brazilian CBO. We believe this would be an interesting endeavor and achievement, and it is our key recommendation for a future study.

7.5. Considerations, Limitations and Future Improvements

As previously mentioned, one of the key motivations to perform this research was to appraise and eventually challenge Frey & Osborne (2017)'s findings, especially the authors' ranking of occupations according to their susceptibility to computerization. The first step in our journey was to evaluate and understand in more detail one of O*NET's occupation framework key building blocks, Abilities, which are enduring capabilities required to perform occupations. Based on the opinion of experts, findings in Chapter 6 helped us in realizing the maturity and progress of technologies in several areas, but most importantly, it helped in evaluating the likelihood of Artificial Intelligence, Robotics, and related technologies of emulating Abilities, that is, imitating and performing abilities as good as (or better than) humans in an autonomous way, but not necessarily using the same approach. With the Ability variable defined and outputs from the experts' opinions, we could then concentrate on building an alternative ranking that addressed what we believed were Frey & Osborne (2017)'s weaknesses regarding method, analysis, and conclusions.

In the process of building the alternative ranking, we noticed that occupations more labor-intensive seemed to be more affected by Artificial Intelligence, Robotics, and related technologies than those more intellectual-intensive. This observation is similar to that of Frey & Osborne (2017) that affirm that "computerization of production occupations simply suggests a continuation of a trend that has been observed over the past decades, with industrial robots taking on the routine tasks of most operatives in manufacturing". Moreover, several occupations in Business, Management, Legal, Healthcare, Education, Arts, seem to be less affected by technologies, occupations with greater human and social factors, heavily dependable in features such as creativity, empathy, and interaction. However, Abilities is not the best descriptor to evaluate this social interactive component, since these characteristics are majorly covered by Skills. We also noticed, as Frey & Osborne (2017), that technologies "(…) will be able to perform a wider scope of non-routine manual tasks" – actually, all occupations will be impacted to a greater or lesser extent by technologies, based on the indirect opinions of the experts.

When checking for the bottlenecks applied into the occupation context, that is, considering the complexity requirements, Originality, Oral Comprehension, and Written Comprehension were confirmed as the top 3 bottlenecks, in line with the findings from Chapter 6. These outcomes are different from the British authors, that considered Finger and Manual Dexterities as a major obstacle for technologies, though they mentioned that "tasks involving mobility and dexterity will diminish over time, the pace of labor substitution in service occupations is likely to increase even further" (Frey & Osborne, 2017). Finger and Manual Dexterities were not in the top 10 of our bottlenecks.

But our greatest collaboration to the discussion is related to complexity and integration. We were already aware that the more complex the occupations are, meaning abilities with higher complexity requirements, the lesser technologies can emulate. In that sense, and based on findings of this research, we believe that technologies may emulate individual abilities to a higher extent, but more important than that is being able to harmonically combine the capabilities and make them work together with synergy to achieve even basic tasks of occupations. This is hard for humans that want to be successful in their jobs, but it is a great challenge for machines, that still today are very specific in content and application. This integration challenge corroborates the fact that no matter how advanced technology might be in a specific ability, it takes more than that for machines to successfully replace humans in an occupation. For that reason, we believe in a future of collaboration between humans and machines, rather than the replacement and displacement.

Therefore, we created and included in our ranking an Integration Complexity Reduction Factor. As a major supposition, we assumed that the abilities and ability types network that rules the integration complexity had similar form and behavior to that of Telecommunications Networks and that we could derive Metcalfe's Law to estimate the integration complexity factor of the Ability Network for each occupation. The results showed that most of the occupations with less integration complexity, like clerks and assistant positions, are more susceptible of being replaced, while the ones that demand the higher integration of abilities are practically not at risk. In the top positions in the susceptibility risk, all above 90% of the risk of being emulated by Artificial Intelligence, Robotics, and related technologies in twenty years were Telemarketers, Credit Checkers, Customer Service Representatives, Proofreaders and Copy Markers, Medical Secretaries and Human Resources Specialists. On the other side, Pilots in general, Firefighters and medical careers such Surgeons are the ones with higher integration requirements, harder to perform. The complete list of the 967 occupations, their susceptibility index, and the ranking are in Appendix 5.

Interestingly, Telemarketers, which was used as an example in previous rounds and was placed in 1st position in Frey & Osborne (2017)'s ranking, was also the 1st in terms of susceptibility in our ranking, though we had different methods and different inputs. Actually, it demonstrates an important point about this occupation, which is the fact that it has three key characteristics that drive susceptibility of being replaced. First, this occupation is comprised of basic repetitive activities; second, it is not intellectually demanding, since most of the work is based on pre-defined scripts; and third, it is not difficult in terms of complexity Level and integrations, with few abilities and ability types. Occupations that have these three characteristics will very likely be highly impacted by Artificial Intelligence, Robotics, and related technologies – or, as Frey & Osborne (2017) put it, computerization – in the next twenty years. Nonetheless, we cannot forget the social component of each occupation. Manicurists and Pedicurists, though in the 41st (out of 967) with 86.76% of susceptibility, are a good example of this scenario, because they require several social and human implicit capabilities which are measured by the Skill descriptor which was not evaluated.

These results are obviously not conclusive and have a high degree of subjectivity from the combined group of experts and of the researchers. However, they help in understanding the current and future situation of this topic and allow us to suggest some possible conclusions. One of the most important, drawn from what can be seen in the 2038 Ranking (with the integration reduction factor), is that once the integration factor is considered, no occupation reached the 100% susceptibility index, which means that not a single occupation can be entirely replaced with acceptable quality by machines that combine Artificial Intelligence, Robotics, and related technologies. There will always be some portion or portions of the occupation (in their current ways of work) that will require some human complement. In other words, we believe that these findings again demonstrate that the complementary perspective between humans and machines is closer to reality than the replacement one.

In regard to similarities between the two rankings, Frey & Osborne (2017)'s and ours, we identified that Office and Administrative Support Occupations and Sales and Related Occupations had similar behaviors. As Frey & Osborne (2017) explained, though it might be counterintuitive that these occupations could be subject to a wave of computerization, we can see several high-risk occupations, for example, Cashiers, Counter and Rental Clerks, and Telemarketers. On the other hand, we did find different results for several occupations and groups of occupations, which was expected considering that we had different methods. In Frey & Osborne (2017)'s ranking, for instance, Transportation and Material Moving Occupations such as Locomotive Engineers, Locomotive Firers, Sailors and Marine Oilers were highly susceptible to computerization. However, several of these occupations require many abilities, ability types and a high average of complexity level which creates a challenge for integrating and, consequently, automating them. In our ranking, these occupations were in the above-average range, but not as highly susceptible. Another example was Management Occupations, pointed out as low susceptibility in Frey & Osborne (2017). Actually, the authors explained that "(…) most management, business, and finance occupations, which are intensive in generalist tasks requiring social intelligence, are largely confined to the low-risk category" (Frey & Osborne, 2017). In our ranking, though, several occupations within this group, like Sales Managers, Marketing Managers, Purchasing Managers had high susceptibilities for the reason that they did not require high levels of complexity and integration. We believe in this case, this observation is a result of only considering Abilities – therefore, Skills like Social Perceptiveness, Negotiation, and Persuasion, indicated as bottlenecks were not taken into account.

Afterward, we crosschecked our susceptibility ranking with the job market in the U.S., just like Frey & Osborne (2017) did. In spite of the differences in method and inputs (part of them), in the results of the new ranking and the lower number of occupations in the high-risk category, the outcomes found were exactly the same as those of Frey & Osborne (2017). Based on the calculations, 47% to 51% of the job positions in the U.S. both in 2016 and 2026 are in the high-risk category, meaning that occupations are potentially replaceable by Artificial Intelligence, Robotics, and related technologies in two decades or so. We interpret that the key reason to explain such a scenario is that our ranking, despite having fewer occupations in the high-risk caregory, had more impact in those that have the higher volume of job positions, which, in most cases, are characterized with less complexity and that require less integration of abilities.

Our major consideration in regard to this job market impact is that it is far from conclusive and should not be used indiscriminately as irrefutable. As mentioned, there are several other technical and non-technical variables that were not considered and that, most certainly, would have a reducing effect on the statistics just shared. Nonetheless, when evaluated in combination with Frey & Osborne (2017)'s findings, which have also several limitations, it is an important result to create awareness of the problem at hand, which is that Artificial Intelligence, Robotics, and related technologies can severely impact occupations and job markets, though not necessarily replacing humans. This is also a concern that was clearly highlighted by experts in the Delphi research, which is evaluated next in Chapter 0.

In terms of limitations, most of them are a derivation of those presented in Chapter 6, since its findings were an important input to calculate the rankings. Nonetheless, there are a few more to consider and some are similar to

Frey & Osborne (2017)'s paper. First of them is that this is forward-looking research and most of the described technological developments are yet to be implemented across industries and on a broader scale. In spite of using the Delphi method and the best knowledge from a group of the experts, as Frey & Osborne (2017) explain, "(…) making predictions about technological progress is notoriously difficult." Thus, it is important to note that, since O*NET does not cover any specific measures on the automatability of jobs, the estimates presented here are based on several assumptions and are a result of extrapolations of Abilities that computer-controlled equipment can be expected to perform. Second, is that O*NET occupational framework is a simplification of an intricate ecosystem and, as Frey & Osborne (2017) did, we also use part of it to derive a ranking, in this case, restricting our model only to Abilities. Occupations and Job Market are very complex and we just focused on part of the technical variables, not taking into account several other important exogenous variables that would have a lessening effect, such as social, economic and political bottlenecks yet to unfold – these are evaluated in Chapter 0. Third is related to the limitation of instruments and method themselves, which could not be adequate for this type of research or an eventual bias in the experts, more enthusiastic about technologies and/or more pessimistic about the future of occupations than we anticipated. Fourth is that we limit our evaluation on the Job Market to risk ranges and based on its current composition – job mix from 2016. As Frey & Osborne (2017), "we make no attempt to estimate how many jobs will actually be automated" and we don't make predictions on how the Job Market is going to evolve – for instance with new occupations yet to be uncovered. In that sense, there is a limitation in forward-looking based on the current picture, evaluating only part of the problem. Another limitation is about the Integration Complexity Reduction Factor. Unfortunately, we lack referenceable studies that can support and justify the decision of using Metcalfe's Law as the function that better represents the challenge of integrating technologies.

As mentioned, our initial intention to execute the same analysis on the impacts on Job Market in Brazil, and evaluate the potential impact of Artificial Intelligence, Robotics, and related technologies in a developing country and compare it to the findings in the U.S.. We expect that the impacts may be even higher due to the Brazilian market composition – though the cost/benefit equation may be quite averse to machines in a country where the cost of human labor is still cheap. We believe this would be an interesting endeavor and achievement, and it is our key recommendation for a future study. Expanding this research to an extended group, non-technical, could be interesting future complementation of the ranking – however, it would demand a different method, and finding mathematical confirmation of our key assumption of using Metcalfe's Law to represent the integration complexity would be two other suggestions for future studies.

8. Delphi Analysis and Discussion

In this chapter, we focus on the results of the Delphi research, which was designed to collect qualitative feedback from experts regarding impacts and bottlenecks of Artificial Intelligence and related technologies. First, we share some important considerations about the treatment of the data as mediators of the process. Then, we present in three sections the key findings in terms of implications to Organizations and to Work, Occupations, and Labor Market and finally the bottlenecks. In the closing section of this chapter, we present key considerations, conclusions, and limitations.

8.1. Preliminary Considerations

In Chapters 6 and 7 we managed to already identify some implications of Artificial Intelligence to Occupations and the Labor Market. However, we considered it was equally important to cross-check and confirm if experts indirectly agreed or not with these findings and conclusions by performing this Delphi Research. By indirectly we mean that the objective was not informed to participants in the interactions – we planned to collect their unbiased opinions, so we did not share any results from previous chapters. In this process of cross-checking, we understood it was also possible to uncover additional impacts, positive and negative, assessing what experts believed would be the key implications of using these technologies in Organizations and Work, Occupations, and Labor Market. Since we were accessing two different groups of professionals, with two different backgrounds (scholar and market), we also wanted to evaluate if there was any deviance between them. As in other topics in Information System and Management in general, scholars could have a different perspective from that of market professionals.

Apart from that, as seen in Chapters 6 and 7, Occupation is a very complex construct with many endogenous and exogenous variables. In the previous chapters, we evaluated only part of the technical endogenous variables measured by O*NET and did not take into account other important bottlenecks that could also have a lessening effect on the conclusions we previously shared. Therefore, with the Delphi Research, we also intended to partially address this analysis by collecting complementary opinions from experts regarding bottlenecks. We understood that thru this qualitative questioning and discussion among experts, we would be able to reaffirm known bottlenecks, but also uncover additional ones and define an overall ranking of bottlenecks.

Taking into account these objectives, and as explained in Chapter 5, we focused the attention of the experts to five key questions on Artificial Intelligence impacts and bottlenecks, which is the key structure of this section, since these questions were repeated in all 3 rounds, as we seek for rankings. The 5 questions were:

- What will be the key **Positive Impacts** of **Artificial Intelligence** (and related technologies) **to Organizations** in the next twenty years?

- What will be the key **Negative Impacts** of **Artificial Intelligence** (and related technologies) **to Organizations** in the next twenty years?

- What will be the key **Positive Impacts** of **Artificial Intelligence** (and related technologies) **to Occupations and Labor Market** in the next twenty years?

- What will be the key **Negative Impacts** of **Artificial Intelligence** (and related technologies) **to Occupations and Labor Market** in the next twenty years?

- What are (and will be) the key **Bottlenecks** for the progress of **Artificial Intelligence** (and related technologies), in other words, which areas AI will not be able to advance and will remain essentially human in the next twenty years?

Before proceeding, it is important to share the operational definition of the key terms in the questions for a correct understanding of what was asked to experts and of the results. These definitions are dictionary-based[238] adjusted to the context we are evaluating in this research.

- Artificial Intelligence: products and research in Machine Learning (ML), Data Mining and Big Data, Machine Vision (MV), Computational Statistics, as well as Mobile Robotics (MR) and other research fields in technology, Computer Sciences, Robotics and Mathematics related to AI. Experts were requested to consider all technologies they were aware of.

- Positive Impacts: something that produces good or helpful results or effects or that promotes well-being, in other words, resulting advantages and benefits; in this work, we are evaluating the benefits that Artificial Intelligence application may bring to Organizations and Work, Occupations, and Labor Market.

- Negative Impacts: something that produces disadvantageous, objectionable, not propitious results, in other words, resulting issues, problems, and drawbacks; in this work, we are also evaluating the drawbacks that Artificial Intelligence application may bring to Organizations and Work, Occupations, and Labor Market.

- Organizations: administrative and functional business structures, public and private companies and institutions, as well as and non-governmental groups, considering it as one of the major areas of interest in the area of Business, Administration and Management.

- Occupations and Work: types of regular remunerative jobs in different fields that require a mix of knowledge, skills, and abilities, and are performed using a variety of activities and tasks for several types that may be partially or totally executed by Artificial Intelligence, Robotics, and related

[238] https://www.merriam-webster.com

technologies. Labor Market is the complete set of occupations and the total positions in a particular geography.

- Bottlenecks: something that delays or blocks free movement and progress; in this case, we are considering bottlenecks of computerization and use of Artificial Intelligence, which means challenging or hindering areas for these technologies to automate, a concept shared by Frey & Osborne (2017).

In spite of including the term twenty years from now in the questions, we were not concerned with the time variable in this part of the research. The period served merely as a reference for experts so that they could better visualize the possible impacts and bottlenecks in a particular set of time. Therefore, in the following sections, we do not address any explanation or expect any confirmation in regard to time.

Evaluation Process

Based on this common foundation and in the Delphi Design and Execution detailed in Chapter 5, we share now how the evaluation process was executed and its supporting calculations and statistics.

In the 1st Round of the Delphi, we presented 5 open questions to experts, one for each of the major themes above-mentioned. We intentionally let experts share as much item as they wanted, asking them to point out at least 3 per question, "to maximize the chance of unearthing the most important issues, the respondents should be encouraged to submit as many issues as possible in this first phase" (Schmidt, 1997). We managed to collect several different opinions and comments from experts, though we also noticed several ideas which were not in our main scope for this research (such as impacts on society or specific Industries). Nonetheless, we considered these findings interesting, and we did not disregard them.

In this round, the consolidation process was the toughest part of the whole Delphi research analysis. Comments in their majority were very rich but also diverse and, therefore, it required a careful and thorough individual analysis from the researchers to combine the different opinions into a common list. To perform this assignment, for each of the 5 major questions we used a three-step process: first, we gathered all the answers/items from all participants and assessed individually each one of them, selecting keywords; second, for each item, we evaluated if the opinion really addressed the question at hand; third, subjectively, we started to cluster comments by resemblance of ideas and keywords. In doing so, we would combine opinions into new sentences that we believe encompassed similar ideas. In dealing with unstructured qualitative data, subjectivity was a major concern for us, especially of unintentional bias, which could affect the quality and reliability of the final results. Nonetheless, we tried to extract and use as much as possible the words, expressions, and sentences from the experts' opinions. Consolidation process was performed as a unique task for all comments, meaning we did not segregate opinions from scholar or market groups.

As part of the Delphi processes, our feedback to experts regarding the 1st Round was to present them the lists of impacts and bottlenecks of Artificial Intelligence based on their combined opinions, interpreted and summarized by the mediators. These lists of items were presented in an aleatory order to avoid possible bias. We had some positive reaction in terms of sharing the lists, with some experts mentioning the results were very interesting. However, we also had some negative reaction, especially about the sentences. According to a couple of experts, items were very alike, which made it very difficult to fulfill the missions requested in the following rounds.

For 2nd Round, we requested all the participants from the previous round to select the 10 most relevant items of each list in their view. We decided on 10 based on other researches and we took into account the fact that respondents had to analyze and execute this same chore for 5 lists, a time-consuming activity. Another reason is that, according to Schmidt (1997), setting an arbitrary size for the list forces the result, meaning it accelerates the consensus. Experts were also requested to submit an individual rank of each list, ordering items from 1 to 10, in order of relevance, no ties allowed. The idea with this second activity was to already force participants to think about prioritization of impacts and bottlenecks.

Once we had all the responses for 2nd Round, we moved on to the analysis and determination of the combined top 10 for each one the 5 questions. In this phase, we considered the responses of the entire group, without segregating between scholar and market yet. According to Schmidt (1997), if it is the study's goal is to compare groups, the lists of impacts and bottlenecks must have a common set of items, otherwise, "(…) the researcher will face great difficulty in subjectively mapping the groups' independently ranked items for comparison". To determine the 10 most relevant per list, first, we evaluated the frequency of each item, meaning how many experts had marked the item as relevant, independent of the ranking – we selected those with the higher frequencies. This required a complement, since we had several items tied in terms of frequencies. Thus, we also considered the average ranking of each item, combing both indicators in a weighted average. This procedure worked in most cases, but eventually, for the last positions in the ranking, we had also to consider a thumb rule to break the ties, which was the times a particular item was pointed as number 1.

Our feedback to experts regarding the 2nd Round was to present them the summarized lists of 10 impacts and bottlenecks based on their combined opinions. These lists of items were presented in an aleatory order to avoid possible bias. We also shared the combined ranking, or mean rank, which was calculated based on a combination of the average ranking and the frequency, a weighted average of the combined rankings. In doing so, we already reduced the options and indirectly forced a faster consensus (if applicable), which should be confirmed by the proper statistics. We also shared with the experts their own rankings, so that they could compare the combined ranking with their individual one. Based on this information, for 3rd Round, we requested all the participants from the previous round to resubmit individual ranking of each list, ordering items from 1 to 10, in order of relevance, no ties allowed. The idea was to consolidate the key items and later on evaluate consensus and compare groups. Apart from the mean rank, Schmidt (1997) suggests replying back to experts the interpretation of the consensus coefficient, the percentage of each of the respondents that selected the item or particular comments. However, we decided not to share this information because preliminary calculations showed that the opinions were very different, and no agreement existed.

In the analysis phase of the 3rd Round, we basically calculated the key statistics to evaluate agreement level, significances and such. As recommended by Schmidt (1997) and applied in Chaves (2011), we used Kendall's Coefficient of Concordance (*W*) as a measure of agreement, which makes "(…) a realistic determination of whether any consensus has been reached, whether the consensus is increasing, and the relative strength of consensus" (Schmidt, 1997). Kendall's *W* is a simple calculation and its results are easier to interpret, following the guidance in Table 66 – it ranges from 0 (total disagreement) to 1 (total agreement). To test the significance of *W*, we followed Chaves (2011) and execute Chi-Square Tests. We calculate *W* and χ^2 to all 5 lists and for the 3 possible scenarios: combined, scholar and market rankings.

W	Interpretation	Confidence in Ranks
0.1	Very weak agreement	None
0.3	Weak agreement	Low
0.5	Moderate agreement	Fair
0.7	Strong agreement	High
0.9	Unusually strong agreement	Very High

Table 66. Interpretation of Kendall's W

Source: Schmidt (1997)

Finally, to evaluate the similarities and, consequently, the agreement between two different groups – scholar and market, we use Kendall's Rank-Order Correlation Coefficient (*T*). According to Schmidt (1997), "*T* is used rather than the Spearman rank-order correlation coefficient because it emphasizes the relative ordering of the issues rather than the magnitude of the difference between ranks". A one-tailed test of significance is also used. If the agreement is not significant, then there are different views between the groups.

8.2. Impacts on Organizations

In the following sections, we evaluate the impacts of Artificial Intelligence, Robotics, and related technologies to Organizations, discussing first the positive ones, hereafter called benefits, and the negative, henceforth called drawbacks. We evaluate those with the help of the statistics just mentioned in the previous section.

Benefits to Organizations

In the first question of the Delphi Research, we intended to understand from experts what would be the key positive impacts of AI and related technologies to organizations in the near future. Once the questionnaire was launched and the responses were gathered for the 1st Round, we had around 80 distinct comments from the 24 experts. Comments were very diverse, which was considered as positive, in the sense that it granted a richer and broader content to work on. We then evaluated each one of these comments, grouped them and consolidated the main ideas as explained in the previous section. The final result was a summarized list of 32 Benefits to Organizations that are presented in Table 67, with the frequency of each item by resemblance.

Code	Description (EN)	Frequency
IPnO.001	Increase in productivity and efficiency of organizations' processes in general ("doing better")	11
IPnO.002	Increase in agility and speed of organizations' processes in general ("doing faster")	2
IPnO.003	Acceleration in the developing process of new products, services and / or technologies	3
IPnO.004	Acceleration in the dispersion of IA application, in an imperceptible, embedded and ubiquous way, and in processes, products and / or services	2
IPnO.005	Development and refinement of decision-making and problem-solving methods, improving decision quality	7
IPnO.006	Greater diversity of interaction forms between man and machine and consequent application in new functions in organizations	1
IPnO.007	Generalized automation of activities, especially those routine, repetitive, also advancing in complex tasks	7
IPnO.008	Evolution in the way of working with a focus on partnership and collaboration between machine and man, combining the strengths of each	3
IPnO.009	Improved knowledge management and training, with intelligent tutors, targeted content and better search support	1
IPnO.010	Evolution of security and defense mechanisms against problems, errors or damages, and prediction and prevention of accidents	2
IPnO.011	Reduction of risks associated with activities of high risk, of insalubrity (and of damages to the health) or of extreme fatigue	3
IPnO.012	Application of robotics and AI in activities and processes of high precision and reliability	3
IPnO.013	Reduction of bureaucracy (public and private) and delays, with the expansion of processes and / or services automation	1
IPnO.014	Propagation of the use of virtual assistants in daily life of organizations, functioning as a new productivity application	2
IPnO.015	Smarter use of resources (natural, human, time), reducing waste and improving the environment	4
IPnO.016	Expansion in the offer of products and / or services, in quantity, novelty and variability ("mix") and with scalability	5
IPnO.017	Improved use of available data, especially unstructured data, with new methods of discovery and analysis	6
IPnO.018	Improved quality of products, services and solutions, more efficient, smarter, and more accessible	10
IPnO.019	Release of people from tedious, alienating and low value-added activities to more challenging and value-added activities	5
IPnO.020	Better understanding of who the customers are, their expectations and desires regarding the products and / or services offered	2
IPnO.021	Improvement in the hiring process, with greater suitability and compliance with requirements and profile	1
IPnO.022	Improvement of supply chains, working more efficiently (fewer losses and breaks) with traceability	2
IPnO.023	Generation of new competitive advantages for organizations prepared for the future technological scenario	1
IPnO.024	Creation of targeted and customized products and / or services for particular needs, adding more value to the customer	7
IPnO.025	Improved data integration, allowing to combine information easily and with better results	1
IPnO.026	Increased governance and transparency, leveraged by new control mechanisms against corruption, diversion and fraud	2
IPnO.027	Evolution in the quality of life and well-being of people in organizations	3
IPnO.028	Creation of new business models (some still nonexistent) closely linked to technology ("uberization of the economy")	1
IPnO.029	Diversification in the nature of organizations, with companies changing offers and / or migrating from sector	2
IPnO.030	Greater accessibility and inclusion of people, technologies will help people with difficulties or with less experience	1
IPnO.031	Shifting the focus of the work from operational activities to analytical and strategic activities	2
IPnO.032	Reduced exposure to risk of errors, rework and work accidents with automation	2

Table 67. Benefits of AI to Organizations – Complete List

Among the 32 benefits collected, 6 were predominant – they were mentioned by more than 5 different experts. Actually, one of them was mentioned by almost half of the experts, which was IPnO.001, Increase in productivity and efficiency of organizations' processes in general ("doing better"). In a way, this particular benefit is a derivation of the key advantage of the preceding industrial and technological revolutions, which is basically improving productivity in organizations. And, as a likely result, increasing the quality of products, services and solutions, while making them more efficient, smarter, and also more accessible to people, which is described by benefit IPnO.018, also selected by several experts. The other preeminent items were miscellaneous, they covered from decision-making improving to a better understanding of customer needs.

Though it was not in the scope of this research, several experts also shared their thoughts on how Artificial Intelligence, Robotics, and related technologies are positively changing economies and industries. For Call Center, they expected better quality and better attendance; for Health Care, better treatments and instruments (both surgical and diagnosis) and fewer mistakes; for Education, better support both in teaching and learning; for

Transportation, improved means of control in logistics; for the Environment, better use of resources, less waste and pollution. Additionally, for Law, faster and better analysis of jurisprudence; for Security, increase in crime prevention, including digital crimes; for the Public Sector, better policies and better services. Many others were mentioned, which shows that experts believe the application of AI would bring benefits to practically all Industries. Another feedback from specialists, though not in the focus of this work, were the benefits to Society in general. Among those nonspecific positive impacts, we highlight five of them: change in mobility and transports, with increasing reliable autonomous options; applications in social welfare, improving people's quality of life; democratization of Medicine and Law, with more people accessing these services; enhanced Smarter Cities, better equipped and prepared for unforeseen changes; and improvement in Health Care services, with better diagnosis, treatments and health in general, leading to a better aging, more healthy and comfortable.

In the 2nd Round we shared the list of the 32 combined benefits and collected feedback from findings. But more importantly, as a result of 2nd Round, we managed to compress the list and find a combined top 10 of benefits of AI to organizations in the near future – this was obtained thru the process described in the previous section. In this process, we noticed that, from the final combined list, the market group presented a closer fit to the final list (8 out of 10) than scholar (5 out of 10), meaning that 8 out of the 10 items selected by market specialists were in the combined selection. We also noticed that some of 32 original benefits were not selected by either one group or both groups as relevant. This happened with the following benefits: IPnO.029, Diversification in the nature of organizations, with companies changing offers and/or migrating from sector; IPnO.010, Evolution of security and defense mechanisms against problems, errors or damages, and prediction and prevention of accidents; IPnO.013, Reduction of bureaucracy (public and private) and delays, with the expansion of processes and/or services automation; and IPnO.021, Improvement in the hiring process, with greater suitability and compliance with requirements and profile.

We then used 3rd Round to further refine the top 10, with special attention to the order of the elements so that we could create a ranking of AI Benefits to Organizations. Table 68 summarizes this top 10, from the most important (1) to the less important (10). Column Selected 2nd Round indicates how many experts chose this item as top 10, while columns Rank 2nd Round and Final Rank 3rd Round show the rankings by the end of each phase for comparison purposes.

Code	Description (EN)	Selected 2nd Round	Rank 2nd Round	Final Rank 3rd Round
IPnO.001	Increase in productivity and efficiency of organizations' processes in general ("doing better")	65%	1	1
IPnO.007	Generalized automation of activities, especially those routine, repetitive, also advancing in complex tasks	50%	3	2
IPnO.017	Improved use of available data, especially unstructured data, with new methods of discovery and analysis	65%	2	3
IPnO.002	Increase in agility and speed of organizations' processes in general ("doing faster")	45%	7	4
IPnO.005	Development and refinement of decision-making and problem-solving methods, improving decision quality	65%	4	5
IPnO.008	Evolution in the way of working with a focus on partnership and collaboration between machine and man, combining the strengths of each	40%	6	6
IPnO.004	Acceleration in the dispersion of IA application, in an imperceptible, embedded and ubiquous way, and in processes, products and / or services	35%	5	7
IPnO.018	Improved quality of products, services and solutions, more efficient, smarter, and more accessible	45%	9	8
IPnO.028	Creation of new business models (some still nonexistent) closely linked to technology ("uberization of the economy")	40%	8	9
IPnO.011	Reduction of risks associated with activities of high risk, of insalubrity (and of damages to the health) or of extreme fatigue	40%	10	10

Table 68. Benefits of AI to Organizations – Top 10

Next, we evaluated the level of opinion consensus among the experts about this ranking. We calculated Kendall's coefficient of concordance W_{OPI} statistic as explained in the previous section and the result was 0.33, which can be considered as a weak to moderate agreement according to Schmidt (1997)'s ranges. We also calculated Chi-Square's χ^2_{OPI} statistic to evaluate W's significance and the result was 57.23, which means W_{OPI} is significant in $p < .001$. According to Chaves (2011) and Schmidt (1997), based on both statistics, we can consider that this ranking reached some level of agreement.

Code	Description (EN)	Final Rank 3rd Round	Scholar Rank 3rd Round	Market Rank 3rd Round
IPnO.001	Increase in productivity and efficiency of organizations' processes in general ("doing better")	1	1	1
IPnO.007	Generalized automation of activities, especially those routine, repetitive, also advancing in complex tasks	2	2	2
IPnO.017	Improved use of available data, especially unstructured data, with new methods of discovery and analysis	3	3	3
IPnO.002	Increase in agility and speed of organizations' processes in general ("doing faster")	4	4	5
IPnO.005	Development and refinement of decision-making and problem-solving methods, improving decision quality	5	5	4
IPnO.008	Evolution in the way of working with a focus on partnership and collaboration between machine and man, combining the strengths of each	6	7	5
IPnO.004	Acceleration in the dispersion of IA application, in an imperceptible, embedded and ubiquous way, and in processes, products and / or services	7	6	8
IPnO.018	Improved quality of products, services and solutions, more efficient, smarter, and more accessible	8	9	7
IPnO.028	Creation of new business models (some still nonexistent) closely linked to technology ("uberization of the economy")	9	7	9
IPnO.011	Reduction of risks associated with activities of high risk, of insalubrity (and of damages to the health) or of extreme fatigue	10	10	10

Table 69. Benefits of AI to Organizations – Scholar vs Market

Considering that we had two groups of background, scholar and market, we wanted to confirm if there was some kind of discrepancy in their evaluation of the Benefits of AI to Organizations. Table 69 illustrates this discussion, presenting the combined ranking, the scholar ranking, and the market ranking, all from the end of the 3rd Round. We can visually check that scholar ranking is pretty similar to the consolidated one, especially in the top 5 positions, while the market ranking has more variances. Nonetheless, there is a high agreement in the top 3 and in regard to IPnO.001, which was the first in frequency in Round 1 and also the top 1 in all three rankings.

In spite of having more respondents (11), which could potentially affect the consensus, in the scholar ranking we can note a higher agreement as a group, than in the market group, as shown in Table 70 with the help of the group *W*'s. To measure the agreement between the two groups, we calculate and evaluate Kendall's rank-order correlation coefficient *T* as indicated by Schmidt (1997). We found $T_{OPI} = 0.87$ and consulting a table of exact probabilities for *T*, the one-tailed probability is $p < .001$, so the two groups of experts, scholars and market professionals, do agree on the ranking of Benefits of AI to Organizations.

Statistic	Final Rank 3rd Round	Scholar Rank 3rd Round	Market Rank 3rd Round
Kendall's W_{OPI}	0.33	0.37	0.32
W's interpretation	weak to moderate	moderate	weak to moderate
Chi Square's X_{OPI}	57.23	36.48	22.75
Significance	p < .001	p < .001	p < .01
Experts (n)	19	11	8

Table 70. Benefits of AI to Organizations – Scholar vs Market

As key findings in regard to Benefits of AI to Organizations, we interpret experts to believe that, with the generalization and widespread dispersion of Artificial Intelligence, automation will happen not only to repetitive tasks but to some complex ones too. This will allow organizations to do things better and do them faster, with improved quality of products, services, and solutions, more efficient, smarter, and more accessible – actually, processes, products and/or services will have AI imperceptibly embedded in them. We understand that those positive impacts are similar in form (but not content) to predecessor technological revolutions. Moreover, AI and related technologies will also improve the use of available data, especially unstructured data, with new methods of discovery and analysis and support the development and refinement of decision-making and problem-solving methods, improving quality in decisions. Technologies will also improve the quality of life within organizations and reduce risks associated with activities of high risk, insalubrity or extreme fatigue. Experts also believe one of the key benefits of AI to organizations will be the creation of new business models (some that do not exist today) closely linked to technology ("uberization of the economy"). Finally, we see a confirmation in one of the topics previously evaluated. Experts consider that AI will also change and evolve the ways of working within the organizations, with an increasing focus on partnership and collaboration between machine and man, combining the strengths of each, which is a view we share with the experts.

Drawbacks to Organizations

The objective of the second question of the Delphi research, on the other hand, was to understand from experts what would be the key drawbacks and negative impacts of AI, Robotics and related technologies to organizations in the near future. We managed to collect in 1st Round around 70 distinct comments from the 24 experts. Once again, comments were diverse and granted a richer but complex analysis. We evaluated each one of the comments, grouped them and consolidated the main ideas in a summarized list of 31 Drawbacks of AI to Organizations that are presented in Table 71, with the frequency of each item by resemblance.

Code	Description (EN)	Frequency
INnO.001	Problems arising from the inability to identify and decide in unknown, new or bursting scenarios	3
INnO.002	Excessive dependence of organizations on machines, generating problems when these do not have responses	3
INnO.003	Mass replacement of human labor by machinery in organizations, collaborating with potential unemployment	7
INnO.004	Need for mass retraining of staff due to obsolescence of careers and functions at all levels	1
INnO.005	Reduction in the demand for products and / or services, due to the increase in the potential unemployment generated by the technologies	1
INnO.006	Distrust and dissatisfaction with AI due to lack of transparency in the decision-making process ("black box" effect)	3
INnO.007	Misapplication, bias, misuse of technology, for improper, unethical, illegal and / or criminal purposes	12
INnO.008	Problems with socially inadequate AI behaviors such as racial, sexual, religious, political discrimination, etc.	4
INnO.009	Loss or lack of control of the organizations on the 'autonomous' algorithms, or inability to detect errors in these algorithms	1
INnO.010	Overvaluation of machines (and their results) to the detriment of human opinions, expertise and experiences	3
INnO.011	Banalization of the use of technologies, that is, unrestricted application in tasks and services in which human skills are essential	3
INnO.012	Intensification of privacy issues: data breach, use without consent and / or for inappropriate purposes	11
INnO.013	Increased costs in information security to control IA and to combat privacy, audit and mitigation issues	3
INnO.014	Loss of competitiveness and risk of bankruptcy of organizations that do not change to the new paradigm quickly	8
INnO.015	Expansion in people and organizations the control, affecting privacy, restriction of freedoms and individualities, etc.	2
INnO.016	Excessive control and economic, social and knowledge concentration in few organizations	4
INnO.017	Problems due to a new organization / employee relationship with different forms and natures	2
INnO.018	New legislation to protect employment, such as creating market reserves, intensifying the regulatory role of the State	3
INnO.019	Lack of skilled labor, since the educational system is not prepared for the new requirements	2
INnO.020	Continuous and increasing growth in technology costs (hardware, software, algorithms, robots, professionals, etc.)	3
INnO.021	Distancing between expectations and reality with AI, since the implementation of quality is still slow, costly and limited	1
INnO.022	Aversion or resistance to change, varied difficulties in dealing with technologies and / or slow speed of adoption	3
INnO.023	Inequality and increasing imbalance among human resources in organizations, affecting their overall performance	1
INnO.024	Increased competitiveness on a global scale with commercial battles including those between organizations (and their algorithms)	1
INnO.025	Obsolescence of various current business strategies (for example, outsourcing of labor to less expensive countries)	1
INnO.026	Conflicts in the lack of definition of roles and responsibilities between machines and humans ("what should the machine do or should not do?")	0
INnO.027	Problems arising from inability to treat or identify scenarios with potential ethical and moral conflicts	0
INnO.028	Negative consequences of image and market value of organizations due to the different issues described	0
INnO.029	Reduction of entry barriers, with new "non-traditional" competitors (lean, agile, productive, technology-based)	0
INnO.030	Increased unpredictability, volatility, and dynamism of sectors and markets, affecting organizations' planning and strategies	0
INnO.031	Problems of organizations in creating, maintaining, recognizing and retaining talent considering the new reality of employment	0

Table 71. Drawbacks of AI to Organizations – Complete List

Among the drawbacks, 4 were predominant – they were mentioned by more than 5 different experts. Actually, two of them were mentioned by half of the experts: INnO.007, Misapplication, bias, misuse of technology, for improper, unethical, illegal and/or criminal purposes and INnO.012, Intensification of privacy issues: data breach, use without consent and/or for inappropriate purposes. Both are topics extensively discussed currently, as shown in recent World Economic Forums[239]. On the other hand, some of them were not directly mentioned by experts in this particular question but were gathered and derived from other comments, several of them associated with the organizational environment.

As in the Benefits, several experts also shared their thoughts on how Artificial Intelligence will negatively impact Industries and Society. Some of them were examples and illustrations of the drawbacks presented in

[239] https://www.youtube.com/watch?v=Lzqw5c0Myqw

Table 71. Experts demonstrated some concerns regarding the usage of these technologies for warfare and for critical decision situations, where a sense of ethics, moral and legal knowledge are required. Also, as a consequence of the replacement and unemployment of several people, specialists believe it may increase the social inequality within countries and among countries, with what could be a new International Division of Labor, in line with Brynjolfsson & McAfee (2014) discussion. Two other negative comments were about the increase of misinformation about what is AI and how it can be used for good, as well as consequences of the exponential increase of data volume and data traffic.

In the 2nd Round, we shared the list of the 31 combined drawbacks and collected feedback from findings. We managed to compress the list and find a combined top 10 of Drawbacks of AI to Organizations in the near future. In this process, we noticed that the from the final combined list, scholar group presented a closer fit to the final list (9 out of 10) than the market (8 out of 10), meaning that 9 out of the 10 items selected by scholar specialists were in the final combined selection. We also identified some drawbacks that were not selected by either one or both groups. This was the case of INnO.017, Problems due to a new organization / employee relationship with different forms and natures; INnO.028, Negative consequences of image and market value of organizations due to the different issues described; INnO.031, Problems of organizations in creating, maintaining, recognizing and retaining talent considering the new reality of employment; INnO.020, Continuous and increasing growth in technology costs (hardware, software, algorithms, robots, professionals, etc.); and INnO.023, Inequality and increasing imbalance among human resources in organizations, affecting their overall performance.

In 3rd Round, we further refined the top 10, with special attention to the order of the elements in order to create a ranking of drawbacks to organizations. Table 72 summarizes the top 10, from the most important (1) to the less important (10). Column Selected 2nd Round indicates how many experts chose this item as top 10, while columns Rank 2nd Round and Final Rank 3rd Round show the rankings by the end of each phase for comparison purposes.

Code	Description (EN)	Selected 2nd Round	Rank 2nd Round	Final Rank 3rd Round
INnO.006	Distrust and dissatisfaction with AI due to lack of transparency in the decision-making process ("black box" effect)	80%	1	1
INnO.004	Need for mass retraining of staff due to obsolescence of careers and functions at all levels	50%	3	2
INnO.007	Misapplication, bias, misuse of technology, for improper, unethical, illegal and / or criminal purposes	80%	1	3
INnO.003	Mass replacement of human labor by machinery in organizations, collaborating with potential unemployment	60%	4	4
INnO.012	Intensification of privacy issues: data breach, use without consent and / or for inappropriate purposes	55%	6	5
INnO.021	Distancing between expectations and reality with AI, since the implementation of quality is still slow, costly and limited	55%	5	6
INnO.019	Lack of skilled labor, since the educational system is not prepared for the new requirements	40%	9	7
INnO.027	Problems arising from inability to treat or identify scenarios with potential ethical and moral conflicts	65%	7	8
INnO.016	Excessive control and economic, social and knowledge concentration in few organizations	45%	8	9
INnO.010	Overvaluation of machines (and their results) to the detriment of human opinions, expertise and experiences	40%	10	10

Table 72. Drawbacks of AI to Organizations – Top 10

Next, we evaluated the level of opinion consensus among the experts about this ranking. We calculated Kendall's coefficient of concordance W_{ONI} statistic and the result was 0.18, which can be considered as a very weak agreement based on Schmidt (1997)'s ranges. In fact, the conclusion here is that there is no agreement on the top 10 drawbacks of AI to Organizations, between experts, even though the calculated Chi-Square's χ^2_{ONI} statistic was 29.82, which means W_{ONI} is significant in $p < .001$.

Considering that we had two groups of background, Scholar and Market, we wanted to confirm if there was some kind of discrepancy in their evaluation of the key Drawbacks of AI in Organizations. Table 73 illustrates this evaluation, presenting the combined ranking, the scholar ranking, and the market ranking, all from the end of the 3rd Round. We can visually check that scholar ranking is pretty similar to the consolidated one, especially in the top 5 positions, while the market ranking has more variances. Nonetheless, there is a high agreement in the top 3.

Code	Description (EN)	Final Rank 3rd Round	Scholar Rank 3rd Round	Market Rank 3rd Round
INnO.006	Distrust and dissatisfaction with AI due to lack of transparency in the decision-making process ("black box" effect)	1	1	2
INnO.004	Need for mass retraining of staff due to obsolescence of careers and functions at all levels	2	3	1
INnO.007	Misapplication, bias, misuse of technology, for improper, unethical, illegal and / or criminal purposes	3	3	3
INnO.003	Mass replacement of human labor by machinery in organizations, collaborating with potential unemployment	4	2	7
INnO.012	Intensification of privacy issues: data breach, use without consent and / or for inappropriate purposes	5	5	4
INnO.021	Distancing between expectations and reality with AI, since the implementation of quality is still slow, costly and limited	6	6	5
INnO.019	Lack of skilled labor, since the educational system is not prepared for the new requirements	7	8	7
INnO.027	Problems arising from inability to treat or identify scenarios with potential ethical and moral conflicts	8	10	6
INnO.016	Excessive control and economic, social and knowledge concentration in few organizations	9	7	10
INnO.010	Overvaluation of machines (and their results) to the detriment of human opinions, expertise and experiences	10	9	9

Table 73. Drawbacks of AI to Organizations – Scholar vs Market

Scholar ranking was the one with less disagreement, compared to the market group, as shown in Table 74 with the help of the individual *W*'s. To measure the agreement between the two groups, we calculate and evaluate Kendall's rank-order correlation coefficient *T* as indicated by Schmidt (1997). We found $T_{ONI} = 0.51$ and consulting a table of exact probabilities for *T*, the one-tailed probability is $p < .05$, so the two groups of experts, scholars and market professionals, do agree to a certain extent on the ranking of Drawbacks of AI to Organizations.

Statistic	Final Rank 3rd Round	Scholar Rank 3rd Round	Market Rank 3rd Round
Kendall's W_{ONI}	0.18	0.24	0.18
W's interpretation	very weak	very weak	very weak
Chi Square's X_{ONI}	29.82	21.51	12.93
Significance	$p < .001$	$p < .01$	not significant
Experts (n)	18	10	8

Table 74. Drawbacks of AI to Organizations – Scholar vs Market

As key conclusions, we can interpret that experts have several concerns with the usage and the ways of working of AI, such as lack of transparency in the decision-making process; AI misapplication, bias, misuse for improper, unethical, illegal and/or criminal purposes; inability to treat or identify scenarios with potential ethical and moral conflicts; and intensification of privacy issues like data breach, use without consent and/or for inappropriate purposes. Those drawbacks are especially worrying when we could face situations where there is an overvaluation of machines (and their results) to the detriment of human opinions, expertise, and experiences. There is also a major group of AI drawbacks related to work, such as the increase in unemployment due to the replacement of human labor by machinery in organizations, the lack of skilled labor, since the educational system is not prepared for the new requirement, and, as a consequence, a major retraining effort of staff due to obsolescence of careers and functions at all levels. These negative impacts are in line with what was found in the previous chapters, meaning that experts confirmed also in this qualitative piece that consequences to employment and occupations are one of the key drawbacks of the application of Artificial Intelligence. Some of these occupational drawbacks are covered in the following sections in further detail when we evaluate implications to Occupations. Another important drawback is the excessive economic, social, and knowledge control that hold this knowledge in a few organizations. Finally, there is also a concern with the usual overpromising seen in the Information Systems area, meaning the increasing gap between expectations and reality with AI applications, since the good implementations are still slow, costly and limited.

8.3. Impacts on Work, Occupations and Labor Market

In the following sections, we evaluate the impacts of Artificial Intelligence, Robotics, and related technologies to Work, Occupations and Labor Market, discussing first the positive ones, Benefits, and then negative, Drawbacks. We evaluate those with the help of the statistics just mentioned in the previous section.

Benefits to Work, Occupations and Labor Market

The third question of the Delphi research was intended to capture from experts what were the key positive impacts of Artificial Intelligence and related technologies to work, occupations and labor market in the near future. We managed to collect in 1st Round around 70 distinct comments from the 24 experts and evaluated each one of them, grouped and consolidated the main ideas in a summarized list of 29 Benefits of AI to Work, Occupations and Labor Market, presented in Table 75, with the frequency of each item by resemblance.

Code	Description (EN)	Frequency
IPnT.001	Advantages for professionals in areas less affected by new technologies	1
IPnT.002	Valuing professionals with a solid background, high level of education, skills and experience in new technologies	10
IPnT.003	Creation of new careers and functions within organizations, significant part is technologically based, yet more demanding	14
IPnT.004	Improved productivity and individual efficiency at work	6
IPnT.005	Creation of new jobs, to meet new types of business, products and / or services	9
IPnT.006	Creation of new public (or private) social policies as minimum income, in order to balance the labor market	1
IPnT.007	Increased longevity of professionals in the labor market, associated with an increase in life expectancy	2
IPnT.008	Reduction of current working hours volume and greater flexibility in working hours	3
IPnT.009	Increased importance of non-governmental or non-profit organizations in the labor market (jobs)	1
IPnT.010	Replacement of human labor in repetitive, tedious, alienating and / or low value-added activities	11
IPnT.011	Replacement of human labor in activities of high risk, unhealthy (and damage to health) and / or extreme fatigue	4
IPnT.012	Extension of remote work, reducing the need for commuting or great distances to work	2
IPnT.013	Change in the work and the profile of the requested professional: more creative, innovative, analytical, strategic, intellectual and abstract	11
IPnT.014	Reducing geographic and cultural barriers to hiring trained resources	1
IPnT.015	Dissemination and democratization of knowledge and information and, therefore, the possibility of training	2
IPnT.016	Improvement in quality of life and well-being, freeing people and allowing a better balance between leisure and work	2
IPnT.017	Reduction of human errors, as well as of accidents at work with the increasing automation of processes	2
IPnT.018	Better use, exploration, and enhancement of the unique talents and skills of humans	2
IPnT.019	New way of working, of partnership between machine and man, where the strengths of each are combined in synergy	2
IPnT.020	Propagation of the use of virtual assistants in people's daily life, functioning as a new productivity application	1
IPnT.021	Creation of a parallel labor market of workforce made of robots and artificial intelligence	1
IPnT.022	Evolution of the academic curriculum to meet the new demand of professionals, careers, skills and knowledge	1
IPnT.023	Increased awareness of people's contexts and knowledge	1
IPnT.024	Improvement of professions with the use of technologies, mainly those based on data	1
IPnT.025	Reformulation of labor laws and change in the way human resources are managed	1
IPnT.026	Greater satisfaction at work, with more rewarding, satisfactory and enriching functions	1
IPnT.027	Valuing professionals with skills such as adaptability, multidisciplinarity and improvisation	0
IPnT.028	Greater accessibility and inclusion of people, technologies will help people with difficulties or with less experience	0
IPnT.029	Enhancement in training, with intelligent tutors, targeted content and better search support	0

Table 75. Benefits of AI to Work, Occupations and Labor Market – Complete List

Among the benefits, 6 were predominant – they were mentioned by more than 5 different experts. One of them was mentioned by more than half of the experts, which was IPnT.003, Creation of new careers and functions within organizations, a significant part technologically based, yet more demanding. Three other were also quite frequent: IPnT.010, Replacement of human labor in repetitive, tedious, alienating and/or low value-added activities; IPnT.013, Change in the work and the profile of the requested professional: more creative, innovative, analytical, strategic, intellectual and abstract; and IPnT.002, Valuing professionals with a solid background, high level of education, skills, and experience in new technologies. Some of them were not directly mentioned by experts in this particular question but were gathered or derived based on comments from other questions (the last three on the list which had no counts).

In the 2nd Round, we shared the list of the 29 combined benefits and collected feedback from findings. We managed to compress the list and find a combined top 10 of Benefits of AI to Work, Occupations and Labor Market in the near future. In this process, we noticed that based on the final combined list, both groups presented close fits to the final list, scholar (9 out of 10) and market (8 out of 10). We also verified that several benefits that were not selected by either group, actually, 9 of them, which resulted in an unexpected concentration in few benefits. Either scholar or specialists experts did not select the following benefits: IPnT.006, Creation of new public (or private) social policies as minimum income, in order to balance the labor market; IPnT.007, Increased longevity of professionals in the labor market, associated with an increase in life expectancy; IPnT.008, Reduction of current working hours volume and greater flexibility in working hours; IPnT.015, Dissemination and democratization of knowledge and information and, therefore, the possibility of training; IPnT.016, Improvement in quality of life and well-being, freeing people and allowing a better balance between leisure and work; IPnT.021, Creation of a parallel labor market of the workforce made of robots and artificial intelligence; IPnT.023, Increased awareness of people's contexts and knowledge; IPnT.025, Reformulation of labor laws and change in the way human resources are managed; and IPnT.029, Enhancement in training, with intelligent tutors, targeted content and better search support.

In 3rd Round, we further refined the top 10, with special attention to the order of the elements whit the objective of creating a ranking of benefits of AI to work, occupations and labor market. Table 76 summarizes the top 10, from the most important (1) to the less important (10). Column Selected 2nd Round indicates how many experts chose this item as top 10, while columns Rank 2nd Round and Final Rank 3rd Round show the rankings by the end of each phase for comparison purposes.

Code	Description (EN)	Selected 2nd Round	Rank 2nd Round	Final Rank 3rd Round
IPnT.003	Creation of new careers and functions within organizations, significant part is technologically based, yet more demanding	68%	2	1
IPnT.010	Replacement of human labor in repetitive, tedious, alienating and / or low value-added activities	79%	3	2
IPnT.004	Improved productivity and individual efficiency at work	58%	1	3
IPnT.013	Change in the work and the profile of the requested professional: more creative, innovative, analytical, strategic, intellectual and abstract	84%	5	4
IPnT.011	Replacement of human labor in activities of high risk, unhealthy (and damage to health) and / or extreme fatigue	63%	8	5
IPnT.019	New way of working, of partnership between machine and man, where the strengths of each are combined in synergy	58%	6	6
IPnT.005	Creation of new jobs, to meet new types of business, products and / or services	68%	4	7
IPnT.002	Valuing professionals with a solid background, high level of education, skills and experience in new technologies	74%	7	8
IPnT.027	Valuing professionals with skills such as adaptability, multidisciplinarity and improvisation	58%	9	9
IPnT.024	Improvement of professions with the use of technologies, mainly those based on data	58%	10	10

Table 76. Benefits of AI to Work, Occupations and Labor Market – Top 10

Next, we evaluated the level of opinion consensus among the experts about this ranking. We calculated Kendall's coefficient of concordance W_{WPI} statistic and the result was 0.19, which can be considered as a weak agreement based on Schmidt (1997)'s ranges. In fact, the conclusion here is that there is no agreement on the top 10 benefits of AI to Work. We calculated Chi-Square's χ^2_{WPI} statistic to evaluate W's significance and the result was 30.12, which means W_{WPI} is significant in $p < .001$.

An interesting analysis comes from the comparison of the two groups, Scholar and Market. Table 77 illustrates this discussion, presenting the combined ranking, the scholar ranking, and the market ranking, all from the end of the 3rd Round. We can see several differences, especially in the market ranking.

Code	Description (EN)	Final Rank 3rd Round	Scholar Rank 3rd Round	Market Rank 3rd Round
IPnT.003	Creation of new careers and functions within organizations, significant part is technologically based, yet more demanding	1	1	6
IPnT.004	Improved productivity and individual efficiency at work	3	2	3
IPnT.010	Replacement of human labor in repetitive, tedious, alienating and / or low value-added activities	2	3	2
IPnT.013	Change in the work and the profile of the requested professional: more creative, innovative, analytical, strategic, intellectual and abstract	4	4	5
IPnT.005	Creation of new jobs, to meet new types of business, products and / or services	7	5	7
IPnT.002	Valuing professionals with a solid background, high level of education, skills and experience in new technologies	8	6	10
IPnT.011	Replacement of human labor in activities of high risk, unhealthy (and damage to health) and / or extreme fatigue	5	7	4
IPnT.019	New way of working, of partnership between machine and man, where the strengths of each are combined in synergy	6	8	1
IPnT.027	Valuing professionals with skills such as adaptability, multidisciplinarity and improvisation	9	9	8
IPnT.024	Improvement of professions with the use of technologies, mainly those based on data	10	10	9

Table 77. Benefits of AI to Work, Occupations and Labor Market – Scholar vs Market

Apart from the visual differences, we could confirm that group rankings showed more agreement within themselves than the combined analysis of all the participants. In other words, there are considerable differences in how scholar and market professionals see the benefits of Artificial Intelligence to work, occupations and market labor. Scholar ranking was the one with less disagreement, as shown in Table 78. To confirm this analysis between the two groups, we calculate and evaluate Kendall's rank-order correlation coefficient T as indicated by Schmidt (1997). We found $T_{WPI} = -0.24$ and consulting a table of exact probabilities for T, the one-tailed probability is not significant, which corroborates the previous analysis of disagreement between the two groups.

Statistic	Final Rank 3rd Round	Scholar Rank 3rd Round	Market Rank 3rd Round
Kendall's W_{WPI}	0.19	0.33	0.26
W's interpretation	very weak	weak to moderate	weak
Chi Square's X_{WPI}	30.12	29.47	18.87
Significance	$p < .001$	$p < .001$	$p < .05$
Experts (n)	18	10	8

Table 78. Benefits of AI to Work, Occupations and Labor Market – Scholar vs Market

The difference between the two groups can be summarized in two specific benefits. On one hand, while scholars understood that the key benefit of AI will be the creation of new careers and functions within organizations (IPnT.003), market professionals did not rank it between the top 5 benefits. On the other hand, in the combined opinions of market professionals, the key benefit of IA will be the introduction of new ways of working, evidencing the partnership between machine and man, where the strengths of each are combined in synergy (IPnT.019) – scholars ranked this as one of the last in their top 10 benefits.

As key considerations about benefits of AI, Robotics, and related technologies, we interpret that experts believe these technologies will bring positive impacts for several risky or alienating occupations, replacing humans in repetitive, tedious and/or low value-added activities and also in unhealthy (and damaging to health) and/or extreme fatigue activities. Also, it will improve work and occupations by increasing their productivity thru the increasing use of technologies and data. They also expect a positive change for people. The profile of the requested professional will be more creative, innovative, analytical, strategic, intellectual and abstract, professionals with a solid background, high level of education, skills, and experience in new technologies will be highly valued, especially with adaptability, multidisciplinarity and improvisation skills. Experts also believe that Artificial Intelligence will create new careers and functions within organizations, mostly technologically based and new job positions to meet new types of business, products and/or services. Finally, experts believe in a new way of working, of the partnership between machine and man, where the strengths of each are combined in synergy, confirming one of the results seen in the previous chapters.

Drawbacks to Work, Occupations and Labor Market

The fourth question of the Delphi research was designed to identify from experts the key negative impacts of AI and related technologies to work, occupations and labor market in the near future. Around 65 distinct comments were collected from experts in 1st Round. We evaluated the comments, grouped them and consolidated the main ideas in a summarized list of 31 drawbacks to work, occupations and the labor market that are presented in Table 79, with the frequency of each item by resemblance.

INnT.002, Compulsive withdrawal from the labor market of the less qualified and schooled (repetitive and traditional tasks), was pointed out by two-thirds of the experts. Other predominant impacts, mentioned by more than 5 different experts, were INnT.001, Unemployment, due to the faster and more intense reduction of opportunities compared to the creation of new jobs; INnT.003, Sensitive changes (and in the limit, extinction) of careers and functions at all levels and in various areas and purposes; INnT.012; Intense compulsory retraining, to adjust the new skills required by jobs and the labor market; and INnT.014, Low and/or slow adaptation of people to the new requirements, especially those with low technological knowledge.

Code	Description (EN)	Frequency
INnT.001	Unemployment, due to the faster and more intense reduction of opportunities compared to the creation of new jobs	13
INnT.002	Compulsive withdrawal from the labor market of the less qualified and schooled (repetitive and traditional tasks)	16
INnT.003	Significant changes (and in the limit, extinction) of careers and functions at all levels and in various areas and purposes	7
INnT.004	Excessive dependence of professionals on machines, generating problems when the machines do not have answers	1
INnT.005	Growing ignorance and difficulty of understanding technologies due to a lack of an adequate conceptual basis	2
INnT.006	Need for public (or private) social policies and minimum income, in order to balance the labor market	1
INnT.007	Excessive expansion in professionals supply in the labor market due to the increase in people's life expectancy	1
INnT.008	General deterioration of personal relationships in the work environment, becoming increasingly impersonal	2
INnT.009	Excessive concentration of employment in certain areas and economic sectors to the detriment of others	1
INnT.010	Increasing, constant and excessive need for especialization of professionals	2
INnT.011	Greater unpredictability, volatility and dynamism in the labor market, generating anxiety and stress for professionals	3
INnT.012	Intense compulsory retraining, to adjust the new skills required by jobs and the labor market	6
INnT.013	Problems in setting limits, not only ethical and moral but also for the use of new technologies at work	1
INnT.014	Low and / or slow adaptation of people to the new requirements, especially those with low technological knowledge	9
INnT.015	Intensification of the difficulties of allocating age extremes in the market (lack of experience or difficulty of adaptation)	2
INnT.016	Problems in view of the new reality in the organization / employee relationship with different forms and natures	1
INnT.017	Increase in informality and employment volatility with more ephemeral relationships between organizations and professionals	3
INnT.018	Difficulties in reallocation (time and cost), either due to lack of skills, jobs or an increase in professionals supply	1
INnT.019	Devaluation of human labor, illustrated by the reduction of salary in those activities in which the machine is better	1
INnT.020	Lack of skilled labor, since the educational system is not prepared for the new requirements	3
INnT.021	Increasing mismatch between academia and market, that is, between the training of people and the needs of the market	2
INnT.022	Increased competitiveness and rivalry between professionals in the environment and the labor market	2
INnT.023	Reversion in the wave of 'outsourcing', mainly affecting labor markets in developing countries	1
INnT.024	Excessive economic, social and knowledge control in few individuals and / or organizations	3
INnT.025	Increasingly mix of demanding skills, knowledge and practical experience to perform more elaborate work	2
INnT.026	Requirement for good professionals in both technical skills (hard skills) and personal skills (soft skills)	1
INnT.027	Varied difficulties in dealing with or adapting to technologies and / or slow adoption speed	1
INnT.028	Labor legislation lagged and unbalanced by changes caused by AI, responding too late to problems	2
INnT.029	Increased time and investment in education until entrying into the labor market due to the level of job requirements	1
INnT.030	Inequality and growing imbalance among professionals, professions and labor markets	0
INnT.031	Reduction in people's quality of life: more unemployed, more demands, greater competition and job retention	0

Table 79. Drawbacks of AI to Work, Occupations and Labor Market – Complete List

In the 2nd Round, we shared the list of the 31 combined drawbacks and collected feedback from findings. We managed to compress the list and find a combined top 10 of drawbacks of AI to work, occupations and labor market in the near future. In this process, we noticed that from the final combined list, the scholar group presented a closer fit to the final list (9 out of 10) than the market (6 out of 10). I was also identified that some drawbacks were not selected by either one of the groups. None of the experts selected INnT.007, Excessive expansion in professionals supply in the labor market due to the increase in people's life expectancy; and INnT.017, Increase in informality and employment volatility with more ephemeral relationships between organizations and professionals.

In 3rd Round, we further refined the top 10, with special attention to the order of the elements, to create a top 10 ranking of drawbacks. Table 80 summarizes the top 10, from the most important (1) to the less important (10). Column Selected 2nd Round indicates how many experts chose this item as top 10, while columns Rank 2nd Round and Final Rank 3rd Round show the rankings by the end of each phase for comparison purposes.

Code	Description (EN)	Selected 2nd Round	Rank 2nd Round	Final Rank 3rd Round
INnT.002	Compulsive withdrawal from the labor market of the less qualified and schooled (repetitive and traditional tasks)	70%	1	1
INnT.014	Low and / or slow adaptation of people to the new requirements, especially those with low technological knowledge	55%	3	2
INnT.003	Significant changes (and in the limit, extinction) of careers and functions at all levels and in various areas and purposes	55%	2	3
INnT.013	Problems in setting limits, not only ethical and moral but also for the use of new technologies at work	55%	5	4
INnT.012	Intense compulsory retraining, to adjust the new skills required by jobs and the labor market	45%	8	5
INnT.020	Lack of skilled labor, since the educational system is not prepared for the new requirements	50%	4	6
INnT.001	Unemployment, due to the faster and more intense reduction of opportunities compared to the creation of new jobs	40%	6	7
INnT.011	Greater unpredictability, volatility and dynamism in the labor market, generating anxiety and stress for professionals	50%	7	8
INnT.028	Labor legislation lagged and unbalanced by changes caused by AI, responding too late to problems	45%	9	9
INnT.024	Excessive economic, social and knowledge control in few individuals and / or organizations	40%	10	10

Table 80. Drawbacks of AI to Work, Occupations and Labor Market – Top 10

We evaluated the level of opinion consensus among the experts in regard to this ranking. We calculated Kendall's coefficient of concordance W_{WNI} statistic and the result was 0.16, which can be considered as a very weak agreement based on Schmidt (1997)'s ranges. In fact, the conclusion here is that there is no agreement on the top 10 drawbacks of AI to Work. We calculated Chi-Square's χ^2_{WNI} statistic to evaluate W's significance and the result was 27.75, which means W_{WNI} is significant in $p < .001$.

Considering that we had two groups of background, Scholar and Market, we also checked if there was some kind of discrepancy in their evaluation of the key drawbacks of AI in Work. Table 81 illustrates this evaluation, presenting the combined ranking, the scholar ranking, and the market ranking, all from the end of the 3rd Round.

Code	Description (EN)	Final Rank 3rd Round	Scholar Rank 3rd Round	Market Rank 3rd Round
INnT.002	Compulsive withdrawal from the labor market of the less qualified and schooled (repetitive and traditional tasks)	1	1	1
INnT.014	Low and / or slow adaptation of people to the new requirements, especially those with low technological knowledge	2	2	6
INnT.003	Significant changes (and in the limit, extinction) of careers and functions at all levels and in various areas and purposes	3	3	3
INnT.013	Problems in setting limits, not only ethical and moral but also for the use of new technologies at work	4	4	2
INnT.012	Intense compulsory retraining, to adjust the new skills required by jobs and the labor market	5	6	4
INnT.020	Lack of skilled labor, since the educational system is not prepared for the new requirements	6	8	5
INnT.001	Unemployment, due to the faster and more intense reduction of opportunities compared to the creation of new jobs	7	5	7
INnT.011	Greater unpredictability, volatility and dynamism in the labor market, generating anxiety and stress for professionals	8	6	7
INnT.028	Labor legislation lagged and unbalanced by changes caused by AI, responding too late to problems	9	9	9
INnT.024	Excessive economic, social and knowledge control in few individuals and / or organizations	10	10	10

Table 81. Drawbacks of AI to Work, Occupations and Labor Market – Scholar vs Market

The market ranking was the one with less disagreement, but very similar to the scholar group, as shown in Table 82 with the help of the individual *W*'s. We found $T_{WNI} = 0.60$ and consulting a table of exact probabilities for *T*, the one-tailed probability is $p < .01$, so the two groups of experts, scholars and market professionals, do agree on the ranking of drawbacks of AI to Work.

Statistic	Final Rank 3rd Round	Scholar Rank 3rd Round	Market Rank 3rd Round
Kendall's W_{WNI}	0.16	0.17	0.22
W's interpretation	very weak	very weak	very weak
Chi Square's X_{WNI}	27.75	16.53	15.52
Significance	p < .05	not significant	not significant
Experts (n)	19	11	8

Table 82. Drawbacks of AI to Work, Occupations and Labor Market – Scholar vs Market

Based on the previous analysis, we can interpret that experts have several concerns in terms of drawbacks of AI to work, occupations and labor market. First and foremost, there is the concern with mass unemployment as a result of the faster pace in reduction of opportunities than the creation of new jobs and with compulsive withdrawal from the labor market of the less qualified and schooled. These qualitative anxieties based on experts' opinions confirm the findings pointed out in Chapter 7 of unemployment as a major setback. These issues are aggravated when we consider the increase in unpredictability, volatility, and dynamism in the labor market. Experts also mentioned drawbacks related to the occupations and the professionals. They believe there will be significant changes (extinction in some cases) of most careers and functions and low and/or slow adaptation of people to these new requirements, especially those with low technological knowledge. Actually, intense retraining of people will be necessary, to adjust the new skills required by jobs and the labor market, especially because there is a lack of skilled labor since the educational system is not prepared for the new requirements. Overall, these questions will generate an increasing anxiety and stress for professionals. Regarding work, there will be problems in setting limits, not only ethical and moral but also for the use of new technologies at work and very likely, labor legislation will lag behind the unbalances caused by AI, responding too late to problems. There is also a major drawback according to experts which is the excessive economic, social and knowledge control in few individuals and/or organizations,.

8.4. Bottlenecks

We evaluate now the bottlenecks for Artificial Intelligence, Robotics, and related technologies progress in automation of activities in organizations and work, the fifth and last question of the Delphi Research. Our intention was to confirm previous bottlenecks, but mostly, uncover other barriers. Once the questionnaire was launched and the responses were gathered in the 1st Round, we had around 60 distinct comments from all experts. We evaluated these comments, grouped them based on resemblance and consolidated the main ideas in a summarized list of 29 bottlenecks presented in Table 83, with the frequency of each item.

Code	Description (EN)	Frequency
GIA.001	Sociocultural variables, appropriate treatment of problems involving culture, race, religion, sexuality, politics, etc.	3
GIA.002	Solving complex and unstructured problems (in addition to analyzing database patterns)	4
GIA.003	Genuine creativity, that is, idealization, creation and innovation, producing events until then unusual and unique	13
GIA.004	Empathy and affection, understanding, recognition, and appropriate interaction with human feelings and emotions	11
GIA.005	Genuine reasoning and decision making in a truly autonomous way	4
GIA.006	Human relationship, dependence on interactions with people for the most diverse purposes	6
GIA.007	Relationship with the environment, dependence on interactions with factors that compose the reality in which technology is applied	1
GIA.008	Computational and technological capacity and related costs (hardware, software, data architecture, etc.)	5
GIA.009	Imagination, that is, the ability to evoke and form original images and combine abstract ideas	2
GIA.010	Ethical and moral variables, principles that motivate, distort, discipline or guide human behavior	1
GIA.011	Volume of data (high volume required for simple troubleshooting)	2
GIA.012	Ability to learn and absorb knowledge (still limited in machines)	4
GIA.013	Negotiation and persuasion, that is, ability to lead someone to believe, to accept or to decide on something	1
GIA.014	Artistic expressions in general (music, dance, painting, sculpture, architecture, literature, cinema, photography, etc.)	4
GIA.015	Multidisciplinarity, ability to understand and perform innumerable and distinct activities (non-specialist applications)	6
GIA.016	Communication, expression and oral (and written) argumentation, ability to understand and respond to a difficult conversation	4
GIA.017	Interpretation, that is, ability to understand and determine the meaning of subliminal messages, nuances, ironies and sarcasm	1
GIA.018	Accuracy and, simultaneously, amplitude of the five senses (touch, taste, smell, hearing, sight)	3
GIA.019	Tacit knowledge, not explicit and hardly transmitted ('good sense' or 'common sense')	4
GIA.020	Consciousness, that is, ability to perceive, understand and discern about a theme or idea, and its impact on others	3
GIA.021	Improvisation and adaptability, that is, ability to execute suddenly, without preparation, and with acceptable result	2
GIA.022	Amplified motor coordination and multiple function combination	2
GIA.023	Low predisposition to algorithm errors and risks arising from these errors, for example in the medical areas	2
GIA.024	Energy constraints, even with improvements in efficiency, the current energy matrix may limit technologies and their application	1
GIA.025	Quantity and quality of human resources trained to meet the demands of AI and robotics	2
GIA.026	Movements of resistance to change and technology, including boycotts and active opposition	0
GIA.027	Legal factors, new barriers to legislation limiting, reserving, decelerating or even prohibiting the use	0
GIA.028	Efficient integration of multiple and different technologies and methods	0
GIA.029	Intuition, that is, ability to perceive, discern or perceive things, regardless of reasoning or analysis	0

Table 83. Bottlenecks to AI – Complete List

Among the 29 bottlenecks, two were quite predominant, half of the experts indicated them both: GIA.003, Genuine creativity, that is, idealization, creation, and innovation, producing events until then unusual and unique and GIA.004, Empathy and affection, understanding, recognition, and appropriate interaction with human feelings and emotions. These two are compatible with the literature, with Frey & Osborne (2017) and with the findings from Chapter 6, though no specific ability directly covered empathy and affection.

In the 2nd Round, we shared this list of 29 combined bottlenecks and collected feedback from findings. But more importantly, as a result of 2nd Round, we managed to compress the list and find a combined top 10 of bottlenecks in the near future. In this process, we noticed that in the final combined list, market group presented a closer fit to the final list (9 out of 10) than scholar (5 out of 10), meaning that 9 out of the 10 items selected by market specialists were in the combined selection. We also identified some bottlenecks were not selected by either group, which was the case of GIA.014, Artistic expressions in general (music, dance, painting, sculpture, architecture, literature, cinema, photography, etc.), GIA.018, Accuracy and, simultaneously, the amplitude of the five senses (touch, taste, smell, hearing, sight) and GIA.022, Amplified motor coordination and multiple function combination.

We then used 3rd Round to further refine the top 10, with special attention to the order of the elements to create a ranking of bottlenecks. Table 84 summarizes this top 10, from the most important (1) to the less important (10). Column Selected 2nd Round indicates how many experts chose this item as top 10, while columns Rank 2nd Round and Final Rank 3rd Round show the rankings by the end of each phase for comparison purposes.

Code	Description (EN)	Selected 2nd Round	Rank 2nd Round	Final Rank 3rd Round
GIA.019	Tacit knowledge, not explicit and hardly transmitted ('good sense' or 'common sense')	65%	2	1
GIA.010	Ethical and moral variables, principles that motivate, distort, discipline or guide human behavior	60%	3	2
GIA.004	Empathy and affection, understanding, recognition, and appropriate interaction with human feelings and emotions	50%	1	3
GIA.015	Multidisciplinarity, ability to understand and perform innumerable and distinct activities (non-specialist applications)	55%	4	4
GIA.002	Solving complex and unstructured problems (in addition to analyzing database patterns)	50%	5	5
GIA.005	Genuine reasoning and decision making in a truly autonomous way	40%	6	5
GIA.017	Interpretation, that is, ability to understand and determine the meaning of subliminal messages, nuances, ironies and sarcasm	65%	8	7
GIA.020	Consciousness, that is, ability to perceive, understand and discern about a theme or idea, and its impact on others	50%	9	8
GIA.012	Ability to learn and absorb knowledge (still limited in machines)	50%	10	9
GIA.027	Legal factors, new barriers to legislation limiting, reserving, decelerating or even prohibiting the use	50%	7	10

Table 84. Bottlenecks to AI – Top 10

Next, we evaluated the level of opinion consensus among the experts about this ranking. We calculated Kendall's coefficient of concordance W_{BOT} statistic as explained in the previous section and the result was 0.16, which can be considered as a very weak agreement according to Schmidt (1997)'s ranges. We also calculated Chi-Square's χ^2_{BOT} statistic to evaluate W's significance and the result was 28.17, which means W_{BOT} is significant in $p < .001$.

Considering that we had two groups of background, Scholar and Market, we wanted to confirm if there was some kind of discrepancy in their evaluation of the key bottlenecks to progress of AI. Table 85 illustrates this discussion, presenting the combined ranking, the scholar ranking, and the market ranking, all from the end of the 3rd Round.

Code	Description (EN)	Final Rank 3rd Round	Scholar Rank 3rd Round	Market Rank 3rd Round
GIA.019	Tacit knowledge, not explicit and hardly transmitted ('good sense' or 'common sense')	1	1	1
GIA.010	Ethical and moral variables, principles that motivate, distort, discipline or guide human behavior	2	6	2
GIA.004	Empathy and affection, understanding, recognition, and appropriate interaction with human feelings and emotions	3	3	4
GIA.015	Multidisciplinarity, ability to understand and perform innumerable and distinct activities (non-specialist applications)	4	2	7
GIA.002	Solving complex and unstructured problems (in addition to analyzing database patterns)	5	5	4
GIA.005	Genuine reasoning and decision making in a truly autonomous way	5	7	3
GIA.017	Interpretation, that is, ability to understand and determine the meaning of subliminal messages, nuances, ironies and sarcasm	7	4	6
GIA.020	Consciousness, that is, ability to perceive, understand and discern about a theme or idea, and its impact on others	8	8	9
GIA.012	Ability to learn and absorb knowledge (still limited in machines)	9	9	8
GIA.027	Legal factors, new barriers to legislation limiting, reserving, decelerating or even prohibiting the use	10	10	10

Table 85. Bottlenecks to AI – Scholar vs Market

Market professionals ranking had a higher agreement than the Scholar group, as shown in Table 86 with the help of the individual *W*'s. To measure the agreement between the two groups, we calculate and evaluate Kendall's rank-order correlation coefficient *T* as indicated by Schmidt (1997). We found $T_{BOT} = 0.33$ and consulting a table of exact probabilities for *T*, the one-tailed probability is not significant, so the two groups of experts, scholars and market professionals, do not agree on the rank of the bottlenecks of AI.

Statistic	Final Rank 3rd Round	Scholar Rank 3rd Round	Market Rank 3rd Round
Kendall's W_{BOT}	0.16	0.19	0.22
W's interpretation	very weak	very weak	very weak
Chi Square's X_{BOT}	28.17	18.99	15.87
Significance	p < .001	p < .05	not significant
Experts (n)	19	11	8

Table 86. Bottlenecks to AI – Statistics

Based on experts' opinions, among the key bottlenecks to AI we have several that can be considered as unique capabilities of human beings, such as empathy and affection, to appropriately interact with other humans, enhanced interpretation, to understand meaning in complex situations, genuine reasoning, to execute decision making an autonomous way, and consciousness, to perceive, understand and discern about a theme or idea. Two others are related which what are long term difficulties of Artificial Intelligence solutions, which are multidisciplinarity, the ability to understand and perform innumerable and distinct activities and solving complex and unstructured problems in addition to analyzing database patterns. We also found out some bottlenecks associated with knowledge, either being able to learn and absorb it, which is currently very limited in machines, and to work with tacit knowledge, not explicit and hardly transmitted (good sense or common sense). In occupations, we confirmed the ethical and moral concerns, which are being discussed throughout the world, and also the legal factors and new barriers to limit, reserve, decelerate or even prohibit the use of such technologies.

Interestingly, for experts, the integration challenge mentioned in Chapter 7 was not in the top 10 of bottlenecks (it was in position 13 out of 29). In addition to that, in spite of being mentioned by more than half of the experts in the 1st Round, genuine creativity was not pointed out among the top 10.

8.5. Considerations, Limitations and Future Improvements

Overall, we had good participation from the experts in this qualitative part of the research, with rich and diverse opinions on several topics. With this content, we were able to build up from opinions five lists of around 30 items each on impacts and bottlenecks of Artificial Intelligence. In the process of refining them and defining the top 10 elements of each, we identified in general low agreement between the whole group of experts in ordering these rankings. Highest Kendall's coefficient of concordance *W* was seen in Benefits of AI to Organizations, with an index of 0.33, which can be considered as a weak to a moderate agreement and significant with $p < .001$. However, the other 4 showed very weak agreement, or simply put, disagreement among the experts with coefficients between 0.16 and 0.19, some not significant at all (Kendall's coefficient of concordance varies between 0.00, total disagreement, to 1.00, total agreement). Despite the lack of consensus among experts in most lists, we decided not to rerun new interactions, since the consensus itself was not a key concern for us. Actually, Linstone & Turoff (2011) explain that the seek for consensus in Delphi is a misperception. We understood the improvement would probably exist in subsequent rounds, but it would be only marginal and our key objective with the Delphi was already achieved, with the lists, the top 10s, and the qualitative analysis performed.

Additionally, we evaluated similarities between the two groups of experts we had contacted: on one side, scholar experts and, on the other, the market professional experts. To measure the resemblance between the two groups, we compared Kendall's coefficient of concordance and also used Kendall's rank-order correlation coefficient *T* and we noticed that once again that Benefits of Artificial Intelligence to Organizations was the list with more similarities between the two groups, with an index of 0.87 and significant. Drawbacks of AI to Organizations and Drawbacks of AI to Work also presented a satisfactory fit between scholar and market with indexes higher than 0.50. On the other hand, Benefits of AI to Work and Bottlenecks were the ones with low *T* coefficients and not significant, which means that scholars and market professionals disagree on the order of the ranking for these questions, which was not an issue at all. Another relevant finding in this comparison between groups is that, in general, opinions from market experts were usually more disperse or different, while scholars were more homogeneous. We did not find a proper explanation for that, but we believe that it probably reflects the individual challenges of the market professionals, that may have a wider diversity in the background.

As key findings in regard to Benefits of AI to Organizations, we interpret experts to believe that, with the generalization and widespread dispersion of Artificial Intelligence, automation will happen not only to repetitive tasks but to some complex ones too. This will allow organizations to do things better and do them faster, with improved quality of products, services, and solutions, more efficient, smarter, and more accessible – actually, processes, products, and/or services will have AI imperceptibly embedded in them. We understand that those positive impacts are similar in form (but not content) to predecessor technological revolutions. Moreover, AI and related technologies will also improve the use of available data, especially unstructured data, with new methods of discovery and analysis and support the development and refinement of decision-making and problem-solving methods, improving quality in decisions. Technologies will also improve the quality of life within organizations and reduce risks associated with activities of high risk, insalubrity or extreme fatigue. Experts also believe one of the key benefits of AI to organizations will be the creation of new business models (some that still do not exist currently) closely linked to technology ("uberization of the economy"). Finally, we see a confirmation in one of the topics evaluated previously. Experts consider that AI will also change and evolve the ways of working within the organizations, with an increasing focus on partnership and collaboration between machine and man, combining the strengths of each, which is a view we share with the experts.

As Drawbacks of Artificial Intelligence to Organizations, we can interpret that experts have several concerns with the usage and the ways of working of AI, such as lack of transparency in the decision-making process; AI misapplication, bias, misuse for improper, unethical, illegal and/or criminal purposes; inability to treat or identify scenarios with potential ethical and moral conflicts; and intensification of privacy issues like data breach, use without consent and/or for inappropriate purposes. Those drawbacks are especially worrying when we face situations where there is an overvaluation of machines (and their results) to the detriment of human opinions, expertise, and experiences. There is also a major group of AI drawbacks related to work, such as the increase in unemployment due to the replacement of human labor by machinery in organizations, the lack of skilled labor, since the educational system is not prepared for the new requirement, and, as a consequence, a major retraining effort of staff due to obsolescence of careers and functions at all levels. These negative impacts are in line with what was found in the previous chapters, meaning that experts also confirmed in this qualitative piece that consequences to employment and occupations are one of the key drawbacks of the application of Artificial Intelligence. Another important drawback is the excessive economic, social and knowledge control that holds this knowledge in few organizations. Finally, there is also a concern with the usual overpromising seen in the Information Systems area, meaning the increasing gap between expectations and reality with AI applications, since the good implementations are still slow, costly and limited.

As key considerations about benefits of AI, Robotics and related technologies to Work, we interpret that experts believe these technologies will bring positive impacts for several risky or alienating occupations, replacing humans in repetitive, tedious and/or low value-added activities and also in unhealthy (and damaging to health) and/or extreme fatigue activities. Also, it will improve work and occupations by increasing their productivity thru the increasing use of technologies and data. They also expect a positive change for people. The profile of the requested professional will be more creative, innovative, analytical, strategic, intellectual and abstract, professionals with a solid background, high level of education, skills, and experience in new technologies will be highly valued, especially with adaptability, multidisciplinarity, and improvisation skills. Experts also believe that Artificial Intelligence will create new careers and functions within organizations, mostly technologically based and new job positions to meet new types of business, products and/or services. Finally, experts believe in a new way of working, that of partnership between machine and man, where the strengths of each are combined in synergy, confirming one of the results seen in the previous chapters.

We can interpret that experts have several concerns in terms of drawbacks of AI to work, occupations and labor market. First and foremost, there is the concern with mass unemployment as a result of the faster pace in reduction of opportunities than the creation of new jobs and with compulsive withdrawal from the labor market of the less qualified and schooled. These qualitative anxieties based on experts' opinions confirm the findings pointed out in Chapter 7 of unemployment as a major setback. These issues are aggravated when we consider the increase in unpredictability, volatility, and dynamism in the labor market. Experts also mentioned drawbacks related to the occupations and the professionals. They believe there will be significant changes (extinction in some cases) of most careers and functions and low and/or slow adaptation of people to these new requirements, especially those with low technological knowledge. Actually, intense retraining of people will be necessary, to adjust the new skills required by jobs and the labor market, especially because there is a lack of skilled labor since the educational system is not prepared for the new requirements. Overall, these questions will generate and increasing anxiety and stress for professionals. In regard to work, there will be problems in setting limits, not only ethical and moral but also for the use of new technologies at work and very likely, labor legislation will lag behind the unbalances caused by AI, responding too late to problems. There is also a major drawback according to experts which is the excessive economic, social and knowledge control in few individuals and/or organizations.

Based on experts' opinions, among the key bottlenecks to AI we have several that can be considered as unique capabilities of human beings, such as empathy and affection, to appropriately interact with other humans, enhanced interpretation, to understand meaning in complex situations, genuine reasoning, to execute decision making an autonomous way, and consciousness, to perceive, understand and discern about a theme or idea. Two others are related which what are long term difficulties of Artificial Intelligence solutions, which are multidisciplinarity, the ability to understand and perform innumerable and distinct activities and solving complex and unstructured problems in addition to analyzing database patterns. There are also some bottlenecks associated with knowledge, either being able to learn and absorb it, which is currently very limited in machines, and to work with tacit knowledge, not explicit and hardly transmitted (good sense or common sense). In occupations, we confirmed the ethical and moral concerns, which are being discussed throughout the world, and also the legal factors and new barriers to limit, reserve, decelerate or even prohibit the use of such technologies. Interestingly, for experts, the integration challenge mentioned in Chapter 7 was not in the top 10 of bottlenecks (it was in position 13 out of 29). In addition to that, in spite of being mentioned by more than half of the experts in the 1st Round, genuine creativity was not pointed out among the top 10.

We understand these findings are in line with the results that were found in Chapters 6 and 7, which corroborate their significance. First, on the positive side, we noticed that among key benefits to both Organizations and Work, experts highlighted a new way of working, of the partnership between machine and man, where the strengths of each are combined in synergy, improving the quality of work and products. This was pointed out in the previous chapters, considering that few occupations could be really completely replaced by machines. Second, on the opposite direction, there is great concern with mass unemployment as a result of the faster pace in reduction of opportunities than creation of new jobs and with compulsive withdrawal from the labor market of the less qualified and schooled, which also confirm the findings pointed out in Chapter 7 of unemployment as a major setback. Finally, we believe we partially covered a complementary analysis on the bottlenecks based on opinions from experts, confirming or identifying new variables that could have a lessening effect on the massive automation.

In terms of limitations, considering this was a qualitative process, we face the usual restrictions of this type of research. Nonetheless, one of the key limitations is subjectivity in the process and in the analysis. In dealing with unstructured qualitative data, subjectivity was a major concern for us from start, especially of unintentional bias, which could affect the quality and reliability of the final results. Thought we tried to address this by using excerpts and wording from the experts' comments, it was an impossible mission to rewrite impacts and bottlenecks in a way that all experts felt comfortable and represented by them. Therefore, we did face some negative feedback especially about the items, which according to a couple of experts were very alike and made it very difficult to complete the tasks.

Another limitation is a consequence of the level and quality of feedback. Though we had good participation, with 80% of the 24 experts taking part in all rounds, the volume and quality of feedback were very limited. In spite of formally requesting it, few of the participants shared their views and details about their decisions, though this is an essential part of the Delphi Research – we believe that richer results could be found with deeper feedback. Additionally, the lack of feedback also restricted confirmation or denial on the items of the lists. Finally, despite the lack of consensus among experts in most lists, we decided not to rerun new interactions. This can also be considered as a limitation in our study, especially in regard to the rankings. Because of these limitations, our findings from this research should be presented as lists of key items (impacts or bottlenecks), but not really ordered lists. Overall, we believe the disagreement in most cases is a direct consequence of diverse individual opinions in a topic which is still unfolding. Nonetheless, we do not see this as a major problem in our research.

9. Final Considerations

We cover now the key conclusions and final considerations of this work, tying them back to the original research question and the key objectives set at the beginning of this document. The research limitations are also evaluated, as well as recommendations for further studies, and we close this research with a debate over its implications and contributions.

9.1. Key Conclusions

This work was motivated by Frey & Osborne (2017)'s research on how susceptible jobs are to computerization and had as its first objective to scrutinize the authors' research, debating methods, outcomes, and limitations, in order to confirm or refute their findings. Frey & Osborne (2017)'s method and results are a worthy initiative, a major cornerstone in the occupations automation susceptibility debate, but we believe there are some limitations in the method applied by the researchers and consequently in their findings. We identified at least five of them, which are subjectivity in the process, oversimplification of the problem, overlook of the Importance scale, technological bias on bottlenecks, and decision method unclear. To overcome part of these limitations, especially the discussion on the bottlenecks and the final results achieved by the authors, we decided to execute an alternative evaluation on the abilities that are more or less susceptible of being emulated by machines in the near future – the twenty-year window proposed by Frey & Osborne (2017). In taking one step back and evaluating one of the building blocks of occupations (abilities), instead of the direct occupations like Frey and Osborne did, we believed it would allow us to have a more sensible and fair measure of the real susceptibility of occupations.

Based in an Abilities Survey included in a Delphi panel performed with experts from Brazil, we managed to address our second objective, which was to explore occupational characteristics to understand what drives the risk of replacement by Artificial Intelligence, Robotics, and related technologies. Our first conclusion was that all abilities, without exceptions, increased their likelihood of being emulated by machines over the next twenty years, which means that experts believe Artificial Intelligence, Robotics, and related technologies will all continue to advance in the following years, and in doing so, the complexity level of their applications will improve, corroborating Ginni Rometty's observation that AI will change 100 percent of jobs within the next years[240].. The direct implication of this phenomena is that the possibility of having different technologies emulating more and better human abilities will also increase significantly. Considering Ability Types, which are groups of related abilities from O*NET, Memory, Attentiveness and Perceptual Abilities were rated as the top 3 in terms of emulation likelihood in the near future, very close to its maximum level. This means that occupations highly dependable on these abilities could partially use machines to perform tasks, replacing humans. Partially is an important word in this observation because, an occupation is comprised of a combination of several competencies, which means that full replacement is more complex than it really seems. On the other hand, Verbal Abilities, Idea Generation and Reasoning Abilities and Flexibility, Balance, and Coordination Abilities

[240] https://www.cnbc.com/2019/04/02/ibm-ceo-ginni-romettys-solution-to-closing-the-skills-gap-in-america.html

were the bottom 3 ability types in terms of emulation likelihood in twenty years – they comprise abilities such as Originality, Written Expression, Oral Comprehension, Gross Body Coordination and Fluency of Ideas.

By comparing findings from this survey with those from Frey & Osborne (2017), we had some remarkable findings. First of all, based on the experts' opinions, Originality was the ability less likely to be adequately executed or emulated by Artificial Intelligence, Robotics, and related technologies. It was, therefore, confirmed as a bottleneck for computerization, similarly to Frey & Osborne (2017)'s outcomes. On the opposite direction to these authors' observations, however, experts that participated in this survey did not perceive Manual Dexterity and Finger Dexterity as key bottlenecks for Artificial Intelligence, Robotics, and related technologies. However, other abilities not mentioned by Frey & Osborne (2017) did surface from the opinion analysis as bottlenecks, such as Written Expression, Oral Comprehension, Gross Body Coordination and Fluency of Ideas. Additionally, there were other abilities that, if not bottlenecks, could be evaluated as challenges to overcome in the next years.

Another important observation is that, based on the combined opinions, we can interpret that specialists do not perceive technical plateaus that could indefinitely block technological progress to perform abilities – like happen to Artificial Intelligence in the past. Bottlenecks and challenges may exist, as mentioned, but experts believe in new developments, approaches, and achievements to gradually overcome them. However, there seems to be a non-technical plateau in the opinion of most of the experts, which is related to several capabilities that are intrinsically human, most of them intellectual. As much as machines could mimic abilities like Originality and Fluency of Ideas, for instance, according to experts they could never do it spontaneously, autonomously and adaptatively as humans do. More than bottlenecks, these areas can be considered as indefinite barriers, corroborating the idea of the Weak AI.

Despite eventual disadvantages and inadequacy to the purpose of this research, we believe that leveraging O*NET's framework, definitions and even questionnaires worked as an accelerator and a powerful tool to achieve these conclusions. Also, it allowed us to illustrate the complexity of this discussion and to uncover an important construct in the occupation's discussion thru the expert feedback, which is the integration of technologies.

With the results of the Abilities Survey, we could then propose an alternate ranking of occupation's susceptibility to computerization based on a different method, another goal of this work. In the process of building the alternative ranking, we noticed that occupations more labor-intensive seemed to be more affected by Artificial Intelligence, Robotics, and related technologies than those more intellectual-intensive. This observation is similar to that of Frey & Osborne (2017) that affirm that "computerization of production occupations simply suggests a continuation of a trend that has been observed over the past decades, with industrial robots taking on the routine tasks of most operatives in manufacturing". Moreover, several occupations in Business, Management, Legal, Healthcare, Education, Arts, seem to be less affected by technologies, occupations with greater human and social factors, heavily dependable in features such as creativity, empathy, and interaction. However, the Ability descriptor is not the best variable to evaluate this social interactive component, since these characteristics are majorly covered by Skills. We also noticed, as Frey & Osborne

(2017), that technologies "(…) will be able to perform a wider scope of non-routine manual tasks" – actually, all occupations will be impacted to a greater or lesser extent by technologies, based on the indirect opinions of the experts.

When checking for the bottlenecks applied into the occupation context, that is, considering the complexity requirements, Originality, Oral Comprehension, and Written Comprehension were confirmed as the top 3 bottlenecks. These outcomes are different from the British authors, that considered Finger and Manual Dexterities as a major obstacle for technologies, though they mentioned that "tasks involving mobility and dexterity will diminish over time, the pace of labor substitution in service occupations is likely to increase even further" (Frey & Osborne, 2017). Finger and Manual Dexterities were not in the top 10 of our bottlenecks.

But we believe our key contribution is related to complexity and integration. We were already aware that the more complex the occupations are, meaning abilities with higher complexity requirements, the lesser technologies are able to emulate. In that sense, and based on findings of this research, we believe that technologies may emulate individual abilities to a higher extent, but more important than that is being able to harmonically combine these capabilities and make them work together with synergy to achieve even basic tasks of occupations. This is hard for humans that want to be successful in their jobs, but it is a great challenge for machines, that still today are very specific in content and application. This integration challenge corroborates the fact that no matter how advanced technology might be in a specific ability, it takes more than that for machines to successfully replace humans in an occupation. For that reason, we believe in a future of collaboration between humans and machines, rather than the replacement and displacement.

Therefore, we decided to apply in our susceptibility ranking an Integration Complexity Reduction Factor. As a major supposition, we assumed that the abilities and ability types network that rules the integration complexity had similar form and behavior to that of Telecommunications Networks and that we could derive Metcalfe's Law to estimate the integration complexity factor of the Ability Network for each occupation. The results showed that most of the occupations with less integration complexity, like clerks and assistant positions, were more susceptible of being replaced, while the ones that demand the higher integration of abilities are practically not at risk. In the top positions in the susceptibility risk, all above 90% of the risk of being emulated by Artificial Intelligence, Robotics, and related technologies in twenty years were Telemarketers, Credit Checkers, Customer Service Representatives, Proofreaders and Copy Markers, Medical Secretaries and Human Resources Specialists. On the other side, Pilots in general, Firefighters and medical careers such Surgeons are the ones with higher integration requirements, harder to perform.

Interestingly, Telemarketers, which was placed in 1st position in Frey & Osborne (2017)'s ranking, was also the 1st in terms of susceptibility in our ranking, though we had different methods, different inputs and we included a reduction factor. Actually, it demonstrates an important point about this occupation, which is the fact that it has three key characteristics that drive susceptibility of being replaced. First, this occupation is comprised of basic repetitive activities, despite most of them being about communication; second, it is not intellectually demanding, since most of the work is based on pre-defined scripts; and third, it is not difficult in terms of complexity level and integrations, with few abilities and ability types. Occupations that have these three characteristics will very likely be highly impacted by Artificial Intelligence, Robotics, and related technologies – or, as Frey & Osborne (2017) put it, computerization – in the next twenty years. Nonetheless, we cannot forget the social component of each occupation. Manicurists and Pedicurists, though in the 41st (out of 967) with 86.76% of susceptibility, are a good example of this scenario, because they require several social and human implicit capabilities. And these are capabilities evaluated by Skills, a complementary descriptor from O*NET.

We understand that the results help in elucidating the current and future situation of this theme and allow us to suggest some possible conclusions. One of the most important, drawn from what can be seen in the 2038 ranking with the integration reduction factor, is that once the integration factor is considered, no occupation reached the 100% susceptibility index in twenty years, which means that not a single occupation can be entirely replaced with acceptable quality by machines that combine Artificial Intelligence, Robotics, and related technologies. There will always be some portion or portions of the occupation (in their current ways of work) that will require some human complement. In other words, these findings again demonstrate that the complementary perspective between humans and machines is closer to reality than the replacement.

In regard to similarities between the two rankings, Frey & Osborne (2017)'s and the one created in this research, we identified that Office and Administrative Support Occupations and Sales and Related Occupations had similar behaviors. As Frey & Osborne (2017) explained, though it might be counterintuitive that these occupations could be subject to a wave of computerization, there are several high-risk occupations that include, for example, cashiers, counter and rental clerks, and telemarketers. On the other hand, we did find different results for several occupations and groups of occupations, which was expected considering that we had different methods. In Frey & Osborne (2017)'s ranking, for instance, Transportation and Material Moving Occupations such as Locomotive Engineers, Locomotive Firers, Sailors and Marine Oilers were highly susceptible to computerization. However, several of these occupations require many abilities, ability types and a high average of complexity level which creates a challenge for integrating and, consequently, automating them. In our ranking, these occupations were in the above-average range, but not as highly susceptible. Another example was Management Occupations, pointed out as low susceptibility by Frey & Osborne (2017). In our ranking, however, several occupations within this group, like Sales Managers, Marketing Managers, Purchasing Managers had high susceptibilities for the reason that they did not require high levels of complexity and integration. We believe in this case, this observation is a result of only considering Abilities – therefore, Skills like Social Perceptiveness, Negotiation, and Persuasion, indicated as bottlenecks in the literature were not taken into account.

Afterward, we cross-checked our susceptibility ranking with the job market in the U.S., just like Frey & Osborne (2017) did. Our objective was to evaluate the authors' key finding in regard to employment impact by technologies, confirming or refuting the authors' key conclusion that 47% of total U.S. employment is in high risk of automation by machines over a decade or two. In spite of the differences in the method and inputs (part of them), the lower number of occupations in the high-risk category in the ranking, the outcomes found were exactly the same as those of Frey & Osborne (2017). Based on the calculations, 47% to 51% of the job positions in the U.S. in 2026 are in the high-risk category, meaning that occupations are potentially replaceable by

Artificial Intelligence, Robotics, and related technologies in two decades or so. We interpret that the key reason to explain such a scenario is that our ranking, despite having fewer occupations, had more impact in those that have a higher volume of job positions, which, in most cases, are characterized with less complexity and that require less integration of abilities.

Our major consideration in regard to this job market impact is that it is far from conclusive and should not be used indiscriminately as irrefutable. As mentioned, there are several other technical and non-technical variables that were not considered and that, most certainly, would have a reducing effect on the statistics just shared. Nonetheless, when evaluated in combination with Frey & Osborne (2017)'s findings, which have also several limitations, it is an important result to create awareness of the problem at hand, which is that Artificial Intelligence, Robotics, and related technologies can severely impact occupations and the job markets, though not necessarily replacing humans. This is also a concern that was clearly highlighted by experts in the Delphi research.

The last key objective of this work was to identify key positive and negative impacts of AI on organizations and work, occupations and labor market with the help of experts. As key findings in regard to Benefits of AI to Organizations, we interpret experts to believe that, with the generalization and widespread dispersion of Artificial Intelligence, automation will happen not only to repetitive tasks but to some complex ones too. This will allow organizations to do things better and do them faster, with improved quality of products, services, and solutions, more efficient, smarter, and more accessible – actually, processes, products, and/or services will have AI imperceptibly embedded in them. We understand that those positive impacts are similar in form (but not content) to predecessor technological revolutions. Moreover, AI and related technologies will also improve the use of available data, especially unstructured data, with new methods of discovery and analysis and support the development and refinement of decision-making and problem-solving methods, improving quality in decisions. Technologies will also improve the quality of life within organizations and reduce risks associated with activities of high risk, insalubrity or extreme fatigue. Experts also believe one of the key benefits of AI to organizations will be the creation of new business models (some that still do not exist currently) closely linked to technology. Finally, we see a confirmation in one of the topics evaluated previously. Experts consider that AI will also change and evolve the ways of working within the organizations, with an increasing focus on partnership and collaboration between machine and man, combining the strengths of each, which is a view we share with the experts.

As Drawbacks of Artificial Intelligence to Organizations, we can interpret that experts have several concerns with the usage and the ways of working of AI, such as lack of transparency in the decision-making process; AI misapplication, bias, misuse for improper, unethical, illegal and/or criminal purposes; inability to treat or identify scenarios with potential ethical and moral conflicts; and intensification of privacy issues like data breach, use without consent and/or for inappropriate purposes. Those drawbacks are especially worrying when we face situations where there is an overvaluation of machines (and their results) to the detriment of human opinions, expertise, and experiences. There is also a major group of AI drawbacks related to work, such as the increase in unemployment due to the replacement of human labor by machinery in organizations, the lack of skilled labor, since the educational system is not prepared for the new requirement, and, as a consequence, a major retraining effort of staff due to obsolescence of careers and functions at all levels. Another important drawback is the excessive economic, social and knowledge control that holds this knowledge in few organizations. Finally, there is also a concern with the usual overpromising seen in the Information Systems area, meaning the increasing gap between expectations and reality with AI applications, since the good implementations are still slow, costly and limited.

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We can interpret that experts have several concerns in terms of drawbacks of AI to work, occupations and labor market. First and foremost, there is the concern with mass unemployment as a result of the faster pace in reduction of opportunities than the creation of new jobs and with compulsive withdrawal from the labor market of the less qualified and schooled. These issues are aggravated when we consider the increase in unpredictability, volatility, and dynamism in the labor market. Experts also mentioned drawbacks related to the occupations and the professionals. They believe there will be significant changes (extinction in some cases) of most careers and functions and low and/or slow adaptation of people to these new requirements, especially those with low technological knowledge. Actually, intense retraining of people will be necessary, to adjust the new skills required by jobs and the labor market, especially because there is a lack of skilled labor since the educational system is not prepared for the new requirements. Overall, these questions will generate an increasing anxiety and stress for professionals. Regarding work, there will be problems in setting limits, not only ethical and moral but also for the use of new technologies at work and very likely, labor legislation will lag behind the unbalances caused by AI, responding too late to problems. There is also a major drawback according to experts which is the excessive economic, social and knowledge control in few individuals and/or organizations.

Based on experts' opinions, among the key bottlenecks to AI we have several that can be considered as unique capabilities of human beings, such as empathy and affection, to appropriately interact with other humans, enhanced interpretation, to understand meaning in complex situations, genuine reasoning, to execute decision making an autonomous way, and consciousness, to perceive, understand and discern about a theme or idea. Two others are related which what are long term difficulties of Artificial Intelligence solutions, which are multidisciplinarity, the ability to understand and perform innumerable and distinct activities and solving complex and unstructured problems in addition to analyzing database patterns. There are also some bottlenecks associated with knowledge, either being able to learn and absorb it, which is currently very limited in machines, and to work with tacit knowledge, not explicit and hardly transmitted. In occupations, we confirmed the ethical and moral concerns, which are being discussed throughout the world, and also the legal factors and new barriers to limit, reserve, decelerate or even prohibit the use of such technologies. Interestingly, for experts, the integration challenge mentioned was not in the top 10 of bottlenecks (it was in position 13 out of 29). In addition to that, in spite of being mentioned by more than half of the experts in the 1st Round, genuine creativity was not pointed out among the top 10.

Additionally, we evaluated similarities between the two groups of experts we had contacted: on one side, scholar experts and, on the other, the market professional experts. Supported by statistics, we noticed that Benefits of Artificial Intelligence to Organizations was the list with more similarities between the two groups. Drawbacks of AI to Organizations and Drawbacks of AI to Work also presented a satisfactory fit between scholar and market. On the other hand, Benefits of AI to Work and Bottlenecks were the ones with low *T* coefficients and not significant, which means that scholars and market professionals disagree on the order of the ranking for these questions, which was not an issue at all.

9.2. Limitations and Complementary Research

In defining the overarching research problem, we found our first limitation. As previously mentioned, our apprehension was related to eventual criticisms about building research based on speculations and predictions that could not be reliable, valid or reproducible, key elements of scientific research and scientific papers. Moreover, considering this is about looking into the future and based on opinions after all, there are no guarantees that the results would actually be accurate. Nonetheless, we believe that this limitation was considerable diminished thru the use of a robust and proven method such as Delphi, “a commonly used method in futures research” (Aengenheyster *et al*, 2017) to assess “(…) the direction of long-range trends, with special emphasis on science and technology, and their probable effects on our society and our world” (Gordon & Helmer, 1964).

As part of scientific research, we understand that the abilities survey executed has some limitations, that directly or indirectly may affect its findings and conclusions, and two of them are more relevant. First, the complete analysis was based on only one of the building blocks of the occupations model provided by O*NET, which was Abilities, so it is a simplification and incomplete analysis of the very complex structure of occupations. Second, is that the research considered only opinions from Brazilian experts on Artificial Intelligence, Robotics, and related technologies, which could somehow limit our findings to this particular country – although most of these specialists have a broader knowledge and international experience. There are other technical and methodological limitations such as the reduced sample size, the biased expert background (technical), the long questionnaire, the confusing abilities definitions and abilities anchors taken from O*NET, and the method for combining opinions.

To overcome some of these limitations, we believe future researches should increase the number of participants and background to ensure a broader group of experts and a richer discussion, evaluating opinions of experts from other countries and from other areas, technical (like Robotics) and non-technical (like Business and Economy). Also, questionnaire should by simplified, combining those abilities, skills and other descriptors that have some overlap. To really ensure a combined view of the participants, a Delphi could be performed with further interaction and discussion. Finally, as mentioned, occupations are a combination of several components, abilities being one of them. In that sense, it would be important for a more comprehensive view on the susceptibility matter to evaluate types of skills and other O*NET descriptors. We also believe that more studies using different approaches should be proposed, tested and analyzed in order to continue to evaluate either Frey & Osborne (2017) or this research findings and conclusions.

Regarding our susceptibility ranking and its effects to labor market, we also have several restrictions. First of them is that this is forward-looking research and most of the described technological developments are yet to be implemented across industries and on a broader scale. In spite of using the Delphi method and the best knowledge from a group of the experts, as Frey & Osborne (2017) explain, "(…) making predictions about technological progress is notoriously difficult." Thus, it is important to note that, since O*NET does not cover any specific measures on the automatability of jobs, the estimates presented here are based on several assumptions and are a result of extrapolations of Abilities that computer-controlled equipment can be expected to perform. In other words, these results are obviously not conclusive and have a high degree of subjectivity from the combined group of experts and of the researchers. Second, O*NET occupational framework is a simplification of an intricate ecosystem and, as Frey & Osborne (2017) did, we also use part of it to derive a ranking, in this case, restricting our model only to Abilities. Occupations and Job Market are very complex and we just focused on part of the technical variables, not taking into account several other important exogenous variables that would have a lessening effect, such as social, economic and political bottlenecks yet to unfold. Third is related to the limitation of instruments and method themselves, which could not be adequate for this type of research or an eventual bias in the experts, more enthusiastic about technologies or more pessimistic about the future of occupations than we anticipated. Fourth is that we limit our evaluation on the Job Market to risk ranges and based on its current composition – job mix from 2016. As Frey & Osborne (2017), "we make no attempt to estimate how many jobs will actually be automated" and we don't make predictions on how the Job Market is going to evolve – for instance with new occupations yet to be uncovered and created. In that sense, there is a limitation in forward-looking based on the current picture, evaluating only part of the problem. Another limitation is about the Integration Complexity Reduction Factor. Unfortunately, we lack referenceable studies that can support and justify the decision of using Metcalfe's Law as the function that better represents the challenge of integrating technologies.

Our initial intention to execute the same analysis on the impacts on Job Market in Brazil, and evaluate the potential impact of Artificial Intelligence, Robotics, and related technologies in developing country and compare it to the findings in the U.S.. We expect that the impacts may be even higher due to the Brazilian market composition – though the cost/benefit equation may be quite averse to machines in a country where the cost of human labor is still cheap. We believe this would be an interesting endeavor and achievement, and it is our key recommendation for a future study. Expanding this research to an extended group, non-technical, could be an interesting future complementation of the ranking, just like in the Abilities Survey – however, it would demand a different method, and finding mathematical confirmation of our key assumption of using Metcalfe's Law to represent the integration complexity would be two other suggestions for future studies.

In regard to the Delphi itself, considering this is a qualitative method and process, we face the usual restrictions of this type of research. Nonetheless, one of the key additional limitations is the subjectivity in the process and in the analysis done by the researchers. In dealing with unstructured qualitative data, subjectivity was a major concern for us from start, especially of unintentional bias, which could affect the quality and reliability of the final results. Thought we tried to address this by using excerpts and wording from the experts' comments, it was an impossible mission to rewrite impacts and bottlenecks in a way that all experts felt comfortable and represented by them. Another limitation is a consequence of the level and quality of feedback. Though we had good participation, with 80% of the 24 experts taking part in all rounds, the volume and quality of feedback were very limited. We believe that richer results could be found with deeper feedback. Additionally, the lack of feedback also restricted confirmation or denial on the items of the lists.

Finally, despite the lack of consensus among experts in most lists, we decided not to rerun new interactions. This can also be considered as a limitation in our study, especially in regard to the rankings. Because of these limitations, our findings from this research should be presented as lists of key items (impacts or bottlenecks), but not really ordered lists. Overall, we believe the disagreement in most cases is a direct consequence of diverse individual opinions in a topic which is still unfolding. Nonetheless, we do not see this as a major problem in our research.

9.3. Closing Comments

We believe that the recent revival of Artificial Intelligence led by the big IT corporations and Academic Research will bring transformation and disruption in large scale to the economy, industries, businesses, organizations and people in the years to come. But to what extent and intensity, is still to be defined. Nonetheless, it will most likely profoundly affect business models (either destroying or creating new ones); change current processes and enhance productivity in organizations; challenge companies core competitive advantages and long-term strategies; alter work relations within organizations thru replacement or complementation of humans and affect work, occupations and the labor market in a unpredictable way.

Despite Frey & Osborne (2017)'s first great effort on evaluating the impact of AI in the future of employment, not much has been researched in an academic perspective in this theme nor in sufficient depth yet. Loebbecke & Picot (2015) made one of the first attempts to set up a research agenda on the topic in their article in 2015 in Journal of Strategic Information Systems, but yet, the situation remains unchanged. Considering this scenario, we hope that this research is a relevant yet limited answer to Loebbecke & Picot (2015)'s call for action in trying to develop theories and improve research that allows us, as an academic community, to appropriately tackle this next technological wave. Furthermore, in the process of responding to our overarching goal for this thesis, we hope to have contributed to the current body of knowledge, trying to understand the problem and creating awareness to it. In doing so, we also expect to help societies, organizations, and people to prepare and address fundamental issues such as the future of work and employment, no matter where one stands, on either massive unemployment due to replacement or complementation of man abilities by machines.

In our opinion, our most relevant contribution in this research is related to acknowledging the complexity and integration issue of occupations and trying to address it to some degree. We believe that technologies may emulate individual abilities to a higher extent in the future, but more important than that is being able to harmonically combine these capabilities and make them work together with synergy to achieve even basic tasks of occupations. This is hard for humans that want to be successful in their jobs, but it is potentially an unsurmountable challenge for machines, that still today are very specific in content and application. This integration challenge, bottleneck or plateau in association with Autor (2015)'s Polanyi's paradox corroborates the fact that no matter how advanced technology might be in a specific ability, it takes more than that for machines to successfully replace humans in an occupation. For that reason, we believe in a future of collaboration and synergy between humans and machines, rather than the replacement and displacement, and we are backed up by experts. We agree with the perception that all occupations will be impacted by AI in the following years, yet, few occupations will be completely replaced with acceptable quality by machines that combine Artificial Intelligence, Robotics, and related technologies. There will always be some particularities of the occupations (in their current ways of work) that will require some human complement. Overall, this is the main reason why we do not support Frey & Osborne (2017)'s conclusion (and our own) that 47% of total the U.S. employment are potentially automatable over some unspecified number of years. We believe it to be inaccurate and highly inflated.

We close this work quoting Buchanan (2006), and his important considerations about Artificial Intelligence and its impacts. "With our successes in AI, however, come increased responsibility to consider the societal implications of technological success and educate decision makers and the general public so they can plan for them. The issues our critics raise must be taken seriously. These include job displacement, failures of autonomous machines, loss of privacy, and the issue we started with: the place of humans in the universe. On the other hand we do not want to give up the benefits that AI can bring, including less drudgery in the workplace, safer manufacturing and travel, increased security, and smarter decisions to preserve a habitable planet."

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Appendix 1. Scope and Overview of AIS Journals

European Journal of Information Systems (EJIS)
Established in 1991

Link:
http://link.springer.com/journal/41303

Editorial Guidelines and Scope:
The Journal's Editors and Editorial Board particularly welcome submissions with a critical and empirical view on information systems technology, development, implementation, strategy, management and policy. We encourage first rate research articles by academics, but also case studies and reflective articles by practitioners.

Key Words / Topics:
- Operation Research/Decision Theory
- Business and Management, general
- Information Systems and Communication Service
- Innovation/Technology Management
- Business Information Systems

Information Systems Journal (ISJ)
Established in 1991

Link:
http://onlinelibrary.wiley.com/journal/10.1111/%28ISSN%291365-2575

Editorial Guidelines and Scope:
The Information Systems Journal (ISJ) is an international journal promoting the study of, and interest in, information systems. Articles are welcome on research, practice, experience, current issues and debates. The ISJ encourages submissions that reflect the wide and interdisciplinary nature of the subject and articles that integrate technological disciplines with social, contextual and management issues, based on research using appropriate research methods. The ISJ has particularly built its reputation by publishing qualitative research and it continues to welcome such papers. Quantitative research papers are also welcome but they need to emphasise the context of the research and the theoretical and practical implications of their findings. The ISJ does not publish purely technical papers.

Key Words / Topics:
- Information systems
- Computer-aided systems engineering
- Computers
- Information science
- Information systems (IS)
- Information technology (IT)
- Information system research

Information Systems Research (ISR)
Established in 1990

Link:
http://pubsonline.informs.org/journal/isre

Editorial Guidelines and Scope:
Information Systems Research (ISR) is a leading peer-reviewed, international journal focusing on theory, research, and intellectual development for information systems in organizations, institutions, the economy,

and society. It is dedicated to furthering knowledge in the application of information technologies to human organizations and their management and, more broadly, to improving economic and social welfare. The journal serves the interest of the information systems research and practitioner communities by providing an effective forum for the timely dissemination of research and addresses prominent and topical issues that are relevant to executives in practice.

Key Words / Topics:

- Computer-Mediated Communication
- Data Communications
- Decision Support Systems
- E-Learning
- Electronic Commerce
- Information Technology
- IT Diffusion and Adoption
- Knowledge Management
- Network Economics
- Outsourcing
- Software Development Methodologies
- Systems Design and Implementation
- Virtual Teams
- Workflow and Process Management

Journal of Association for Information Systems (JAIS)
Established in 2000

Link:
http://aisel.aisnet.org/jais/

Editorial Guidelines and Scope:
The Journal of the Association for Information Systems (JAIS), the flagship journal of the Association for Information Systems (AIS), publishes scholarly contributions that represent the highest quality in the field of information systems. JAIS particularly welcomes contributions that provide theoretical insights that advance our understanding of information systems and information technology in organizations and society. New insights may include proposing a new theoretical model, challenging or clarifying existing theory, integrating diverse strands of research in information systems so as to advance new concepts and relationships, or developing a compelling argument for the field to develop a new theory. JAIS is inclusive in its coverage of topics, level and unit of analysis, theory, method, and philosophical and research approaches - reflecting all aspects of information systems research globally.

Key Words / Topics:
not found

Journal of Information Technology (JIT)
Established in 1986

Link:
http://link.springer.com/journal/41265

Editorial Guidelines and Scope:
The Journal of Information Technology (JIT) is a top-ranked journal in its field, focused on new research addressing technology and the management of IT - including strategy, change, infrastructure, human resources, sourcing, system development and implementation, communications, technology developments, technology futures, national policies and standards, as well as articles that advance understanding and application of research approaches and methods.
The journal publishes work from all disciplinary, theoretical and methodological perspectives. It is designed to be read by researchers, scholars, teachers and advanced students in the fields of Information Systems and Information Science, as well as IT developers, consultants, software vendors, and senior IT executives

seeking an update on current experience and future prospects in relation to contemporary information and communications technology.

Key Words / Topics:
- Business and Management, general
- Innovation/Technology Management
- Information Systems and Communication Service
- Management
- Business Information Systems

Journal of Management Information Systems (JMIS)
Established in 1984

Link:
http://www.jmis-web.org/issues

Editorial Guidelines and Scope:
The journal is a widely recognized forum for the presentation of research that advances the practice and understanding of organizational information systems. It serves those investigating new modes of information delivery and the changing landscape of information policy making, as well as practitioners and executives managing the information resource. A vital aim of the quarterly is to bridge the gap between theory and practice of management information systems.

Key Words / Topics:
- Business processes and management enabled by information technology
- Business value of information technology
- Management of information resources
- Integration of information systems planning into business plans
- Business globalization and information technology
- Relationship between information technology and organizational performance and structures
- Enterprise-wide systems architectures and infrastructures
- Electronic commerce and net-enabled organizations
- Robustness and security of information-technology infrastructures
- Informational support of collaborative work
- Knowledge management, organizational learning, and organizational memory
- Systems sourcing, development, and stewardship in organizations
- The human element in organizational computing
- Data-and knowledge-based system architectures

Journal of Strategic Information Systems (JSIS)
Established in 1991

Link:
http://www.sciencedirect.com/science/journal/09638687

Editorial Guidelines and Scope:
The Journal of Strategic Information Systems focuses on the strategic management, business and organizational issues associated with the introduction and utilization of information systems, and considers these issues in a global context. The emphasis is on the incorporation of IT into organizations' strategic thinking, strategy alignment, organizational arrangements and management of change issues. The journal publishes research from around the world which (a) investigate the changing nature of business in the context of emerging IT, (b) discuss the justification and evaluation of information systems, (c) discuss the organizational implications of IT and (d) consider how organizations have been transformed as a result of the astute management and application of IT.

Key Words / Topics:
- Organizational transformation on the back of IT

- Information systems/business strategy alignment
- Inter-organizational systems
- Global issues and cross-cultural issues
- The impact and significance of emerging IT

Management Information Systems Quarterly (MISQ)
Established in

Link:
http://misq.org/

Editorial Guidelines and Scope:
The editorial objective of the MIS Quarterly is the enhancement and communication of knowledge concerning the development of IT-based services, the management of IT resources, and the use, impact, and economics of IT with managerial, organizational, and societal implications. Professional issues affecting the IS field as a whole are also in the purview of the journal.

Key Words / Topics:
not found

Appendix 2. Abilities, Ability Types, Categories – Descriptions and Anchors

The Ability Categories, Types and individual Abilities and their Level Scale Anchors were retrieved from O*NET database. Available in:

https://www.onetcenter.org/database.html

https://www.onetcenter.org/dictionary/20.1/excel/level_scale_anchors.html

ID	Ability Category	Ability Category Description
1.A.1	Cognitive Abilities	Abilities that influence the acquisition and application of knowledge in problem solving
1.A.2	Psychomotor Abilities	The ability to keep your hand and arm steady while moving your arm or while holding your arm and hand in one position
1.A.3	Physical Abilities	Abilities that influence strength, endurance, flexibility, balance and coordination
1.A.4	Sensory Abilities	Abilities that influence visual, auditory and speech perception

ID	Ability Type	Ability Type Description
1.A.1.a	Verbal Abilities	Abilities that influence the acquisition and application of verbal information in problem solving
1.A.1.b	Idea Generation and Reasoning Abilities	Abilities that influence the application and manipulation of information in problem solving
1.A.1.c	Quantitative Abilities	Abilities that influence the solution of problems involving mathematical relationships
1.A.1.d	Memory	Abilities related to the recall of available information
1.A.1.e	Perceptual Abilities	Abilities related to the acquisition and organization of visual information
1.A.1.f	Spatial Abilities	Abilities related to the manipulation and organization of spatial information
1.A.1.g	Attentiveness	Abilities related to application of attention
1.A.2.a	Fine Manipulative Abilities	Abilities related to the manipulation of objects
1.A.2.b	Control Movement Abilities	Abilities related to the control and manipulation of objects in time and space
1.A.2.c	Reaction Time and Speed Abilities	Abilities related to speed of manipulation of objects
1.A.3.a	Physical Strength Abilities	Abilities related to the capacity to exert force
1.A.3.b	Endurance	The ability to exert oneself physically over long periods without getting out of breath
1.A.3.c	Flexibility, Balance, and Coordination	Abilities related to the control of gross body movements
1.A.4.a	Visual Abilities	Abilities related to visual sensory input
1.A.4.b	Auditory and Speech Abilities	Abilities related to auditory and oral input

ID	Ability	Ability Description
1.A.1.a.1	Oral Comprehension	The ability to listen to and understand information and ideas presented through spoken words and sentences
1.A.1.a.2	Written Comprehension	The ability to read and understand information and ideas presented in writing
1.A.1.a.3	Oral Expression	The ability to communicate information and ideas in speaking so others will understand
1.A.1.a.4	Written Expression	The ability to communicate information and ideas in writing so others will understand
1.A.1.b.1	Fluency of Ideas	The ability to come up with a number of ideas about a topic (the number of ideas is important, not their quality, correctness, or creativity)
1.A.1.b.2	Originality	The ability to come up with unusual or clever ideas about a given topic or situation, or to develop creative ways to solve a problem
1.A.1.b.3	Problem Sensitivity	The ability to tell when something is wrong or is likely to go wrong It does not involve solving the problem, only recognizing there is a problem
1.A.1.b.4	Deductive Reasoning	The ability to apply general rules to specific problems to produce answers that make sense
1.A.1.b.5	Inductive Reasoning	The ability to combine pieces of information to form general rules or conclusions (includes finding a relationship among seemingly unrelated events)
1.A.1.b.6	Information Ordering	The ability to arrange things or actions in a certain order or pattern according to a specific rule or set of rules (eg, patterns of numbers, letters, words, pictures, mathematical operations)
1.A.1.b.7	Category Flexibility	The ability to generate or use different sets of rules for combining or grouping things in different ways
1.A.1.c.1	Mathematical Reasoning	The ability to choose the right mathematical methods or formulas to solve a problem
1.A.1.c.2	Number Facility	The ability to add, subtract, multiply, or divide quickly and correctly
1.A.1.d.1	Memorization	The ability to remember information such as words, numbers, pictures, and procedures
1.A.1.e.1	Speed of Closure	The ability to quickly make sense of, combine, and organize information into meaningful patterns
1.A.1.e.2	Flexibility of Closure	The ability to identify or detect a known pattern (a figure, object, word, or sound) that is hidden in other distracting material
1.A.1.e.3	Perceptual Speed	The ability to quickly and accurately compare similarities and differences among sets of letters, numbers, objects, pictures, or patterns The things to be compared may be presented at the same time or one after the other This ability also includes comparing a presented
1.A.1.f.1	Spatial Orientation	The ability to know your location in relation to the environment or to know where other objects are in relation to you
1.A.1.f.2	Visualization	The ability to imagine how something will look after it is moved around or when its parts are moved or rearranged
1.A.1.g.1	Selective Attention	The ability to concentrate on a task over a period of time without being distracted
1.A.1.g.2	Time Sharing	The ability to shift back and forth between two or more activities or sources of information (such as speech, sounds, touch, or other sources)
1.A.2.a.1	Arm-Hand Steadiness	The ability to keep your hand and arm steady while moving your arm or while holding your arm and hand in one position
1.A.2.a.2	Manual Dexterity	The ability to quickly move your hand, your hand together with your arm, or your two hands to grasp, manipulate, or assemble objects
1.A.2.a.3	Finger Dexterity	The ability to make precisely coordinated movements of the fingers of one or both hands to grasp, manipulate, or assemble very small objects
1.A.2.b.1	Control Precision	The ability to quickly and repeatedly adjust the controls of a machine or a vehicle to exact positions
1.A.2.b.2	Multilimb Coordination	The ability to coordinate two or more limbs (for example, two arms, two legs, or one leg and one arm) while sitting, standing, or lying down It does not involve performing the activities while the whole body is in motion
1.A.2.b.3	Response Orientation	The ability to choose quickly between two or more movements in response to two or more different signals (lights, sounds, pictures) It includes the speed with which the correct response is started with the hand, foot, or other body part
1.A.2.b.4	Rate Control	The ability to time your movements or the movement of a piece of equipment in anticipation of changes in the speed and/or direction of a moving object or scene
1.A.2.c.1	Reaction Time	The ability to quickly respond (with the hand, finger, or foot) to a signal (sound, light, picture) when it appears
1.A.2.c.2	Wrist-Finger Speed	The ability to make fast, simple, repeated movements of the fingers, hands, and wrists
1.A.2.c.3	Speed of Limb Movement	The ability to quickly move the arms and legs

1.A.3.a.1	Static Strength	The ability to exert maximum muscle force to lift, push, pull, or carry objects
1.A.3.a.2	Explosive Strength	The ability to use short bursts of muscle force to propel oneself (as in jumping or sprinting), or to throw an object
1.A.3.a.3	Dynamic Strength	The ability to exert muscle force repeatedly or continuously over time This involves muscular endurance and resistance to muscle fatigue
1.A.3.a.4	Trunk Strength	The ability to use your abdominal and lower back muscles to support part of the body repeatedly or continuously over time without 'giving out' or fatiguing
1.A.3.b.1	Stamina	The ability to exert yourself physically over long periods of time without getting winded or out of breath
1.A.3.c.1	Extent Flexibility	The ability to bend, stretch, twist, or reach with your body, arms, and/or legs
1.A.3.c.2	Dynamic Flexibility	The ability to quickly and repeatedly bend, stretch, twist, or reach out with your body, arms, and/or legs
1.A.3.c.3	Gross Body Coordination	The ability to coordinate the movement of your arms, legs, and torso together when the whole body is in motion
1.A.3.c.4	Gross Body Equilibrium	The ability to keep or regain your body balance or stay upright when in an unstable position
1.A.4.a.1	Near Vision	The ability to see details at close range (within a few feet of the observer)
1.A.4.a.2	Far Vision	The ability to see details at a distance
1.A.4.a.3	Visual Color Discrimination	The ability to match or detect differences between colors, including shades of color and brightness
1.A.4.a.4	Night Vision	The ability to see under low light conditions
1.A.4.a.5	Peripheral Vision	The ability to see objects or movement of objects to one's side when the eyes are looking ahead
1.A.4.a.6	Depth Perception	The ability to judge which of several objects is closer or farther away from you, or to judge the distance between you and an object
1.A.4.a.7	Glare Sensitivity	The ability to see objects in the presence of glare or bright lighting
1.A.4.b.1	Hearing Sensitivity	The ability to detect or tell the differences between sounds that vary in pitch and loudness
1.A.4.b.2	Auditory Attention	The ability to focus on a single source of sound in the presence of other distracting sounds
1.A.4.b.3	Sound Localization	The ability to tell the direction from which a sound originated
1.A.4.b.4	Speech Recognition	The ability to identify and understand the speech of another person
1.A.4.b.5	Speech Clarity	The ability to speak clearly so others can understand you

ID	Ability	Anchor Description	Anchor Value
1.A.1.a.1	Oral Comprehension	Understand a television commercial	2
1.A.1.a.1	Oral Comprehension	Understand a coach's oral instructions for a sport	4
1.A.1.a.1	Oral Comprehension	Understand a lecture on advanced physics	6
1.A.1.a.2	Written Comprehension	Understand signs on the highway	2
1.A.1.a.2	Written Comprehension	Understand an apartment lease	4
1.A.1.a.2	Written Comprehension	Understand an instruction book on repairing missile guidance systems	6
1.A.1.a.3	Oral Expression	Cancel newspaper delivery by phone	2
1.A.1.a.3	Oral Expression	Give instructions to a lost motorist	4
1.A.1.a.3	Oral Expression	Explain advanced principles of genetics to college freshmen	6
1.A.1.a.4	Written Expression	Write a note to remind someone to take food out of the freezer	1
1.A.1.a.4	Written Expression	Write a job recommendation for a subordinate	4
1.A.1.a.4	Written Expression	Write an advanced economics textbook	6
1.A.1.b.1	Fluency of Ideas	Name four different uses for a screwdriver	2
1.A.1.b.1	Fluency of Ideas	Think of as many ideas as possible for the name of a new company	4
1.A.1.b.1	Fluency of Ideas	Name all the possible strategies for a military battle	6
1.A.1.b.2	Originality	Use a credit card to open a locked door	2
1.A.1.b.2	Originality	Redesign job tasks to be interesting for employees	4
1.A.1.b.2	Originality	Invent a new type of man-made fiber	6
1.A.1.b.3	Problem Sensitivity	Recognize that an unplugged lamp won't work	2
1.A.1.b.3	Problem Sensitivity	Recognize from the mood of prisoners that a prison riot is likely to occur	4
1.A.1.b.3	Problem Sensitivity	Recognize an illness at an early stage of a disease when there are only a few symptoms	6
1.A.1.b.4	Deductive Reasoning	Know that a stalled car can coast downhill	2
1.A.1.b.4	Deductive Reasoning	Decide what factors to consider in selecting stocks	5
1.A.1.b.4	Deductive Reasoning	Design an aircraft wing using principles of aerodynamics	6
1.A.1.b.5	Inductive Reasoning	Decide what to wear based on the weather report	2
1.A.1.b.5	Inductive Reasoning	Determine the prime suspect based on crime scene evidence	4
1.A.1.b.5	Inductive Reasoning	Diagnose a disease using results of many different lab tests	6
1.A.1.b.6	Information Ordering	Put things in numerical order	1
1.A.1.b.6	Information Ordering	Follow the correct steps to make change	2
1.A.1.b.6	Information Ordering	Assemble a nuclear warhead	6
1.A.1.b.7	Category Flexibility	Sort nails in a toolbox on the basis of length	2

1.A.1.b.7	Category Flexibility	Classify flowers according to size, color, and smell	3
1.A.1.b.7	Category Flexibility	Classify man-made fibers in terms of their strength, cost, flexibility, melting points, etc.	6
1.A.1.c.1	Mathematical Reasoning	Determine how much 10 oranges will cost when they are priced at 2 for 20 cents	1
1.A.1.c.1	Mathematical Reasoning	Decide how to calculate profits to determine the amounts of yearly bonuses	4
1.A.1.c.1	Mathematical Reasoning	Determine the mathematics required to simulate a space craft landing on the moon	6
1.A.1.c.2	Number Facility	Add 2 and 7	1
1.A.1.c.2	Number Facility	Balance a checkbook	3
1.A.1.c.2	Number Facility	Compute the interest payment that should be generated from an investment	5
1.A.1.d.1	Memorization	Remember the number on your bus to be sure you get back on the right one	1
1.A.1.d.1	Memorization	Recite the first names of the five people you just met	4
1.A.1.d.1	Memorization	Recite the Gettysburg Address after studying it for 15 minutes	6
1.A.1.e.1	Speed of Closure	Recognize a song after hearing only the first few notes	3
1.A.1.e.1	Speed of Closure	Make sense out of strange handwriting	4
1.A.1.e.1	Speed of Closure	Interpret patterns on weather radar to decide if the weather is changing	5
1.A.1.e.2	Flexibility of Closure	Tune in a radio in a noisy truck	2
1.A.1.e.2	Flexibility of Closure	Look for a golf ball in the rough	4
1.A.1.e.2	Flexibility of Closure	Identify camouflaged tanks from a high-speed airplane	6
1.A.1.e.3	Perceptual Speed	Sort mail according to ZIP codes with no time pressure	2
1.A.1.e.3	Perceptual Speed	Read five temperature gauges in 10 seconds to make sure each temperature is within safe limits	4
1.A.1.e.3	Perceptual Speed	Inspect electrical parts for defects as they flow by on a fast-moving assembly line	6
1.A.1.f.1	Spatial Orientation	Use the floor plan to locate a store in a mall	2
1.A.1.f.1	Spatial Orientation	Find your way through a dark room without hitting anything	3
1.A.1.f.1	Spatial Orientation	Navigate an ocean voyage using only the positions of the sun and stars	6
1.A.1.f.2	Visualization	Imagine how to put paper in a typewriter so that the letterhead comes out on top	2
1.A.1.f.2	Visualization	Follow a diagram to assemble a metal storage cabinet	4
1.A.1.f.2	Visualization	Anticipate opponent's as well as your own future moves in a chess game	6
1.A.1.g.1	Selective Attention	Answer a business call with coworkers talking nearby	2
1.A.1.g.1	Selective Attention	Monitor security TV screens for intruders throughout the night shift	4
1.A.1.g.1	Selective Attention	Study a technical manual in a noisy boiler room	6
1.A.1.g.2	Time Sharing	Listen to music while filing papers	2
1.A.1.g.2	Time Sharing	Watch street signs while driving at 30 miles an hour	3
1.A.1.g.2	Time Sharing	Monitor radar and radio transmissions to keep track of aircraft during periods of heavy traffic	6

1.A.2.a.1	Arm-Hand Steadiness	Light a candle	2
1.A.2.a.1	Arm-Hand Steadiness	Thread a needle	4
1.A.2.a.1	Arm-Hand Steadiness	Cut facets in a diamond	6
1.A.2.a.2	Manual Dexterity	Screw a light bulb into a light socket	1
1.A.2.a.2	Manual Dexterity	Pack oranges in crates as quickly as possible	4
1.A.2.a.2	Manual Dexterity	Perform open heart surgery with surgical instruments	7
1.A.2.a.3	Finger Dexterity	Put coins in a parking meter	2
1.A.2.a.3	Finger Dexterity	Attach small knobs to stereo equipment on an assembly line	4
1.A.2.a.3	Finger Dexterity	Put together the inner workings of a small wrist watch	6
1.A.2.b.1	Control Precision	Adjust a room light with a dimmer switch	2
1.A.2.b.1	Control Precision	Adjust farm tractor controls	4
1.A.2.b.1	Control Precision	Drill a tooth	6
1.A.2.b.2	Multilimb Coordination	Row a boat	2
1.A.2.b.2	Multilimb Coordination	Operate a forklift truck in a warehouse	4
1.A.2.b.2	Multilimb Coordination	Play the drum set in a jazz band	6
1.A.2.b.3	Response Orientation	When the doorbell and telephone ring at the same time, quickly select which to answer first	2
1.A.2.b.3	Response Orientation	Hit either the automobile brake or gas pedal in a skid situation	4
1.A.2.b.3	Response Orientation	In an out of control spacecraft, react quickly to restore control	7
1.A.2.b.4	Rate Control	Ride a bicycle alongside a jogger	1
1.A.2.b.4	Rate Control	Keep up with a car that changes speed	4
1.A.2.b.4	Rate Control	Shoot a duck in flight	5
1.A.2.c.1	Reaction Time	Start to slow down the car when a traffic light turns yellow	2
1.A.2.c.1	Reaction Time	Throw a switch when a red warning light goes off	4
1.A.2.c.1	Reaction Time	Hit the brake when a pedestrian steps in front of the car	6
1.A.2.c.2	Wrist-Finger Speed	Use a manual pencil sharpener	2
1.A.2.c.2	Wrist-Finger Speed	Carve roast beef in a cafeteria	3
1.A.2.c.2	Wrist-Finger Speed	Type a document at 90 words per minute	6
1.A.2.c.3	Speed of Limb Movement	Saw through a thin piece of wood	2
1.A.2.c.3	Speed of Limb Movement	Swat a fly with a fly swatter	4
1.A.2.c.3	Speed of Limb Movement	Throw punches in a boxing match	6
1.A.3.a.1	Static Strength	Push an empty shopping cart	1
1.A.3.a.1	Static Strength	Pull a 40-pound sack of fertilizer across the lawn	4

1.A.3.a.1	Static Strength	Lift 75-pound bags of cement onto a truck	6
1.A.3.a.2	Explosive Strength	Hit a nail with a hammer	2
1.A.3.a.2	Explosive Strength	Jump onto a 3-foot high platform	4
1.A.3.a.2	Explosive Strength	Throw a shot-put in a track meet	7
1.A.3.a.3	Dynamic Strength	Use pruning shears to trim a bush	2
1.A.3.a.3	Dynamic Strength	Climb a 48-foot long ladder	5
1.A.3.a.3	Dynamic Strength	Perform a gymnastics routine using the rings	6
1.A.3.a.4	Trunk Strength	Sit up in an office chair	2
1.A.3.a.4	Trunk Strength	Shovel snow for half an hour	4
1.A.3.a.4	Trunk Strength	Do 100 sit-ups	6
1.A.3.b.1	Stamina	Walk 1/4 mile	1
1.A.3.b.1	Stamina	Climb 6 flights of stairs	4
1.A.3.b.1	Stamina	Run 10 miles	6
1.A.3.c.1	Extent Flexibility	Reach for a microphone in a patrol car	2
1.A.3.c.1	Extent Flexibility	Reach for a box on a high warehouse shelf	4
1.A.3.c.1	Extent Flexibility	Work under the dashboard of a car	6
1.A.3.c.2	Dynamic Flexibility	Hand pick a bushel of apples from a tree	2
1.A.3.c.2	Dynamic Flexibility	Perform a dance routine as part of a cheerleading squad	5
1.A.3.c.2	Dynamic Flexibility	Maneuver a kayak through swift rapids	6
1.A.3.c.3	Gross Body Coordination	Get in and out of a truck	2
1.A.3.c.3	Gross Body Coordination	Swim the length of a pool	4
1.A.3.c.3	Gross Body Coordination	Perform a ballet dance	6
1.A.3.c.4	Gross Body Equilibrium	Stand on a ladder	2
1.A.3.c.4	Gross Body Equilibrium	Walk on ice across a pond	4
1.A.3.c.4	Gross Body Equilibrium	Walk on narrow beams in high-rise construction	6
1.A.4.a.1	Near Vision	Read dials on the dashboard of a car	2
1.A.4.a.1	Near Vision	Read the fine print of a legal document	5
1.A.4.a.1	Near Vision	Detect minor defects in a diamond	6
1.A.4.a.2	Far Vision	Read a roadside billboard	2
1.A.4.a.2	Far Vision	Focus a slide projector	4
1.A.4.a.2	Far Vision	Detect differences in ships on the horizon	7
1.A.4.a.3	Visual Color Discrimination	Separate laundry into colors and whites	1

1.A.4.a.3	Visual Color Discrimination	Trace electrical circuits marked by various colored wires	4
1.A.4.a.3	Visual Color Discrimination	Paint a color portrait of a live person	6
1.A.4.a.4	Night Vision	Read street signs at dusk (just after sunset)	2
1.A.4.a.4	Night Vision	Take notes during a slide presentation	4
1.A.4.a.4	Night Vision	Find your way through the woods on a moonless night	6
1.A.4.a.5	Peripheral Vision	Keep in step while marching in a military formation	2
1.A.4.a.5	Peripheral Vision	Be aware of the location of your teammates while dribbling a basketball	4
1.A.4.a.5	Peripheral Vision	Distinguish friendly from enemy planes during air combat	6
1.A.4.a.6	Depth Perception	Merge a car into traffic on a city street	2
1.A.4.a.6	Depth Perception	Operate a crane to move materials from a truck bed to the ground	4
1.A.4.a.6	Depth Perception	Throw a long pass to a closely guarded teammate	6
1.A.4.a.7	Glare Sensitivity	Drive on a familiar road on a cloudy day	2
1.A.4.a.7	Glare Sensitivity	See boats on the horizon when sailing	5
1.A.4.a.7	Glare Sensitivity	Snow ski in bright sunlight	6
1.A.4.b.1	Hearing Sensitivity	Notice when a watch alarm goes off	2
1.A.4.b.1	Hearing Sensitivity	Diagnose what's wrong with a car engine from its sound	4
1.A.4.b.1	Hearing Sensitivity	Tune an orchestra	6
1.A.4.b.2	Auditory Attention	Listen to a lecture while people nearby are talking	2
1.A.4.b.2	Auditory Attention	Listen for your flight announcement at a busy airport	4
1.A.4.b.2	Auditory Attention	Listen to instructions from a coworker in a noisy saw mill	6
1.A.4.b.3	Sound Localization	Listen to a stereo to determine which speaker is working	2
1.A.4.b.3	Sound Localization	Find a ringing telephone in an unfamiliar apartment	4
1.A.4.b.3	Sound Localization	Determining the direction of an emergency vehicle from the sound of the siren	6
1.A.4.b.4	Speech Recognition	Recognize the voice of a coworker	2
1.A.4.b.4	Speech Recognition	Identify a former customer's voice over the telephone	4
1.A.4.b.4	Speech Recognition	Understand a speech presented by someone with a strange accent	6
1.A.4.b.5	Speech Clarity	Call numbers in a bingo game	1
1.A.4.b.5	Speech Clarity	Make announcements over the loudspeaker at a sports event	4
1.A.4.b.5	Speech Clarity	Give a lecture to a large audience	6

Appendix 3. O*NET Profile on Telemarketers

O*NET OnLine

Updated 2019

Summary Report for:
41-9041.00 - Telemarketers

Solicit donations or orders for goods or services over the telephone.

Sample of reported job titles: Telemarketer, Telemarketing Sales Representative, Telephone Sales Representative (TSR), Telephone Service Representative (TSR), Telesales Representative, Telesales Specialist

View report: Summary | Details | Custom

Tasks | Technology Skills | Tools Used | Knowledge | Skills | Abilities | Work Activities | Detailed Work Activities | Work Context | Job Zone | Education | Credentials | Interests | Work Styles | Work Values | Related Occupations | Wages & Employment | Job Openings | Additional Information

Tasks

5 of 12 displayed

- Deliver prepared sales talks, reading from scripts that describe products or services, to persuade potential customers to purchase a product or service or to make a donation.
- Contact businesses or private individuals by telephone to solicit sales for goods or services, or to request donations for charitable causes.
- Explain products or services and prices, and answer questions from customers.
- Obtain customer information such as name, address, and payment method, and enter orders into computers.
- Record names, addresses, purchases, and reactions of prospects contacted.

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Technology Skills

5 of 8 displayed **Show 5 tools used**

- **Access software** — Remote access call center software
- **Customer relationship management CRM software** — Database Systems Corp Telemation; Microsoft Dynamics
- **Electronic mail software** — Microsoft Outlook
- **Helpdesk or call center software** — Acarda Sales Technologies Acarda Outbound; Automatic call distribution software; Softphone software
- **Spreadsheet software** — Microsoft Excel

Hot Technology — a technology requirement frequently included in employer job postings.

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Knowledge

All 4 displayed

- **Sales and Marketing** — Knowledge of principles and methods for showing, promoting, and selling products or services. This includes marketing strategy and tactics, product demonstration, sales techniques, and sales control systems.

- **English Language** — Knowledge of the structure and content of the English language including the meaning and spelling of words, rules of composition, and grammar.
- **Customer and Personal Service** — Knowledge of principles and processes for providing customer and personal services. This includes customer needs assessment, meeting quality standards for services, and evaluation of customer satisfaction.
- **Telecommunications** — Knowledge of transmission, broadcasting, switching, control, and operation of telecommunications systems.

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Skills

5 of 6 displayed

- **Speaking** — Talking to others to convey information effectively.
- **Persuasion** — Persuading others to change their minds or behavior.
- **Active Listening** — Giving full attention to what other people are saying, taking time to understand the points being made, asking questions as appropriate, and not interrupting at inappropriate times.
- **Service Orientation** — Actively looking for ways to help people.
- **Social Perceptiveness** — Being aware of others' reactions and understanding why they react as they do.

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Abilities

5 of 6 displayed

- **Oral Expression** — The ability to communicate information and ideas in speaking so others will understand.
- **Oral Comprehension** — The ability to listen to and understand information and ideas presented through spoken words and sentences.
- **Speech Clarity** — The ability to speak clearly so others can understand you.
- **Speech Recognition** — The ability to identify and understand the speech of another person.
- **Selective Attention** — The ability to concentrate on a task over a period of time without being distracted.

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Work Activities

5 of 11 displayed

- **Selling or Influencing Others** — Convincing others to buy merchandise/goods or to otherwise change their minds or actions.
- **Interacting With Computers** — Using computers and computer systems (including hardware and software) to program, write software, set up functions, enter data, or process information.
- **Communicating with Persons Outside Organization** — Communicating with people outside the organization, representing the organization to customers, the public, government, and other external sources. This information can be exchanged in person, in writing, or by telephone or e-mail.
- **Getting Information** — Observing, receiving, and otherwise obtaining information from all relevant sources.
- **Establishing and Maintaining Interpersonal Relationships** — Developing constructive and cooperative working relationships with others, and maintaining them over time.

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Detailed Work Activities

5 of 9 displayed

- Contact current or potential customers to promote products or services.
- Answer customer questions about goods or services.
- Deliver promotional presentations to current or prospective customers.
- Explain technical product or service information to customers.
- Maintain records of customer accounts.

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Work Context

5 of 22 displayed

- **Contact With Others** — 99% responded “Constant contact with others.”
- **Telephone** — 100% responded “Every day.”
- **Spend Time Sitting** — 96% responded “Continually or almost continually.”
- **Deal With Unpleasant or Angry People** — 81% responded “Every day.”
- **Face-to-Face Discussions** — 70% responded “Every day.”

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Job Zone

Title	Job Zone Two: Some Preparation Needed
Education	These occupations usually require a high school diploma.
Related Experience	Some previous work-related skill, knowledge, or experience is usually needed. For example, a teller would benefit from experience working directly with the public.
Job Training	Employees in these occupations need anywhere from a few months to one year of working with experienced employees. A recognized apprenticeship program may be associated with these occupations.
Job Zone Examples	These occupations often involve using your knowledge and skills to help others. Examples include orderlies, forest firefighters, customer service representatives, security guards, upholsterers, and tellers.
SVP Range	(4.0 to < 6.0)

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Education

Percentage of Respondents	Education Level Required
59	High school diploma or equivalent
30	Less than high school diploma
11	Some college, no degree

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Credentials

Find Certifications Find Licenses APPRENTICESHIP.GOV

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Interests

All 2 displayed

Interest code: **EC** Want to discover your interests? Take the O*NET Interest Profiler at My Next Move.

- **Enterprising** — Enterprising occupations frequently involve starting up and carrying out projects. These occupations can involve leading people and making many decisions. Sometimes they require risk taking and often deal with business.
- **Conventional** — Conventional occupations frequently involve following set procedures and routines. These occupations can include working with data and details more than with ideas. Usually there is a clear line of authority to follow.

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Work Styles

5 of 12 displayed

- **Integrity** — Job requires being honest and ethical.
- **Stress Tolerance** — Job requires accepting criticism and dealing calmly and effectively with high stress situations.
- **Persistence** — Job requires persistence in the face of obstacles.
- **Achievement/Effort** — Job requires establishing and maintaining personally challenging achievement goals and exerting effort toward mastering tasks.
- **Dependability** — Job requires being reliable, responsible, and dependable, and fulfilling obligations.

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Work Values

All 3 displayed

- **Relationships** — Occupations that satisfy this work value allow employees to provide service to others and work with co-workers in a friendly non-competitive environment. Corresponding needs are Co-workers, Moral Values and Social Service.
- **Support** — Occupations that satisfy this work value offer supportive management that stands behind employees. Corresponding needs are Company Policies, Supervision: Human Relations and Supervision: Technical.
- **Achievement** — Occupations that satisfy this work value are results oriented and allow employees to use their strongest abilities, giving them a feeling of accomplishment. Corresponding needs are Ability Utilization and Achievement.

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Related Occupations

5 of 10 displayed

43-2011.00	Switchboard Operators, Including Answering Service
43-2021.00	Telephone Operators
43-3011.00	Bill and Account Collectors
43-4171.00	Receptionists and Information Clerks **Bright Outlook**
43-9041.01	Insurance Claims Clerks

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Wages & Employment Trends

Median wages (2017)	$11.76 hourly, $24,460 annual
State wages	Local Salary Info
Employment (2016)	217,000 employees
Projected growth (2016-2026)	Little or no change (-1% to 1%)
Projected job openings (2016-2026)	33,300
State trends	Employment Trends
Top industries (2016)	Administrative and Support Services

Source: Bureau of Labor Statistics 2017 wage data and 2016-2026 employment projections. "Projected growth" represents the estimated change in total employment over the projections period (2016-2026). "Projected job openings" represent openings due to growth and replacement.

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Job Openings on the Web

Find Jobs

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Sources of Additional Information

All 1 displayed

Disclaimer: Sources are listed to provide additional information on related jobs, specialties, and/or industries. Links to non-DOL Internet sites are provided for your convenience and do not constitute an endorsement.

- American Society for Quality

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Appendix 4. Delphi Questionnaires

1st Round Questionnaire (in Portuguese) – Extract, pages 1-9 out of 62

Universidade de São Paulo
Faculdade de Economia, Administração e Contabilidade
Departamento de Administração
Programa de Pós-Graduação em Administração

Pesquisa de Tese de Doutorado
Impactos da Inteligência Artificial
Questionário Delphi
Maio de 2018 – 1ª Rodada

Prezado participante,

Como um especialista no campo de Inteligência Artificial ou Robótica, temos o prazer de informar que você foi selecionado para fazer parte de um painel de especialistas sobre os impactos recentes e futuros da tecnologia, devido principalmente aos desenvolvimentos mais recentes e em andamento de IA, Robótica e áreas relacionadas.

Esta pesquisa está sendo conduzida por um aluno do doutorado da FEA USP e será usada apenas para fins acadêmicos, como meio de obtenção da titulação indicada. Esta pesquisa tem total apoio da mencionada faculdade e do Professor Doutor Cesar Alexandre de Souza, professor e coordenador da área de Sistemas de Informação, Departamento de Administração de Empresas da FEA USP.

Sua participação é essencial, por isso gostaríamos de agradecer antecipadamente pelo seu tempo e dedicação em respondê-lo. Apreciamos sua compreensão e interesse e esperamos compartilhar logo mais as descobertas com você.

Em caso de dúvidas sobre o questionário ou sobre a pesquisa, por favor, não hesite em nos contatar por e-mail ou telefone. Será um prazer responder.

Nossos cordiais cumprimentos.

Sergi Pauli, MSc
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Cesar Alexandre de Souza, PhD
Professor Doutor FEA USP

Nome:

Data Recebida:

Prazo de Entrega:

1

Universidade de São Paulo
Faculdade de Economia, Administração e Contabilidade
Departamento de Administração
Programa de Pós-Graduação em Administração

Pesquisa de Tese de Doutorado
Impactos da Inteligência Artificial
Questionário Delphi
Maio de 2018 – 1ª Rodada

Seção 1. Introdução

Como parte de uma pesquisa em andamento do doutorado, estamos executando este painel de experts com especialistas em Inteligência Artificial, Robótica e áreas correlatadas. O objetivo principal deste painel é coletar opiniões de especialistas em uma variedade de questões e, posteriormente, compartilhar as descobertas com a comunidade acadêmica.

Este painel de experts é baseado na Técnica Delphi e será inteiramente realizado remotamente através de questionários como este, sem necessidade de presença física ou interação direta entre os participantes. Esta é a primeira rodada de possivelmente três, onde são coletadas as opiniões iniciais. As rodadas subsequentes serão mais simples, usadas para refinamento e eventuais debates indiretos. As rodadas terão aproximadamente um mês de diferença entre si. A duração da pesquisa será de 3-4 meses, mas o tempo total de dedicação é de apenas 3 horas durante todo este período.

Outros especialistas acadêmicos foram selecionados e participarão desta pesquisa respondendo a este questionário. Eles podem representar diferentes organizações, diferentes locais e diferentes opiniões. Para aprimorar o debate e evitar possíveis vieses nas respostas, pedimos que evite discutir, compartilhar ou comentar esta pesquisa com outras pessoas enquanto ela estiver em andamento. Todas as respostas individuais permanecerão em sigilo durante a pesquisa e depois dela. Em rodadas posteriores, essas opiniões anônimas serão combinadas e as justificativas poderão eventualmente ser compartilhadas entre os participantes para enriquecer potenciais debates, mas sempre prezando pelo anonimato.

Este questionário está dividido em 3 seções adicionais, além desta introdução. A segunda seção é focada em dados dos participantes; a terceira seção é focada em impactos e gargalos da IA através de perguntas abertas; finalmente, a quarta seção trata da avaliação de habilidades com perguntas fechadas, baseadas em questionários pré-existentes. Como as seções são diferentes em conteúdo e forma, por favor, leia atentamente todas as instruções da seção.

Sugerimos que você planeje um horário específico para responder ao questionário e, de preferência, faça-o em um local silencioso para minimizar as interrupções. Responder em uma única vez é recomendado, mas você pode ver, rever e refinar o quanto quiser até a hora de devolvê-lo. Não há respostas certas ou erradas, já que estamos trabalhando com opiniões e previsões. É permitido consultar quaisquer dados ou fontes que você ache que possam ajudá-lo a formar uma opinião ou justificá-la.

O tempo estimado para o preenchimento do questionário é de cerca de 45 minutos. Você terá duas semanas para responder – o prazo de entrega para essa rodada está na primeira página deste questionário. Pedimos gentil e encarecidamente que respeite esta data.

Seção 2. Dados Gerais

Por favor, responda às seguintes perguntas com a(s) alternativa(s) que melhor descreve(m) você.

Minha área de trabalho principal é...
- ☐ Academia (Professor, Pesquisador)
- ☐ Outro que não Academia

Meu grau de educação mais alto (completo) é...
- ☐ Ensino Médio
- ☐ Licenciatura / Bacharelado
- ☐ Pós-graduação *lato sensu* / MBA
- ☐ Mestrado acadêmico ou profissionalizante
- ☐ Doutorado
- ☐ Pós-Doutorado

Minha principal formação acadêmica é...
- ☐ Humanidades (e.g. história, geografia)
- ☐ Ciências Sociais (e.g. administração, direito)
- ☐ Ciências Naturais (e.g. química, física, biologia)
- ☐ Ciências Formais (e.g. matemática, computação)
- ☐ Ciências Aplicadas (e.g. engenharia, medicina)

Onde você estudou a maior parte do tempo? ☐

Anos de experiência profissional em geral... ☐ Anos em academia e/ou empresa

Anos de experiência profissional em IA... ☐ Anos em academia e/ou empresa

Em relação à IA e Robótica, você se considera um(a)...

1. Antagonista, entendo que há barreiras instransponíveis que impedem a IA e a robótica de emular adequadamente atividades humanas.

2. Cético, entendo que há muitas barreiras que impedem a IA e a robótica de emular adequadamente atividades humanas, mas que vem sendo vencidas lentamente.

3. Neutro, entendo que há barreiras que impedem a IA e a robótica de emular adequadamente algumas atividades humanas, mas outras não.

4. Favorável, entendo que há poucas barreiras que impedem a IA e a robótica de emular adequadamente atividades humanas, mas que vem sendo vencidas rapidamente.

5. Entusiasta, entendo que não há barreiras que impedem a IA e a robótica de emular adequadamente atividades humanas, é apenas uma questão de tempo.

① — ② — ③ — ④ — ⑤

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Seção 3. Impactos e Gargalos da Inteligência Artificial

Entendemos que o termo Inteligência Artificial é um conceito amplo com várias definições e diversos mal-entendidos, um termo empregado muitas vezes incorretamente. Para as seguintes questões, consideramos a definição de IA de Nilsson (1998) como "comportamento inteligente em artefatos" que "envolve percepção, raciocínio, aprendizagem, comunicação e atuação em ambientes complexos", com o objetivo principal de "desenvolver máquinas que possam fazer as coisas tão bem quanto os humanos, ou possivelmente até melhor". Quando mencionamos IA nas seguintes questões, consideramos todos os campos e tópicos relacionados à Inteligência Artificial, incluindo e não limitado a Machine Learning (ML), Data Mining, Machine Vision (MV), Estatística Computacional e também Mobile Robotics (MR). Outros campos de pesquisa em tecnologia, ciências da computação e matemática relacionadas com IA não mencionados aqui, também são bem-vindos nas respostas.

Por favor, responda as seguintes perguntas abertas com base em suas opiniões pessoais.

1) Na sua opinião, quais serão os principais impactos positivos da IA (e tecnologias relacionadas) nas organizações (empresas públicas, privadas e não governamentais) nos próximos vinte anos? Por favor, indique pelo menos 3 impactos com uma breve explicação sobre cada um.

2) Na sua opinião, quais serão os principais impactos negativos da IA (e tecnologias relacionadas) nas organizações (empresas públicas, privadas e não governamentais) nos próximos vinte anos? Por favor, indique pelo menos 3 impactos com uma breve explicação sobre cada um.

3) Na sua opinião, quais serão os principais impactos positivos da IA (e tecnologias relacionadas) no emprego e no mercado de trabalho nos próximos vinte anos? Por favor, indique pelo menos 3 impactos com uma breve explicação sobre cada um.

4) Na sua opinião, quais serão os principais impactos negativos da IA (e tecnologias relacionadas) no emprego e no mercado de trabalho nos próximos vinte anos? Por favor, indique pelo menos 3 impactos com uma breve explicação sobre cada um.

5) Como explica Nilsson (1998), o principal objetivo da IA é "desenvolver máquinas que possam fazer as coisas tão bem quanto os humanos, ou possivelmente até melhor". Na sua opinião, quais são os principais gargalos para o progresso da IA (e tecnologias relacionadas)? Em outras palavras, quais áreas a IA não será capaz de avançar, permanecendo essencialmente humanas nos próximos vinte anos? Por favor, cite pelo menos 3 e as razões.

Seção 4. Avaliação de Habilidades

Uma parte importante desta pesquisa é o mercado de trabalho e como ele será impactado pela IA e Robótica. Nesse sentido, o objetivo principal nesta seção é determinar em que medida as seguintes habilidades podem ser adequadamente executadas ou emuladas por equipamentos controlados por computadores e sistemas de última geração **de forma autônoma, sem envolvimento humano**, mesmo que não da mesma forma. Na resposta, considere os mais recentes desenvolvimentos e pesquisas em andamento em Inteligência Artificial (IA), incluindo e não limitado a Machine Learning (ML), Data Mining, Machine Vision (MV), Estatística Computacional e também Mobile Robotics (MR). Outros campos de pesquisa em tecnologia, ciências da computação e matemática relacionadas com IA não mencionados aqui, também devem ser considerados.

Nas páginas a seguir, habilidades genéricas necessárias em diferentes tarefas são apresentadas. Habilidades são talentos duradouros que permitem que uma pessoa realize um trabalho. Uma escala de complexidade com âncoras específicas é apresentada para cada habilidade (de 1, ‘menor complexidade’ a 7, ‘maior complexidade’) para ajudar a esclarecer aquela capacidade. Essas âncoras são meros exemplos ilustrativos, portanto, **concentre-se na escala em si e não tanto nas ancoras para definir sua resposta**.

São feitas duas perguntas sobre cada habilidade. Considerando sua experiência e conhecimento, responda-as marcando o ponto na escala. As perguntas são muito parecidas, mas **a principal diferença é o horizonte de tempo**: enquanto que a questão ‘a’ lida com a situação atual (**2018**), a questão ‘b’ lida com uma situação futura, uma previsão de 20 anos a partir de agora (**2038**). Justifique sua resposta com uma explicação caso ache relevante, mencionando tecnologia específica, conceito, pesquisa, referência ou aplicação que fundamenta a sua decisão. Suas respostas não devem se limitar ao Brasil. Finalmente, indique seu nível de competência (experiência, conhecimento) para avaliar cada a habilidade (de 0, ‘nenhuma competência’ a 10 ‘competência total’).

Por favor, **responda todas as habilidades e atribua um número a todos os componentes**, não importa o quão confiante você esteja na resposta ou o quanto você se considera conhecedor do assunto.

As respostas individuais a essa avaliação permanecerão em sigilo durante e depois a pesquisa, de modo que seus comentários e respostas serão tratados como confidenciais. Em rodadas posteriores, as opiniões podem ser usadas para enriquecer eventuais debates indiretos, mas elas serão combinadas ou permanecerão anônimas.

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PhD Thesis Research
Artificial Intelligence Impacts Research
Delphi Questionnaire
May 2018

Exemplo ilustrativo e orientações:

Estabilidade de Mão e Braço	**A capacidade de manter a mão e o braço estáveis enquanto movimenta o braço ou enquanto segura o braço e a mão em uma posição.**

Acender uma vela ↓ (2) — Passar um fio na agulha ↓ (4) — Cortar lados de um diamante ↓ (6)

1 — 2 — 3 — 4 — 5 — 6 — 7

Nível mais baixo — Nível mais alto

1) Responda a duas perguntas sobre essa habilidade específica, marcando o número correspondente na escala.

a) Na sua opinião e com base no seu conhecimento, até que ponto (nível) a IA e outras tecnologias disponíveis em **2018** (atualmente) podem executar ou emular esta habilidade adequadamente?

1 — 2 — ~~3~~ — 4 — 5 — 6 — 7

b) Na sua opinião e com base no seu conhecimento, até que ponto (nível) a IA e outras tecnologias disponíveis até **2038** (próximos 20 anos) poderão executar ou emular esta habilidade adequadamente?

1 — 2 — 3 — 4 — ~~5~~ — 6 — 7

2) Justifique sua resposta e indique seu nível de competência no assunto.

Justificativa	Competência (0 a 10)
Boston Dynamics	*5*

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PhD Thesis Research
Artificial Intelligence Impacts Research
Delphi Questionnaire
May 2018

Habilidade 1:

Compreensão Oral	**A capacidade de ouvir e compreender informações e ideias apresentadas através de palavras e frases faladas.**

Entender um comercial de TV → 2
Entender instruções orais de um treinador para um esporte → 4
Entender uma palestra de física avançada → 6

① — ② — ③ — ④ — ⑤ — ⑥ — ⑦

Nível mais baixo ... Nível mais alto

Marque o número correspondente na escala para as duas perguntas, a e b.

a) Na sua opinião e com base no seu conhecimento, até que ponto (nível) a IA e outras tecnologias disponíveis em **2018** (atualmente) podem executar ou emular esta habilidade adequadamente?

① — ② — ③ — ④ — ⑤ — ⑥ — ⑦

b) Na sua opinião e com base no seu conhecimento, até que ponto (nível) a IA e outras tecnologias disponíveis até **2038** (próximos 20 anos) poderão executar ou emular esta habilidade adequadamente?

① — ② — ③ — ④ — ⑤ — ⑥ — ⑦

Justifique sua resposta breve e indique seu nível de competência no assunto.

Justificativa (opcional)	Competência

2nd Round Questionnaire (in Portuguese) – Full

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Impactos da Inteligência Artificial
Questionário Delphi
2ª Rodada

Prezado participante,

Em primeiro lugar, gostaríamos de agradecer pela participação e empenho na primeira fase deste painel. Informamos que atingimos a meta de respostas pretendidas e que a qualidade das respostas e observações foi muito boa, assim como os diferentes feedbacks sobre o questionário. Aproveitamos para pedir sinceras desculpas àqueles que acabaram gastando mais tempo do que o previsto, principalmente na seção de habilidades.

Em segundo lugar, realizamos a coleta, análise e combinação das respostas e observações dadas no questionário anterior, resultando na construção de 5 listas, com aproximadamente 30 itens cada, a saber:

- Impactos positivos da IA (e tecnologias relacionadas) nas organizações
- Impactos negativos da IA (e tecnologias relacionadas) nas organizações
- Impactos positivos da IA (e tecnologias relacionadas) no emprego e no mercado de trabalho
- Impactos negativos da IA (e tecnologias relacionadas) no emprego e no mercado de trabalho
- Gargalos da IA (e tecnologias relacionadas)

Iniciamos agora a segunda fase deste painel, reenviando as cinco listas a todos os especialistas que participaram na primeira rodada, pedindo agora que classifiquem individualmente e subjetivamente os 10 itens mais relevantes em cada uma das 5 listas. O objetivo final é alcançar um top 10 conjunto entre os participantes (uma terceira rodada deste questionário será necessária para validação e ajustes).

Em cada uma das listas há duas colunas (A e B). De modo a facilitar o preenchimento, primeiro pedimos que na coluna ‘A’ cada participante indique de forma binária se o item é relevante ou não, selecionando apenas 10. A seguir, para os itens pré-selecionados, solicitamos que na coluna ‘B’ classifiquem com um ranking simples de 1 (mais relevante) a 10 (menos relevante), sem repetição dos números. Caso entenda que falta algum item não listado, há um campo adicional no final de cada lista (chamado ‘outro’). O resultado esperado é ilustrado na página seguinte.

Em caso de dúvidas sobre o questionário ou sobre a pesquisa, por favor, não hesite em nos contatar por e-mail ou telefone. Será um prazer responder.

Nossos cordiais cumprimentos e agradecimentos.

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Cesar Alexandre de Souza, PhD
Professor Doutor FEA USP

Nome:

Data Recebida:

Prazo de Entrega:

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Pesquisa de Tese de Doutorado
Impactos da Inteligência Artificial
Questionário Delphi
2ª Rodada

Resultado esperado por lista - exemplo ilustrativo.

		A	B
XXxX.001	Texto 1		
XXxX.002	Texto 2		
XXxX.003	Texto 3	X	3
XXxX.004	Texto 4		
XXxX.005	Texto 5	X	9
XXxX.006	Texto 6		
XXxX.007	Texto 7		
XXxX.008	Texto 8		
XXxX.009	Texto 9		
XXxX.010	Texto 10		
XXxX.011	Texto 11	X	6
XXxX.012	Texto 12	X	5
XXxX.013	Texto 13		
XXxX.014	Texto 14		
XXxX.015	Texto 15		
XXxX.016	Texto 16		
XXxX.017	Texto 17	X	7
XXxX.018	Texto 18		
XXxX.019	Texto 19		
XXxX.020	Texto 20	X	2
XXxX.021	Texto 21	X	10
XXxX.022	Texto 22	X	4
XXxX.023	Texto 23		
XXxX.024	Texto 24		
XXxX.025	Texto 25		
XXxX.026	Texto 26		
XXxX.027	Texto 27		
XXxX.028	Texto 28		
XXxX.029	Texto 29	X	1
XXxX.030	Texto 30		
XXxX.031	Texto 31		
XXxX.032	Texto 32	X	8
Outro			

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1. Considerando a lista a seguir, apresentada em ordem aleatória, classifique os **10 impactos positivos mais relevantes da IA** (e tecnologias relacionadas) **nas organizações**. Por favor, utilize a coluna 'A' para facilitar a escolha inicial dos 10 itens mais relevantes e depois indique o ranking na coluna 'B' (de 1, mais relevante a 10, menos relevante), sem repetir números.

		A	B
IPnO.001	Aumento na produtividade e eficiência dos processos das organizações de forma geral ("fazer melhor")		
IPnO.002	Mais agilidade e velocidade dos processos das organizações de forma geral ("fazer mais rápido")		
IPnO.003	Aceleração no processo de desenvolvimento de novos produtos, serviços e/ou tecnologias		
IPnO.004	Dispersão acelerada na aplicação de IA embutida de modo transparente e ubíqua em processos, produtos e/ou serviços		
IPnO.005	Desenvolvimento e refinamento de métodos de tomada de decisão e resolução de problemas, melhorando a qualidade da decisão		
IPnO.006	Maior diversidade de formas de interação entre homem e máquina e consequente aplicação em novas funções nas organizações		
IPnO.007	Automação generalizada de atividades, principalmente aquelas rotineiras, repetitivas, avançando também em tarefas complexas		
IPnO.008	Evolução na forma de trabalhar com foco na parceria e colaboração entre máquina e homem, combinando os pontos fortes de cada		
IPnO.009	Melhora na gestão do conhecimento e treinamentos, com tutores inteligentes, conteúdo direcionado e melhor suporte à busca		
IPnO.010	Evolução dos mecanismos de segurança e defesa contra problemas, erros ou danos, e de predição e prevenção de acidentes		
IPnO.011	Redução de riscos associados a atividades de alto risco, de insalubridade (e de danos à saúde) ou de extrema fadiga		
IPnO.012	Aplicação da robótica e IA em atividades e processos de alta precisão, que requerem alta confiabilidade		
IPnO.013	Redução da burocracia (pública e privada) e morosidade, com a ampliação da automação de processos e/ou serviços		
IPnO.014	Propagação do uso de assistentes virtuais no cotidiano das organizações, funcionando como um novo aplicativo de produtividade		
IPnO.015	Uso mais inteligente de recursos (naturais, humanos, tempo), reduzindo desperdícios e melhorando o meio ambiente		
IPnO.016	Ampliação na oferta de produtos e/ou serviços, em quantidade, novidade e variabilidade ("mix") e com escalabilidade		
IPnO.017	Aprimoramento do uso de dados disponíveis, principalmente os não estruturados, com novos métodos de descoberta e análise		
IPnO.018	Aprimoramento da qualidade de produtos, serviços e soluções, mais eficientes, mais inteligentes, e mais acessíveis		
IPnO.019	Liberação de pessoas de atividades tediosas, alienantes e de baixo valor agregado para atividades mais desafiantes e de valor		
IPnO.020	Melhor entendimento de quem são os clientes, suas expectativas e anseios em relação aos produtos e/ou serviços ofertados		
IPnO.021	Aprimoramento no processo de contratação de pessoas, com maior adequação e conformidade com requerimentos e perfil		
IPnO.022	Aprimoramento das cadeias de suprimento, trabalhando de forma mais eficiente (menos perdas e quebras) com rastreabilidade		
IPnO.023	Geração de novas vantagens competitivas para as organizações preparadas para o cenário futuro (altamente tecnológico)		
IPnO.024	Criação de produtos e/ou serviços direcionados e personalizados para necessidades particulares, agregando mais valor ao cliente		
IPnO.025	Melhora na integração de dados, permitindo combinar informações de modo mais fácil e com melhores resultados		
IPnO.026	Maior governança e transparência, alavancadas por novos dispositivos de controle contra corrupção, desvios e fraudes		
IPnO.027	Evolução na qualidade de vida e bem-estar das pessoas nas organizações		
IPnO.028	Criação de novos modelos de negócio (alguns ainda inexistentes) intimamente ligados à tecnologia ("uberização da economia")		
IPnO.029	Diversificação na natureza das organizações, com empresas diversificando suas ofertas e/ou migrando de setor / indústria		
IPnO.030	Maior acessibilidade e inclusão das pessoas, tecnologias auxiliarão pessoas com dificuldades ou com menos experiência		
IPnO.031	Deslocamento do foco do trabalho das atividades operacionais para atividades analíticas e estratégicas		
IPnO.032	Diminuição da exposição à risco de erros, retrabalho e acidentes de trabalho com a automação		
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2. Considerando a lista a seguir, apresentada em ordem aleatória, classifique os **10 impactos negativos mais relevantes da IA** (e tecnologias relacionadas) **nas organizações**. Por favor, utilize a coluna 'A' para facilitar a escolha inicial dos 10 itens mais relevantes e depois indique o ranking na coluna 'B' (de 1, mais relevante a 10, menos relevante), sem repetir números.

		A	B
INnO.001	Problemas decorrentes da incapacidade de identificação e decisão em cenários desconhecidos, novos ou de ruptura		
INnO.002	Dependência excessiva das organizações em relação às máquinas, gerando problemas quando estas não tenham respostas		
INnO.003	Substituição em massa da mão-de-obra humana por máquinas nas organizações, colaborando com o potencial desemprego		
INnO.004	Necessidade de recapacitação em massa de funcionários, devido à obsolescência de carreiras e funções em todos os níveis		
INnO.005	Redução na demanda de produtos e/ou serviços, em decorrência do aumento no potencial desemprego gerado pelas tecnologias		
INnO.006	Desconfiança e insatisfação com a AI devido à falta de transparência no processo decisório (efeito "caixa-preta")		
INnO.007	Desvirtuamento, enviesamento, má utilização da tecnologia, com fins impróprios, antiéticos, ilegais e/ou criminosos		
INnO.008	Problemas com comportamentos socialmente inadequados da IA como discriminação racial, sexual, religiosa, política, etc.		
INnO.009	Perda ou falta de controle das organizações sobre os algoritmos 'autônomos', ou incapacidade de detectar erros nestes algoritmos		
INnO.010	Supervalorização das máquinas (e de seus resultados) em detrimento das opiniões, expertise e experiências humanas		
INnO.011	Banalização do uso de tecnologias, isto é, aplicação irrestrita em tarefas e serviços em que habilidades humanas são essenciais		
INnO.012	Intensificação nos problemas de privacidade: violação de dados, utilização sem consentimento e/ou para propósitos inadequados		
INnO.013	Aumento de custos em segurança da informação para combater problemas de privacidade, auditoria e mitigação para controlar IA		
INnO.014	Perda de competitividade e risco de falência das organizações que não mudarem para o novo paradigma rapidamente		
INnO.015	Ampliação no controle das pessoas e das organizações, afetando privacidade, cerceamento de liberdades e individualidades, etc.		
INnO.016	Excessivo controle e concentração econômica, social e de conhecimento em poucas organizações		
INnO.017	Problemas frente à nova realidade na relação organização / funcionário com formas e naturezas distintas das atuais		
INnO.018	Novas legislações visando proteger o emprego, como criação de reservas de mercado, intensificação do papel regulador do Estado		
INnO.019	Falta de mão-de-obra qualificada, uma vez que o sistema educacional não está preparado para as novas exigências		
INnO.020	Aumento contínuo e crescente em custos de tecnologia (hardware, software, algoritmos, robôs, profissionais, etc.)		
INnO.021	Distanciamento entre expectativa e realidade com IA, pois implementação de qualidade ainda é lenta, custosa e limitada		
INnO.022	Aversão ou resistência à mudança, dificuldades variadas em lidar com as tecnologias e/ou lenta velocidade de adoção		
INnO.023	Desigualdade e desequilíbrio crescente entre recursos humanos nas organizações, afetando seu desempenho em geral		
INnO.024	Aumento de competitividade em escala global com guerras comerciais inclusive entre organizações (e seus algoritmos)		
INnO.025	Obsolescência de diversas estratégias de negócio atuais (por exemplo, terceirização da mão-de-obra para países mais baratos)		
INnO.026	Conflitos na indefinição de papéis e responsabilidades entre máquinas e humanos ("o que a máquina deve ou não fazer?")		
INnO.027	Problemas decorrentes da incapacidade de tratar ou identificar cenários com potenciais conflitos éticos e morais		
INnO.028	Consequências negativas de imagem e valor de mercado das organizações devido aos diversos problemas descritos		
INnO.029	Redução de barreiras de entrada, com novos concorrentes "não tradicionais" (enxutos, ágeis, produtivos, baseados em tecnologia)		
INnO.030	Maior imprevisibilidade, volatilidade e dinamismo dos setores e mercados, afetando o planejamento e estratégias das organizações		
INnO.031	Problemas das organizações em criar, manter, reconhecer e reter talentos considerando a nova realidade do emprego		
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3. Considerando a lista a seguir, apresentada em ordem aleatória, classifique os **10 impactos positivos mais relevantes da IA** (e tecnologias relacionadas) **no emprego e no mercado de trabalho**. Por favor, utilize a coluna ‘A’ para facilitar a escolha inicial dos 10 itens mais relevantes e depois indique o ranking na coluna ‘B’ (de 1, mais relevante a 10, menos relevante), sem repetir números.

		A	B
IPnT.001	Vantagens para os profissionais das áreas menos afetadas pelas novas tecnologias		
IPnT.002	Valorização de profissionais com formação sólida, alto nível de escolaridade, competências e experiências nas novas tecnologias		
IPnT.003	Criação de novas carreiras e funções dentro das organizações, grande parte com viés tecnológico, contudo mais exigentes		
IPnT.004	Melhora na produtividade e eficiência individual no trabalho		
IPnT.005	Criação de novos postos de trabalho, para atender novos tipos de negócios, produtos e/ou serviços		
IPnT.006	Criação de novas políticas sociais públicas (ou privadas) como de renda mínima, de modo a balancear mercado de trabalho		
IPnT.007	Maior longevidade de profissionais no mercado de trabalho, associado ao aumento na expectativa de vida		
IPnT.008	Redução da carga horária de trabalho atual e maior flexibilização do horário de trabalho		
IPnT.009	Aumento da importância relativa de organizações não governamentais ou sem fins lucrativos no mercado de trabalho (empregos)		
IPnT.010	Substituição da mão-de-obra humana nas atividades de repetitivas, tediosas, alienantes e/ou de baixo valor agregado		
IPnT.011	Substituição da mão-de-obra humana nas atividades de alto risco, de insalubridade (e de danos à saúde) e/ou de extrema fadiga		
IPnT.012	Ampliação do trabalho à distância (remoto), diminuindo a necessidade de deslocamentos ou viagens para o trabalho		
IPnT.013	Mudança no trabalho e no perfil de profissional requisitado: mais criativo, inovador, analítico, estratégico, intelectual e abstrato		
IPnT.014	Redução das barreiras geográficas e culturais para a contratação de recursos capacitados		
IPnT.015	Disseminação e democratização do conhecimento e da informação e, portanto, da possibilidade de capacitação		
IPnT.016	Melhora na qualidade de vida e bem-estar, desonerando as pessoas e permitindo um melhor equilíbrio entre lazer e trabalho		
IPnT.017	Diminuição de erros humanos, assim como de acidentes de trabalho com a automação crescente de processos		
IPnT.018	Melhor uso, exploração e ampliação dos talentos e competências ímpares dos humanos		
IPnT.019	Nova forma de trabalhar, de parceria entre máquina e homem, onde os pontos fortes de cada um são combinados em sinergia		
IPnT.020	Propagação do uso de assistentes virtuais no cotidiano das pessoas, funcionando como um novo aplicativo de produtividade		
IPnT.021	Criação de um mercado de trabalho paralelo de força de trabalho robotizada e com inteligência artificial		
IPnT.022	Evolução do currículo acadêmico para atender a nova demanda de profissionais, carreiras, competências e conhecimentos		
IPnT.023	Aumento da capacidade de percepção dos contextos e conhecimento das pessoas		
IPnT.024	Aprimoramento de profissões com o uso de tecnologias, principalmente daquelas fundamentadas em dados		
IPnT.025	Reformulação das leis trabalhistas e mudança na forma de administrar recursos humanos		
IPnT.026	Maior satisfação no trabalho, com funções mais gratificantes, satisfatórias e engrandecedoras		
IPnT.027	Valorização de profissionais com habilidades como capacidade de adaptação, multidisciplinaridade e improvisação		
IPnT.028	Maior acessibilidade e inclusão das pessoas, tecnologias auxiliarão pessoas com dificuldades ou com menos experiência		
IPnT.029	Aprimoramento na capacitação, com tutores inteligentes, conteúdo direcionado e melhor suporte à busca		
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4. Considerando a lista a seguir, apresentada em ordem aleatória, classifique os **10 impactos negativos mais relevantes da IA** (e tecnologias relacionadas) **no emprego e no mercado de trabalho**. Por favor, utilize a coluna 'A' para facilitar a escolha inicial dos 10 itens mais relevantes e depois indique o ranking na coluna 'B' (de 1, mais relevante a 10, menos relevante), sem repetir números.

		A	B
INnT.001	Desemprego, devido à redução mais rápida e intensa de oportunidades em comparação com a criação de novos empregos		
INnT.002	Afastamento compulsivo do mercado de trabalho dos menos qualificados e escolarizados (tarefas repetitivas e tradicionais)		
INnT.003	Mudanças sensíveis (e no limite, extinção) de carreiras e funções em todos os níveis e em diversas áreas e finalidades		
INnT.004	Dependência excessiva dos profissionais em relação às máquinas, gerando problemas quando estas não tenham respostas		
INnT.005	Crescente desconhecimento e dificuldade de entendimento das tecnologias por falta de base conceitual adequada		
INnT.006	Necessidade de políticas sociais públicas (ou privadas) como de renda mínima, de modo a balancear mercado de trabalho		
INnT.007	Ampliação excessiva na oferta de profissionais no mercado de trabalho devido ao aumento na expectativa de vida das pessoas		
INnT.008	Deterioração em geral das relações pessoais no ambiente de trabalho, tornando-se cada vez mais impessoais		
INnT.009	Concentração excessiva do emprego em determinadas áreas e setores econômicos em detrimento de outros		
INnT.010	Necessidade crescente, constante e excessiva de especialização por parte dos profissionais		
INnT.011	Maior imprevisibilidade, volatilidade e dinamismo do mercado de trabalho, gerando ansiedade e stress aos profissionais		
INnT.012	Recapacitação obrigatória e intensa, para se adequar as novas competências exigidas pelos empregos e mercado de trabalho		
INnT.013	Problemas em estabelecer limites, não só éticos e morais, mas também para a própria utilização das novas tecnologias no trabalho		
INnT.014	Baixa e/ou lenta adaptação das pessoas para as novas exigências, principalmente daquelas com baixo conhecimento tecnológico		
INnT.015	Intensificação das dificuldades de alocação dos extremos etários no mercado (falta de experiência ou dificuldade de adaptação)		
INnT.016	Problemas frente à nova realidade na relação organização / funcionário com formas e naturezas distintas das atuais		
INnT.017	Incremento na informalidade e volatilidade do emprego com relações entre organizações e profissionais mais efêmeras		
INnT.018	Dificuldades na realocação (tempo e custo), seja por falta de competências, de empregos ou aumento na oferta de profissionais		
INnT.019	Desvalorização do trabalho humano, ilustrada pela redução de salário naquelas atividades nas quais a máquina é melhor		
INnT.020	Falta de mão-de-obra qualificada, uma vez que o sistema educacional não está preparado para as novas exigências		
INnT.021	Descompasso cada vez maior entre academia e mercado, isto é, entre a formação das pessoas e as necessidades do mercado		
INnT.022	Aumento da competitividade e rivalidade entre profissionais no ambiente e mercado de trabalho		
INnT.023	Inversão na onda de 'terceirização', afetando principalmente os mercados de trabalho dos países em desenvolvimento		
INnT.024	Excessivo controle e concentração econômica, social e de conhecimento em poucos indivíduos		
INnT.025	Mix cada vez mais exigente de competências, conhecimento e experiência prática para executar trabalhos mais elaborados		
INnT.026	Exigência por profissionais bons tanto em habilidades técnicas (hard skills) quanto em competências pessoais (soft skills)		
INnT.027	Dificuldades variadas em lidar ou se adaptar com as tecnologias e/ou lenta velocidade de adoção		
INnT.028	Legislação trabalhista defasada e descompassada com as mudanças provocadas pela IA, respondendo tarde demais aos problemas		
INnT.029	Maior tempo e investimento em educação até a entrada no mercado de trabalho, devido ao nível de exigências das profissões		
INnT.030	Desigualdade e desequilíbrio crescente entre profissionais, profissões e mercados de trabalho		
INnT.031	Redução na qualidade de vida das pessoas: mais desempregados, mais exigências, maior competição e manutenção do emprego		
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5. Considerando a lista a seguir, apresentada em ordem aleatória, classifique os **10 gargalos mais relevantes para o progresso da IA** (e tecnologias relacionadas), isto é, barreiras para a evolução e aplicação destas tecnologias. Por favor, utilize a coluna 'A' para facilitar a escolha inicial dos 10 itens mais relevantes e depois indique o ranking na coluna 'B' (de 1, mais relevante a 10, menos relevante), sem repetir números.

		A	B
GIA.001	Variáveis socioculturais, tratamento adequado de problemas que envolvam cultura, raça, religião, sexualidade, política, etc.		
GIA.002	Resolução de problemas complexos e não estruturados (além da análise de padrões sobre bancos de dados)		
GIA.003	Criatividade genuína, isto é, idealização, criação e inovação, produzindo eventos até então incomuns e únicos		
GIA.004	Empatia e afetividade, compreensão, reconhecimento e interação adequada com sentimentos e emoções humanas		
GIA.005	Raciocínio genuíno e tomada de decisões de forma realmente autônoma		
GIA.006	Relacionamento humano, dependência de interações com pessoas para os mais diversos fins		
GIA.007	Relacionamento com o meio, dependência de interações com fatores que compõem a realidade em que a tecnologia é aplicada		
GIA.008	Capacidade computacional e tecnológica e custos relacionados (hardware, software, arquitetura de dados, etc.)		
GIA.009	Imaginação, isto é, capacidade de evocar e formar imagens originais e combinar ideias abstratas		
GIA.010	Variáveis éticas e morais, princípios que motivam, distorcem, disciplinam ou orientam o comportamento humano		
GIA.011	Volume de dados (alto volume necessário até para a resolução de problemas simples)		
GIA.012	Capacidade de aprendizagem e absorção de conhecimento (ainda limitada nas máquinas)		
GIA.013	Negociação e persuasão, isto é, capacidade de levar alguém a acreditar, a aceitar ou a decidir sobre algo		
GIA.014	Expressões artísticas em geral (música, dança, pintura, escultura, arquitetura, literatura, cinema, fotografia, etc.)		
GIA.015	Multidisciplinariedade, capacidade de entender e realizar inúmeras e distintas atividades (aplicações não especialistas)		
GIA.016	Comunicação, expressão e argumentação oral (e escrita), capacidade de entender e responder a uma conversa difícil		
GIA.017	Interpretação, isto é, capacidade de entender e determinar o significado de mensagens subliminares, nuances, ironias e sarcasmos		
GIA.018	Acuracidade e, simultaneamente, amplitude dos cinco sentidos (tato, paladar, olfato, audição, visão)		
GIA.019	Conhecimentos tácitos, não explícitos e dificilmente transmitidos ('bom senso' ou 'senso comum')		
GIA.020	Consciência, isto é, capacidade de perceber, entender e discernir acerca de tema ou ideia, e seus impactos para os demais		
GIA.021	Improvisação e adaptabilidade, isto é, capacidade de executar de repente, sem preparação, e com resultado aceitável		
GIA.022	Coordenação motora amplificada e com combinação de funções múltiplas		
GIA.023	Baixa predisposição a erros dos algoritmos e aos riscos decorrentes destes erros, por exemplo nas áreas médicas		
GIA.024	Limitações energéticas, mesmo com melhorias na eficiência, a atual matriz energética pode limitar as tecnologias e sua aplicação		
GIA.025	Quantidade e qualidade dos recursos humanos capacitados para atender as demandas de IA e robótica		
GIA.026	Movimentos de resistência à mudança e tecnologia, inclusive boicotes e ativa oposição		
GIA.027	Fatores legais, novas barreiras de legislação limitando, reservando, desacelerando ou até proibindo o uso		
GIA.028	Integração eficiente de múltiplas e diferentes tecnologias e métodos		
GIA.029	Intuição, isto é, capacidade de perceber, discernir ou pressentir coisas, independentemente de raciocínio ou de análise		
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6. Se quiser fazer algum comentário sobre o questionário ou sobre o tema, utilize o espaço a seguir (opcional).

3rd Round Questionnaire (in Portuguese) – Full

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Prezado(a) participante,

Mais uma vez gostaríamos de agradecer pela participação e empenho nas fases prévias deste painel.

Realizamos a coleta, análise e combinação das respostas e observações dadas no questionário anterior, e como resultado foi possível priorizar as 5 listas com base na opinião combinada dos diferentes especialistas. Agora as 5 listas contam com 10 itens cada. Apenas para recordar, as cinco listas são:

- Impactos positivos da IA (e tecnologias relacionadas) nas organizações
- Impactos negativos da IA (e tecnologias relacionadas) nas organizações
- Impactos positivos da IA (e tecnologias relacionadas) no emprego e no mercado de trabalho
- Impactos negativos da IA (e tecnologias relacionadas) no emprego e no mercado de trabalho
- Gargalos da IA (e tecnologias relacionadas)

Iniciamos agora a terceira e última fase deste painel, reenviando estas cinco listas priorizadas a todos os especialistas que participaram na rodada anterior, pedindo novamente que classifiquem individualmente e subjetivamente os 10 itens mais relevantes em cada uma das 5 listas. O objetivo final é refinar o top 10 conjunto entre os participantes.

Em cada uma das listas há quatro colunas:

- Freq.: Frequência percentual de pessoas que marcaram este impacto como entre os top 10 na rodada anterior.
- Rank A: Ranking coletivo obtido com base nas respostas combinadas da rodada anterior.
- Rank B: Ranking individual fornecido por você na rodada anterior.*
- Rank C: Ranking particular que pedimos que você preencha considerando essa nova listagem.

* Ao combinar opiniões, itens que você classificou como relevantes na rodada anterior podem ter ficado fora desta lista.

Em caso de dúvidas sobre o questionário ou sobre a pesquisa, por favor, não hesite em nos contatar por e-mail ou telefone. Será um prazer responder.

Nossos cordiais cumprimentos e agradecimentos.

Sergi Pauli, MSc
Doutorando FEA USP
Tel: (11) 989 030 771
Email: sergi@usp.br

Cesar Alexandre de Souza, PhD
Professor Doutor FEA USP

Nome:

Data Recebida:

Prazo de Entrega:

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PhD Thesis Research
Artificial Intelligence Impacts Research
Delphi Questionnaire
2019

1. Considerando a lista a seguir, apresentada em ordem aleatória, classifique os **10 impactos positivos mais relevantes da IA** (e tecnologias relacionadas) **nas organizações**. Por favor, utilize a coluna 'Rank C' para indicar o ranking de 1, mais relevante a 10, menos relevante, **sem repetir números**.

		Freq.	**Rank A**	**Rank B**	**Rank C**
IPnO.001	Aumento na produtividade e eficiência dos processos das organizações de forma geral ("fazer melhor")	65,0%	1		
IPnO.002	Mais agilidade e velocidade dos processos das organizações de forma geral ("fazer mais rápido")	45,0%	7		
IPnO.004	Dispersão acelerada na aplicação de IA embutida de modo transparente e ubíqua em processos, produtos e/ou serviços	35,0%	5		
IPnO.005	Desenvolvimento e refinamento de métodos de tomada de decisão e resolução de problemas, melhorando a qualidade da decisão	65,0%	4		
IPnO.007	Automação generalizada de atividades, principalmente aquelas rotineiras, repetitivas, avançando também em tarefas complexas	50,0%	3		
IPnO.008	Evolução na forma de trabalhar com foco na parceria e colaboração entre máquina e homem, combinando os pontos fortes de cada	40,0%	6		
IPnO.011	Redução de riscos associados a atividades de alto risco, de insalubridade (e de danos à saúde) ou de extrema fadiga	40,0%	10		
IPnO.017	Aprimoramento do uso de dados disponíveis, principalmente os não estruturados, com novos métodos de descoberta e análise	65,0%	2		
IPnO.018	Aprimoramento da qualidade de produtos, serviços e soluções, mais eficientes, mais inteligentes, e mais acessíveis	45,0%	9		
IPnO.028	Criação de novos modelos de negócio (alguns ainda inexistentes) intimamente ligados à tecnologia ("uberização da economia")	40,0%	8		

Legendas:

Freq.: Frequência percentual de pessoas que marcaram este impacto como entre os top 10 na rodada anterior.
Rank A: Ranking coletivo obtido com base nas respostas combinadas da rodada anterior (considera-se também a frequência).
Rank B: Ranking particular fornecido por você na rodada anterior – ao combinar opiniões, itens que você classificou como relevantes podem ter ficado fora desta lista.
Rank C: Ranking particular que pedimos que seja novamente preenchido considerando essa nova listagem.

Comentários em relação a esta lista (opcional):

Universidade de São Paulo
Faculdade de Economia, Administração e Contabilidade
Departamento de Administração
Programa de Pós-Graduação em Administração

2. Considerando a lista a seguir, apresentada em ordem aleatória, classifique os **10 impactos negativos mais relevantes da IA** (e tecnologias relacionadas) **nas organizações**. Por favor, utilize a coluna 'Rank C' para indicar o ranking de 1, mais relevante a 10, menos relevante, **sem repetir números**.

		Freq.	Rank A	Rank B	Rank C
INnO.003	Substituição em massa da mão-de-obra humana por máquinas nas organizações, colaborando com o potencial desemprego	60,0%	4		
INnO.004	Necessidade de recapacitação em massa de funcionários, devido à obsolescência de carreiras e funções em todos os níveis	50,0%	3		
INnO.006	Desconfiança e insatisfação com a AI devido à falta de transparência no processo decisório (efeito "caixa-preta")	80,0%	1		
INnO.007	Desvirtuamento, enviesamento, má utilização da tecnologia, com fins impróprios, antiéticos, ilegais e/ou criminosos	80,0%	1		
INnO.010	Supervalorização das máquinas (e de seus resultados) em detrimento das opiniões, expertise e experiências humanas	40,0%	10		
INnO.012	Intensificação nos problemas de privacidade: violação de dados, utilização sem consentimento e/ou para propósitos inadequados	55,0%	6		
INnO.016	Excessivo controle e concentração econômica, social e de conhecimento em poucas organizações	45,0%	8		
INnO.019	Falta de mão-de-obra qualificada, uma vez que o sistema educacional não está preparado para as novas exigências	40,0%	9		
INnO.021	Distanciamento entre expectativa e realidade com IA, pois implementação de qualidade ainda é lenta, custosa e limitada	55,0%	5		
INnO.027	Problemas decorrentes da incapacidade de tratar ou identificar cenários com potenciais conflitos éticos e morais	65,0%	7		

Legendas:

Freq.: Frequência percentual de pessoas que marcaram este impacto como entre os top 10 na rodada anterior.
Rank A: Ranking coletivo obtido com base nas respostas combinadas da rodada anterior (considera-se também a frequência).
Rank B: Ranking particular fornecido por você na rodada anterior – ao combinar opiniões, itens que você classificou como relevantes podem ter ficado fora desta lista.
Rank C: Ranking particular que pedimos que seja novamente preenchido considerando essa nova listagem.

Comentários em relação a esta lista (opcional):

Universidade de São Paulo
Faculdade de Economia, Administração e Contabilidade
Departamento de Administração
Programa de Pós-Graduação em Administração

Pesquisa de Tese de Doutorado
Impactos da Inteligência Artificial
Questionário Delphi
3ª Rodada

3. Considerando a lista a seguir, apresentada em ordem aleatória, classifique os **10 impactos positivos mais relevantes da IA** (e tecnologias relacionadas) **no emprego e no mercado de trabalho**. Por favor, utilize a coluna 'Rank C' para indicar o ranking de 1, mais relevante a 10, menos relevante, **sem repetir números**.

		Freq.	**Rank A**	**Rank B**	**Rank C**
IPnT.002	Valorização de profissionais com formação sólida, alto nível de escolaridade, competências e experiências nas novas tecnologias	73,7%	6		
IPnT.003	Criação de novas carreiras e funções dentro das organizações, grande parte com viés tecnológico, contudo mais exigentes	68,4%	1		
IPnT.004	Melhora na produtividade e eficiência individual no trabalho	57,9%	3		
IPnT.005	Criação de novos postos de trabalho, para atender novos tipos de negócios, produtos e/ou serviços	63,2%	4		
IPnT.010	Substituição da mão-de-obra humana nas atividades de repetitivas, tediosas, alienantes e/ou de baixo valor agregado	78,9%	2		
IPnT.011	Substituição da mão-de-obra humana nas atividades de alto risco, de insalubridade (e de danos à saúde) e/ou de extrema fadiga	63,2%	8		
IPnT.013	Mudança no trabalho e no perfil de profissional requisitado: mais criativo, inovador, analítico, estratégico, intelectual e abstrato	84,2%	5		
IPnT.019	Nova forma de trabalhar, de parceria entre máquina e homem, onde os pontos fortes de cada um são combinados em sinergia	57,9%	7		
IPnT.024	Aprimoramento de profissões com o uso de tecnologias, principalmente daquelas fundamentadas em dados	57,9%	10		
IPnT.027	Valorização de profissionais com habilidades como capacidade de adaptação, multidisciplinaridade e improvisação	57,9%	9		

Legendas:

Freq.: Frequência percentual de pessoas que marcaram este impacto como entre os top 10 na rodada anterior.
Rank A: Ranking coletivo obtido com base nas respostas combinadas da rodada anterior (considera-se também a frequência).
Rank B: Ranking particular fornecido por você na rodada anterior – ao combinar opiniões, itens que você classificou como relevantes podem ter ficado fora desta lista.
Rank C: Ranking particular que pedimos que seja novamente preenchido considerando essa nova listagem.

Comentários em relação a esta lista (opcional):

4. Considerando a lista a seguir, apresentada em ordem aleatória, classifique os **10 impactos negativos mais relevantes da IA** (e tecnologias relacionadas) **no emprego e no mercado de trabalho**. Por favor, utilize a coluna 'Rank C' para indicar o ranking de 1, mais relevante a 10, menos relevante, **sem repetir números**.

		Freq.	Rank A	Rank B	Rank C
INnT.001	Desemprego, devido à redução mais rápida e intensa de oportunidades em comparação com a criação de novos empregos	40,0%	6		
INnT.002	Afastamento compulsivo do mercado de trabalho dos menos qualificados e escolarizados (tarefas repetitivas e tradicionais)	70,0%	1		
INnT.003	Mudanças sensíveis (e no limite, extinção) de carreiras e funções em todos os níveis e em diversas áreas e finalidades	55,0%	2		
INnT.011	Maior imprevisibilidade, volatilidade e dinamismo do mercado de trabalho, gerando ansiedade e stress aos profissionais	50,0%	7		
INnT.012	Recapacitação obrigatória e intensa, para se adequar as novas competências exigidas pelos empregos e mercado de trabalho	45,0%	8		
INnT.013	Problemas em estabelecer limites, não só éticos e morais, mas também para a própria utilização das novas tecnologias no trabalho	55,0%	5		
INnT.014	Baixa e/ou lenta adaptação das pessoas para as novas exigências, principalmente daquelas com baixo conhecimento tecnológico	55,0%	3		
INnT.020	Falta de mão-de-obra qualificada, uma vez que o sistema educacional não está preparado para as novas exigências	50,0%	4		
INnT.024	Excessivo controle e concentração econômica, social e de conhecimento em poucos indivíduos	40,0%	10		
INnT.028	Legislação trabalhista defasada e descompassada com as mudanças provocadas pela IA, respondendo tarde demais aos problemas	45,0%	9		

Legendas:

Freq.: Frequência percentual de pessoas que marcaram este impacto como entre os top 10 na rodada anterior.
Rank A: Ranking coletivo obtido com base nas respostas combinadas da rodada anterior (considera-se também a frequência).
Rank B: Ranking particular fornecido por você na rodada anterior – ao combinar opiniões, itens que você classificou como relevantes podem ter ficado fora desta lista.
Rank C: Ranking particular que pedimos que seja novamente preenchido considerando essa nova listagem.

Comentários em relação a esta lista (opcional):

5. Considerando a lista a seguir, apresentada em ordem aleatória, classifique os **10 gargalos mais relevantes para o progresso da IA** (e tecnologias relacionadas), isto é, barreiras para a evolução e aplicação destas tecnologias. Por favor, utilize a coluna 'Rank C' para indicar o ranking de 1, mais relevante a 10, menos relevante, **sem repetir números**.

		Freq.	Rank A	Rank B	Rank C
GIA.002	Resolução de problemas complexos e não estruturados (além da análise de padrões sobre bancos de dados)	50,0%	5		
GIA.004	Empatia e afetividade, compreensão, reconhecimento e interação adequada com sentimentos e emoções humanas	50,0%	1		
GIA.005	Raciocínio genuíno e tomada de decisões de forma realmente autônoma	40,0%	6		
GIA.010	Variáveis éticas e morais, princípios que motivam, distorcem, disciplinam ou orientam o comportamento humano	60,0%	3		
GIA.012	Capacidade de aprendizagem e absorção de conhecimento (ainda limitada nas máquinas)	50,0%	10		
GIA.015	Multidisciplinariedade, capacidade de entender e realizar inúmeras e distintas atividades (aplicações não especialistas)	55,0%	4		
GIA.017	Interpretação, isto é, capacidade de entender e determinar o significado de mensagens subliminares, nuances, ironias e sarcasmos	65,0%	8		
GIA.019	Conhecimentos tácitos, não explícitos e dificilmente transmitidos ('bom senso' ou 'senso comum')	65,0%	2		
GIA.020	Consciência, isto é, capacidade de perceber, entender e discernir acerca de tema ou ideia, e seus impactos para os demais	50,0%	9		
GIA.027	Fatores legais, novas barreiras de legislação limitando, reservando, desacelerando ou até proibindo o uso	50,0%	7		

Legendas:

Freq.: Frequência percentual de pessoas que marcaram este impacto como entre os top 10 na rodada anterior.
Rank A: Ranking coletivo obtido com base nas respostas combinadas da rodada anterior (considera-se também a frequência).
Rank B: Ranking particular fornecido por você na rodada anterior – ao combinar opiniões, itens que você classificou como relevantes podem ter ficado fora desta lista.
Rank C: Ranking particular que pedimos que seja novamente preenchido considerando essa nova listagem.

Comentários em relação a esta lista (opcional):

6. Para comentários ou feedback sobre o tema, pesquisa, ou questionários, utilize o espaço a seguir.

Appendix 5. Integration Enhanced Susceptibility Ranking - 2038

SOC Code	Title	Red. Factor	IER Susc.	IER	F&OR Susc.	F&OR
		0 - 100	0 - 100%	1 - 967	0 - 100%	1 - 702
41-9041.00	Telemarketers	6.45	93.55%	1	99.00%	1
43-4041.02	Credit Checkers	7.82	92.18%	2	n/a	n/a
43-4051.00	Customer Service Representatives	8.89	91.11%	3	55.00%	388
43-9081.00	Proofreaders and Copy Markers	9.25	90.75%	4	84.00%	222
43-6013.00	Medical Secretaries	9.77	90.23%	5	81.00%	256
13-1071.00	Human Resources Specialists	9.84	90.16%	6	n/a	n/a
43-4161.00	Human Resources Assistants, Except Payroll and Timekeeping	10.16	89.84%	7	90.00%	171
43-3061.00	Procurement Clerks	10.19	89.81%	8	98.00%	23
43-3021.01	Statement Clerks	10.21	89.79%	9	96.00%	60
43-4031.02	Municipal Clerks	10.68	89.32%	10	n/a	n/a
25-3011.00	Adult Basic and Secondary Education and Literacy Teachers and Instructors	10.81	89.19%	11	19.00%	498
11-9199.01	Regulatory Affairs Managers	10.85	89.15%	12	25.00%	477
41-9091.00	Door-To-Door Sales Workers, News and Street Vendors, and Related Workers	10.90	89.10%	13	94.00%	97
43-4041.01	Credit Authorizers	11.05	88.95%	14	97.00%	36
13-2072.00	Loan Officers	11.17	88.83%	15	98.00%	17
43-5011.00	Cargo and Freight Agents	11.20	88.80%	16	99.00%	7
43-2021.00	Telephone Operators	11.43	88.57%	17	97.00%	39
13-2071.00	Credit Counselors	11.60	88.40%	18	4.00%	577
13-2082.00	Tax Preparers	11.61	88.39%	19	99.00%	8
43-4031.03	License Clerks	11.64	88.36%	20	n/a	n/a
15-1199.09	Information Technology Project Managers	11.77	88.23%	21	n/a	n/a
43-3021.02	Billing, Cost, and Rate Clerks	11.79	88.21%	22	n/a	n/a
43-3051.00	Payroll and Timekeeping Clerks	11.80	88.20%	23	97.00%	37
43-4031.01	Court Clerks	11.97	88.03%	24	46.00%	418
43-2011.00	Switchboard Operators, Including Answering Service	12.00	88.00%	25	96.00%	72
43-9041.02	Insurance Policy Processing Clerks	12.17	87.83%	26	n/a	n/a
23-2093.00	Title Examiners, Abstractors, and Searchers	12.21	87.79%	27	99.00%	2
13-1199.03	Customs Brokers	12.27	87.73%	28	n/a	n/a
41-9021.00	Real Estate Brokers	12.39	87.61%	29	97.00%	40
39-3093.00	Locker Room, Coatroom, and Dressing Room Attendants	12.42	87.58%	30	43.00%	423
43-5011.01	Freight Forwarders	12.49	87.51%	31	n/a	n/a
43-6014.00	Secretaries and Administrative Assistants, Except Legal, Medical, and Executive	12.58	87.42%	32	96.00%	69
19-2041.01	Climate Change Analysts	9.46	87.36%	33	n/a	n/a
13-1023.00	Purchasing Agents, Except Wholesale, Retail, and Farm Products	12.65	87.35%	34	77.00%	280
25-3099.02	Tutors	12.68	87.32%	35	0.95%	655
43-6012.00	Legal Secretaries	12.79	87.21%	36	98.00%	31
19-4061.01	City and Regional Planning Aides	12.82	87.18%	37	n/a	n/a
43-4141.00	New Accounts Clerks	12.90	87.10%	38	99.00%	10
43-4111.00	Interviewers, Except Eligibility and Loan	12.92	87.08%	39	94.00%	103
43-9041.01	Insurance Claims Clerks	13.12	86.88%	40	98.00%	14
39-5092.00	Manicurists and Pedicurists	13.24	86.76%	41	95.00%	93
23-1012.00	Judicial Law Clerks	13.30	86.70%	42	64.00%	350
41-9012.00	Models	13.39	86.61%	43	98.00%	34
13-2052.00	Personal Financial Advisors	13.41	86.59%	44	58.00%	379
13-1199.05	Sustainability Specialists	9.35	86.56%	45	n/a	n/a
11-3111.00	Compensation and Benefits Managers	13.56	86.44%	46	96.00%	73
11-3031.01	Treasurers and Controllers	13.60	86.40%	47	6.90%	551
43-3011.00	Bill and Account Collectors	13.62	86.38%	48	95.00%	90
15-1199.07	Data Warehousing Specialists	13.94	86.06%	49	n/a	n/a
43-4021.00	Correspondence Clerks	14.01	85.99%	50	86.00%	203
43-5032.00	Dispatchers, Except Police, Fire, and Ambulance	14.05	85.95%	51	96.00%	76
43-4171.00	Receptionists and Information Clerks	14.06	85.94%	52	96.00%	75
41-3021.00	Insurance Sales Agents	14.10	85.90%	53	92.00%	138

43-9022.00	Word Processors and Typists	14.11	85.89%	54	81.00%	261
23-2091.00	Court Reporters	14.16	85.84%	55	50.00%	402
13-2051.00	Financial Analysts	14.21	85.79%	56	23.00%	486
43-9061.00	Office Clerks, General	14.23	85.77%	57	96.00%	74
31-9094.00	Medical Transcriptionists	14.24	85.76%	58	89.00%	180
13-1031.01	Claims Examiners, Property and Casualty Insurance	14.29	85.71%	59	98.00%	28
13-2053.00	Insurance Underwriters	14.51	85.49%	60	99.00%	5
11-9199.03	Investment Fund Managers	11.37	85.48%	61	n/a	n/a
41-3041.00	Travel Agents	14.55	85.45%	62	9.90%	535
23-2011.00	Paralegals and Legal Assistants	14.72	85.28%	63	94.00%	94
27-3031.00	Public Relations Specialists	10.54	84.99%	64	18.00%	502
43-4061.00	Eligibility Interviewers, Government Programs	15.03	84.97%	65	70.00%	320
17-3011.02	Civil Drafters	15.07	84.93%	66	n/a	n/a
13-1051.00	Cost Estimators	15.11	84.89%	67	57.00%	382
43-3031.00	Bookkeeping, Accounting, and Auditing Clerks	15.50	84.50%	68	98.00%	32
13-2031.00	Budget Analysts	15.81	84.19%	69	94.00%	109
11-3031.02	Financial Managers, Branch or Department	12.91	84.12%	70	n/a	n/a
13-1075.00	Labor Relations Specialists	11.80	84.11%	71	n/a	n/a
13-1011.00	Agents and Business Managers of Artists, Performers, and Athletes	15.98	84.02%	72	24.00%	483
31-9099.01	Speech-Language Pathology Assistants	16.00	84.00%	73	63.00%	355
13-2099.02	Risk Management Specialists	16.04	83.96%	74	n/a	n/a
11-9121.01	Clinical Research Coordinators	16.09	83.91%	75	n/a	n/a
43-9111.01	Bioinformatics Technicians	16.17	83.83%	76	n/a	n/a
11-9141.00	Property, Real Estate, and Community Association Managers	16.26	83.74%	77	81.00%	257
13-2061.00	Financial Examiners	13.45	83.70%	78	17.00%	505
13-2081.00	Tax Examiners and Collectors, and Revenue Agents	16.32	83.68%	79	93.00%	117
13-2011.02	Auditors	16.54	83.46%	80	n/a	n/a
11-3071.01	Transportation Managers	13.31	83.46%	81	59.00%	375
43-4011.00	Brokerage Clerks	16.70	83.30%	82	98.00%	15
41-3099.01	Energy Brokers	16.71	83.29%	83	n/a	n/a
13-1199.06	Online Merchants	16.71	83.29%	84	n/a	n/a
45-2041.00	Graders and Sorters, Agricultural Products	16.82	83.18%	85	41.00%	429
15-2041.02	Clinical Data Managers	16.91	83.09%	86	n/a	n/a
13-1141.00	Compensation, Benefits, and Job Analysis Specialists	16.93	83.07%	87	47.00%	417
15-1131.00	Computer Programmers	16.98	83.02%	88	48.00%	410
13-1111.00	Management Analysts	13.72	83.01%	89	13.00%	521
43-4131.00	Loan Interviewers and Clerks	17.05	82.95%	90	92.00%	140
13-2071.01	Loan Counselors	17.13	82.87%	91	n/a	n/a
13-2011.01	Accountants	17.33	82.67%	92	94.00%	114
11-9121.02	Water Resource Specialists	17.44	82.56%	93	n/a	n/a
11-9199.04	Supply Chain Managers	17.48	82.52%	94	n/a	n/a
13-2099.04	Fraud Examiners, Investigators and Analysts	17.48	82.52%	95	n/a	n/a
41-1012.00	First-Line Supervisors of Non-Retail Sales Workers	14.17	82.34%	96	7.50%	547
17-3012.01	Electronic Drafters	17.66	82.34%	97	81.00%	260
19-4061.00	Social Science Research Assistants	17.91	82.09%	98	65.00%	346
39-5093.00	Shampooers	17.98	82.02%	99	79.00%	271
27-3022.00	Reporters and Correspondents	13.59	81.83%	100	11.00%	526
25-1192.00	Home Economics Teachers, Postsecondary	11.61	81.79%	101	n/a	n/a
43-9111.00	Statistical Assistants	18.31	81.69%	102	66.00%	337
41-3031.01	Sales Agents, Securities and Commodities	18.37	81.63%	103	1.60%	629
41-4011.00	Sales Representatives, Wholesale and Manufacturing, Technical and Scientific Products	15.52	81.38%	104	25.00%	475
15-1199.01	Software Quality Assurance Engineers and Testers	18.67	81.33%	105	22.00%	491
13-1031.02	Insurance Adjusters, Examiners, and Investigators	18.76	81.24%	106	n/a	n/a
39-7011.00	Tour Guides and Escorts	18.79	81.21%	107	91.00%	157
15-1199.10	Search Marketing Strategists	14.82	81.18%	108	n/a	n/a
15-1199.03	Web Administrators	18.97	81.03%	109	n/a	n/a
41-3031.03	Securities and Commodities Traders	19.22	80.78%	110	n/a	n/a
11-3061.00	Purchasing Managers	15.02	80.73%	111	3.00%	592
13-1041.07	Regulatory Affairs Specialists	19.41	80.59%	112	n/a	n/a

43-5081.02	Marking Clerks	19.44	80.56%	113	n/a	n/a
41-3011.00	Advertising Sales Agents	19.54	80.46%	114	54.00%	391
19-3022.00	Survey Researchers	16.81	80.46%	115	23.00%	488
43-5081.04	Order Fillers, Wholesale and Retail Sales	19.69	80.31%	116	n/a	n/a
13-1081.00	Logisticians	16.14	80.18%	117	1.20%	648
13-2041.00	Credit Analysts	19.83	80.17%	118	98.00%	26
17-3012.02	Electrical Drafters	19.99	80.01%	119	n/a	n/a
13-1081.01	Logistics Engineers	16.95	79.93%	120	n/a	n/a
15-1133.00	Software Developers, Systems Software	16.95	79.81%	121	13.00%	522
13-1131.00	Fundraisers	16.74	79.65%	122	n/a	n/a
15-2011.00	Actuaries	18.02	79.53%	123	21.00%	494
29-2071.00	Medical Records and Health Information Technicians	20.52	79.48%	124	91.00%	153
35-3041.00	Food Servers, Nonrestaurant	20.56	79.44%	125	86.00%	211
11-2021.00	Marketing Managers	16.60	79.44%	126	1.40%	642
37-2012.00	Maids and Housekeeping Cleaners	20.91	79.09%	127	69.00%	322
43-6011.00	Executive Secretaries and Executive Administrative Assistants	21.00	79.00%	128	86.00%	213
25-2022.00	Middle School Teachers, Except Special and Career/Technical Education	21.19	78.81%	129	17.00%	503
41-3031.02	Sales Agents, Financial Services	21.25	78.75%	130	n/a	n/a
39-4021.00	Funeral Attendants	21.33	78.67%	131	37.00%	446
11-9039.01	Distance Learning Coordinators	18.21	78.60%	132	n/a	n/a
13-1161.00	Market Research Analysts and Marketing Specialists	16.39	78.55%	133	61.00%	366
13-1081.02	Logistics Analysts	18.25	78.43%	134	n/a	n/a
17-3013.00	Mechanical Drafters	21.64	78.36%	135	68.00%	325
25-9041.00	Teacher Assistants	21.67	78.33%	136	56.00%	386
39-3031.00	Ushers, Lobby Attendants, and Ticket Takers	21.73	78.27%	137	96.00%	61
35-9031.00	Hosts and Hostesses, Restaurant, Lounge, and Coffee Shop	21.73	78.27%	138	97.00%	35
25-4011.00	Archivists	21.76	78.24%	139	76.00%	288
39-1011.00	Gaming Supervisors	21.76	78.24%	140	28.00%	468
27-3043.04	Copy Writers	17.23	78.13%	141	3.80%	580
13-1151.00	Training and Development Specialists	17.99	77.90%	142	1.40%	639
27-3042.00	Technical Writers	13.59	77.86%	143	89.00%	177
27-2012.04	Talent Directors	22.21	77.79%	144	n/a	n/a
19-3031.02	Clinical Psychologists	10.98	77.74%	145	n/a	n/a
43-3041.00	Gaming Cage Workers	22.31	77.69%	146	39.00%	434
39-6012.00	Concierges	22.32	77.68%	147	21.00%	492
21-2021.00	Directors, Religious Activities and Education	22.38	77.62%	148	2.50%	606
11-9111.00	Medical and Health Services Managers	19.64	77.62%	149	0.73%	667
19-3051.00	Urban and Regional Planners	19.08	77.61%	150	13.00%	519
27-1024.00	Graphic Designers	17.33	77.56%	151	8.20%	542
11-3071.03	Logistics Managers	22.47	77.53%	152	59.00%	375
53-7061.00	Cleaners of Vehicles and Equipment	22.54	77.46%	153	37.00%	447
17-2199.02	Validation Engineers	22.69	77.31%	154	n/a	n/a
25-1191.00	Graduate Teaching Assistants	15.21	77.29%	155	n/a	n/a
11-3121.00	Human Resources Managers	19.38	77.27%	156	0.55%	675
27-4032.00	Film and Video Editors	19.49	77.09%	157	31.00%	459
27-2041.04	Music Composers and Arrangers	17.95	77.09%	158	n/a	n/a
27-2012.02	Directors- Stage, Motion Pictures, Television, and Radio	19.10	77.01%	159	n/a	n/a
13-1021.00	Buyers and Purchasing Agents, Farm Products	23.01	76.99%	160	87.00%	197
11-2011.00	Advertising and Promotions Managers	19.21	76.93%	161	3.90%	579
25-9031.01	Instructional Designers and Technologists	18.96	76.89%	162	n/a	n/a
29-2092.00	Hearing Aid Specialists	23.13	76.87%	163	n/a	n/a
33-9091.00	Crossing Guards	23.17	76.83%	164	49.00%	409
33-3011.00	Bailiffs	23.19	76.81%	165	36.00%	451
51-5111.00	Prepress Technicians and Workers	23.20	76.80%	166	97.00%	43
19-3031.03	Counseling Psychologists	11.93	76.76%	167	n/a	n/a
35-3022.00	Counter Attendants, Cafeteria, Food Concession, and Coffee Shop	23.36	76.64%	168	96.00%	71
15-1199.08	Business Intelligence Analysts	14.98	76.57%	169	n/a	n/a
15-1134.00	Web Developers	20.45	76.51%	170	n/a	n/a
43-4081.00	Hotel, Motel, and Resort Desk Clerks	23.57	76.43%	171	94.00%	99

39-5011.00	Barbers	23.62	76.38%	172	80.00%	264
35-3021.00	Combined Food Preparation and Serving Workers, Including Fast Food	23.67	76.33%	173	92.00%	132
17-3031.02	Mapping Technicians	23.68	76.32%	174	n/a	n/a
51-4121.07	Solderers and Brazers	23.79	76.21%	175	n/a	n/a
27-1025.00	Interior Designers	19.32	76.20%	176	2.20%	610
41-4012.00	Sales Representatives, Wholesale and Manufacturing, Except Technical and Scientific Products	23.81	76.19%	177	85.00%	219
11-1011.03	Chief Sustainability Officers	19.97	76.18%	178	n/a	n/a
39-3091.00	Amusement and Recreation Attendants	23.83	76.17%	179	72.00%	310
35-2011.00	Cooks, Fast Food	23.87	76.13%	180	81.00%	262
37-2011.00	Janitors and Cleaners, Except Maids and Housekeeping Cleaners	24.03	75.97%	181	66.00%	336
43-4151.00	Order Clerks	24.03	75.97%	182	98.00%	16
51-2093.00	Timing Device Assemblers and Adjusters	24.15	75.85%	183	98.00%	13
11-2022.00	Sales Managers	20.39	75.81%	184	1.30%	644
15-1141.00	Database Administrators	21.59	75.66%	185	3.00%	593
15-2031.00	Operations Research Analysts	15.15	75.63%	186	3.50%	586
35-9011.00	Dining Room and Cafeteria Attendants and Bartender Helpers	24.43	75.57%	187	91.00%	148
43-1011.00	First-Line Supervisors of Office and Administrative Support Workers	24.44	75.56%	188	1.40%	638
15-1132.00	Software Developers, Applications	21.16	75.54%	189	4.20%	573
43-9021.00	Data Entry Keyers	24.56	75.44%	190	99.00%	12
11-3021.00	Computer and Information Systems Managers	21.79	75.41%	191	3.50%	585
25-3021.00	Self-Enrichment Education Teachers	24.60	75.40%	192	13.00%	517
53-7064.00	Packers and Packagers, Hand	24.62	75.38%	193	38.00%	439
43-4071.00	File Clerks	24.62	75.38%	194	97.00%	41
15-1199.11	Video Game Designers	20.24	75.18%	195	n/a	n/a
21-1013.00	Marriage and Family Therapists	24.85	75.15%	196	1.40%	641
11-9199.02	Compliance Managers	24.87	75.13%	197	n/a	n/a
27-3021.00	Broadcast News Analysts	21.69	75.11%	198	6.70%	552
39-3012.00	Gaming and Sports Book Writers and Runners	24.92	75.08%	199	91.00%	159
17-3022.00	Civil Engineering Technicians	24.95	75.05%	200	75.00%	290
25-1126.00	Philosophy and Religion Teachers, Postsecondary	10.92	75.02%	201	n/a	n/a
51-3023.00	Slaughterers and Meat Packers	25.00	75.00%	202	60.00%	370
19-3099.01	Transportation Planners	21.57	74.96%	203	4.00%	576
25-1111.00	Criminal Justice and Law Enforcement Teachers, Postsecondary	10.81	74.91%	204	n/a	n/a
39-2021.00	Nonfarm Animal Caretakers	25.12	74.88%	205	82.00%	251
15-1199.12	Document Management Specialists	25.13	74.87%	206	n/a	n/a
15-1121.00	Computer Systems Analysts	22.66	74.81%	207	0.65%	671
43-4121.00	Library Assistants, Clerical	25.26	74.74%	208	95.00%	87
35-2021.00	Food Preparation Workers	25.26	74.74%	209	87.00%	195
25-1067.00	Sociology Teachers, Postsecondary	9.68	74.70%	210	n/a	n/a
25-2053.00	Special Education Teachers, Middle School	21.60	74.65%	211	1.60%	627
27-2012.01	Producers	22.07	74.64%	212	2.20%	611
39-5094.00	Skincare Specialists	25.37	74.63%	213	29.00%	467
11-9131.00	Postmasters and Mail Superintendents	25.37	74.63%	214	75.00%	294
11-2031.00	Public Relations and Fundraising Managers	15.86	74.63%	215	1.50%	636
25-1063.00	Economics Teachers, Postsecondary	13.57	74.58%	216	n/a	n/a
29-1031.00	Dietitians and Nutritionists	16.39	74.53%	217	0.39%	692
51-6021.00	Pressers, Textile, Garment, and Related Materials	25.47	74.53%	218	81.00%	255
21-1092.00	Probation Officers and Correctional Treatment Specialists	25.48	74.52%	219	25.00%	479
13-1199.04	Business Continuity Planners	15.99	74.52%	220	n/a	n/a
25-1065.00	Political Science Teachers, Postsecondary	10.21	74.51%	221	n/a	n/a
49-9064.00	Watch Repairers	25.62	74.38%	222	99.00%	6
15-1152.00	Computer Network Support Specialists	25.62	74.38%	223	n/a	n/a
17-2199.10	Wind Energy Engineers	22.78	74.33%	224	n/a	n/a
31-9095.00	Pharmacy Aides	25.83	74.17%	225	72.00%	309
17-1012.00	Landscape Architects	22.18	74.10%	226	4.50%	570
27-2042.01	Singers	21.69	74.06%	227	7.40%	548
15-1199.04	Geospatial Information Scientists and Technologists	21.15	74.02%	228	n/a	n/a
25-1125.00	History Teachers, Postsecondary	12.38	73.95%	229	n/a	n/a

51-9071.07	Precious Metal Workers	26.08	73.92%	230	n/a	n/a
43-5081.01	Stock Clerks, Sales Floor	26.20	73.80%	231	64.00%	349
19-3011.00	Economists	14.08	73.73%	232	43.00%	421
51-6041.00	Shoe and Leather Workers and Repairers	26.30	73.70%	233	52.00%	399
13-1199.02	Security Management Specialists	26.33	73.67%	234	n/a	n/a
25-1022.00	Mathematical Science Teachers, Postsecondary	11.34	73.65%	235	n/a	n/a
17-2071.00	Electrical Engineers	26.38	73.62%	236	10.00%	531
51-9123.00	Painting, Coating, and Decorating Workers	26.48	73.52%	237	92.00%	136
19-3011.01	Environmental Economists	13.49	73.39%	238	n/a	n/a
27-2012.03	Program Directors	22.90	73.37%	239	n/a	n/a
17-2171.00	Petroleum Engineers	19.56	73.35%	240	16.00%	510
51-9081.00	Dental Laboratory Technicians	26.69	73.31%	241	97.00%	52
17-2072.01	Radio Frequency Identification Device Specialists	26.70	73.30%	242	n/a	n/a
25-1122.00	Communications Teachers, Postsecondary	13.42	73.23%	243	n/a	n/a
43-5061.00	Production, Planning, and Expediting Clerks	26.79	73.21%	244	88.00%	190
17-2111.03	Product Safety Engineers	26.82	73.18%	245	n/a	n/a
15-1199.02	Computer Systems Engineers/Architects	17.62	73.11%	246	n/a	n/a
29-9092.00	Genetic Counselors	15.98	73.09%	247	n/a	n/a
27-1011.00	Art Directors	22.45	73.08%	248	2.30%	608
51-6051.00	Sewers, Hand	26.95	73.05%	249	99.00%	3
13-1022.00	Wholesale and Retail Buyers, Except Farm Products	26.96	73.04%	250	29.00%	466
27-3091.00	Interpreters and Translators	27.03	72.97%	251	38.00%	438
15-1111.00	Computer and Information Research Scientists	24.13	72.89%	252	1.50%	634
43-4051.03	Patient Representatives	27.11	72.89%	253	n/a	n/a
27-4013.00	Radio Operators	27.12	72.88%	254	98.00%	30
17-1021.00	Cartographers and Photogrammetrists	27.17	72.83%	255	88.00%	188
35-3031.00	Waiters and Waitresses	27.20	72.80%	256	94.00%	111
15-1199.06	Database Architects	19.17	72.77%	257	n/a	n/a
25-1081.00	Education Teachers, Postsecondary	13.90	72.68%	258	n/a	n/a
17-2112.01	Human Factors Engineers and Ergonomists	19.57	72.67%	259	n/a	n/a
39-9041.00	Residential Advisors	27.33	72.67%	260	6.40%	555
23-1022.00	Arbitrators, Mediators, and Conciliators	10.98	72.63%	261	6.00%	557
15-1121.01	Informatics Nurse Specialists	23.84	72.62%	262	n/a	n/a
49-9061.00	Camera and Photographic Equipment Repairers	27.38	72.62%	263	97.00%	45
41-2031.00	Retail Salespersons	27.44	72.56%	264	92.00%	133
21-1091.00	Health Educators	27.49	72.51%	265	4.50%	569
25-4031.00	Library Technicians	27.55	72.45%	266	99.00%	11
25-1061.00	Anthropology and Archeology Teachers, Postsecondary	11.67	72.43%	267	n/a	n/a
39-9021.00	Personal Care Aides	27.65	72.35%	268	74.00%	297
15-1122.00	Information Security Analysts	27.67	72.33%	269	n/a	n/a
51-6011.00	Laundry and Dry-Cleaning Workers	27.76	72.24%	270	71.00%	311
29-2081.00	Opticians, Dispensing	27.76	72.24%	271	71.00%	312
39-1012.00	Slot Supervisors	27.82	72.18%	272	54.00%	393
41-2011.00	Cashiers	27.86	72.14%	273	97.00%	46
21-1011.00	Substance Abuse and Behavioral Disorder Counselors	27.89	72.11%	274	3.30%	589
25-1066.00	Psychology Teachers, Postsecondary	11.53	72.00%	275	n/a	n/a
27-2011.00	Actors	28.14	71.86%	276	37.00%	444
27-1023.00	Floral Designers	28.15	71.85%	277	4.70%	567
17-2081.01	Water/Wastewater Engineers	20.80	71.84%	278	n/a	n/a
41-9031.00	Sales Engineers	20.41	71.82%	279	0.41%	689
13-2099.01	Financial Quantitative Analysts	20.61	71.76%	280	33.00%	458
25-1053.00	Environmental Science Teachers, Postsecondary	11.48	71.69%	281	n/a	n/a
39-3092.00	Costume Attendants	28.36	71.64%	282	61.00%	367
43-3071.00	Tellers	28.36	71.64%	283	98.00%	20
25-1064.00	Geography Teachers, Postsecondary	11.87	71.63%	284	n/a	n/a
25-1193.00	Recreation and Fitness Studies Teachers, Postsecondary	22.81	71.56%	285	n/a	n/a
35-9021.00	Dishwashers	28.46	71.54%	286	77.00%	279
11-9033.00	Education Administrators, Postsecondary	12.97	71.53%	287	1.00%	651
19-4099.03	Remote Sensing Technicians	28.56	71.44%	288	n/a	n/a

11-9199.10	Wind Energy Project Managers	28.57	71.43%	289	n/a	n/a
25-1124.00	Foreign Language and Literature Teachers, Postsecondary	11.62	71.42%	290	n/a	n/a
27-3012.00	Public Address System and Other Announcers	28.61	71.39%	291	72.00%	304
11-9199.11	Brownfield Redevelopment Specialists and Site Managers	25.88	71.31%	292	n/a	n/a
17-2199.03	Energy Engineers	21.34	71.28%	293	n/a	n/a
19-3032.00	Industrial-Organizational Psychologists	13.87	71.27%	294	1.20%	646
39-3011.00	Gaming Dealers	28.79	71.21%	295	96.00%	64
17-2061.00	Computer Hardware Engineers	20.61	71.21%	296	22.00%	489
17-2112.00	Industrial Engineers	26.61	71.16%	297	2.90%	599
27-3011.00	Radio and Television Announcers	25.45	71.10%	298	10.00%	532
41-9022.00	Real Estate Sales Agents	28.95	71.05%	299	86.00%	206
19-3094.00	Political Scientists	13.25	70.97%	300	3.90%	578
43-5081.03	Stock Clerks- Stockroom, Warehouse, or Storage Yard	29.13	70.87%	301	n/a	n/a
13-2021.02	Appraisers, Real Estate	29.21	70.79%	302	n/a	n/a
25-2031.00	Secondary School Teachers, Except Special and Career/Technical Education	26.05	70.68%	303	0.78%	662
25-4021.00	Librarians	29.33	70.67%	304	65.00%	343
17-2199.05	Mechatronics Engineers	26.25	70.64%	305	n/a	n/a
39-1021.00	First-Line Supervisors of Personal Service Workers	29.41	70.59%	306	7.60%	546
11-3131.00	Training and Development Managers	20.83	70.55%	307	0.63%	673
41-2012.00	Gaming Change Persons and Booth Cashiers	29.47	70.53%	308	83.00%	233
25-1123.00	English Language and Literature Teachers, Postsecondary	11.04	70.50%	309	n/a	n/a
51-9031.00	Cutters and Trimmers, Hand	29.52	70.48%	310	64.00%	352
15-1143.00	Computer Network Architects	27.44	70.32%	311	n/a	n/a
27-2012.05	Technical Directors/Managers	27.23	70.30%	312	n/a	n/a
19-2011.00	Astronomers	17.28	70.30%	313	4.10%	575
33-9031.00	Gaming Surveillance Officers and Gaming Investigators	29.73	70.27%	314	95.00%	88
25-1082.00	Library Science Teachers, Postsecondary	13.98	70.26%	315	n/a	n/a
51-6052.00	Tailors, Dressmakers, and Custom Sewers	29.75	70.25%	316	84.00%	224
41-4011.07	Solar Sales Representatives and Assessors	29.81	70.19%	317	n/a	n/a
27-1022.00	Fashion Designers	25.61	70.09%	318	2.10%	614
19-3031.01	School Psychologists	14.86	70.05%	319	0.47%	679
41-2021.00	Counter and Rental Clerks	29.96	70.04%	320	97.00%	42
51-2021.00	Coil Winders, Tapers, and Finishers	29.97	70.03%	321	73.00%	300
17-2111.02	Fire-Prevention and Protection Engineers	27.42	70.02%	322	n/a	n/a
13-1041.03	Equal Opportunity Representatives and Officers	16.60	70.01%	323	n/a	n/a
13-1032.00	Insurance Appraisers, Auto Damage	30.10	69.90%	324	98.00%	18
15-2041.00	Statisticians	18.48	69.85%	325	22.00%	490
27-3041.00	Editors	20.41	69.78%	326	5.50%	563
31-9011.00	Massage Therapists	30.26	69.74%	327	54.00%	392
19-2021.00	Atmospheric and Space Scientists	20.19	69.73%	328	67.00%	332
19-3092.00	Geographers	17.07	69.68%	329	25.00%	481
27-1014.00	Multimedia Artists and Animators	27.48	69.60%	330	1.50%	635
47-2082.00	Tapers	30.45	69.55%	331	62.00%	359
25-1194.00	Vocational Education Teachers, Postsecondary	30.50	69.50%	332	n/a	n/a
25-1062.00	Area, Ethnic, and Cultural Studies Teachers, Postsecondary	13.58	69.41%	333	n/a	n/a
19-4041.01	Geophysical Data Technicians	30.70	69.30%	334	91.00%	146
25-1043.00	Forestry and Conservation Science Teachers, Postsecondary	15.06	69.27%	335	n/a	n/a
51-9071.06	Gem and Diamond Workers	30.74	69.26%	336	n/a	n/a
39-9011.00	Childcare Workers	31.02	68.98%	337	8.40%	540
21-1012.00	Educational, Guidance, School, and Vocational Counselors	28.19	68.93%	338	0.85%	659
29-2011.01	Cytogenetic Technologists	31.11	68.89%	339	n/a	n/a
19-2041.03	Industrial Ecologists	18.11	68.85%	340	n/a	n/a
29-2057.00	Ophthalmic Medical Technicians	31.16	68.84%	341	n/a	n/a
43-4181.00	Reservation and Transportation Ticket Agents and Travel Clerks	31.18	68.82%	342	61.00%	365
17-2051.01	Transportation Engineers	24.58	68.80%	343	n/a	n/a
53-1021.01	Recycling Coordinators	31.22	68.78%	344	n/a	n/a
25-2012.00	Kindergarten Teachers, Except Special Education	31.27	68.73%	345	15.00%	512
17-2011.00	Aerospace Engineers	19.52	68.63%	346	1.70%	624
51-6031.00	Sewing Machine Operators	31.43	68.57%	347	89.00%	173

41-9011.00	Demonstrators and Product Promoters	31.50	68.50%	348	51.00%	401
11-3011.00	Administrative Services Managers	31.57	68.43%	349	73.00%	302
27-3043.05	Poets, Lyricists and Creative Writers	17.55	68.40%	350	n/a	n/a
53-7111.00	Mine Shuttle Car Operators	31.75	68.25%	351	37.00%	443
51-3011.00	Bakers	31.78	68.22%	352	89.00%	181
29-1141.02	Advanced Practice Psychiatric Nurses	31.88	68.12%	353	n/a	n/a
21-2011.00	Clergy	22.49	68.00%	354	0.81%	661
17-2081.00	Environmental Engineers	20.33	67.80%	355	1.80%	622
39-1021.01	Spa Managers	32.49	67.51%	356	n/a	n/a
49-9093.00	Fabric Menders, Except Garment	32.59	67.41%	357	96.00%	63
51-6063.00	Textile Knitting and Weaving Machine Setters, Operators, and Tenders	32.71	67.29%	358	73.00%	303
11-9121.00	Natural Sciences Managers	18.20	67.25%	359	1.80%	623
17-3011.01	Architectural Drafters	30.59	67.18%	360	52.00%	398
43-5053.00	Postal Service Mail Sorters, Processors, and Processing Machine Operators	32.87	67.13%	361	79.00%	273
11-1021.00	General and Operations Managers	32.90	67.10%	362	17.00%	508
21-1021.00	Child, Family, and School Social Workers	32.95	67.05%	363	2.80%	601
25-2054.00	Special Education Teachers, Secondary School	30.26	67.00%	364	0.77%	663
25-1121.00	Art, Drama, and Music Teachers, Postsecondary	18.26	66.94%	365	n/a	n/a
43-5051.00	Postal Service Clerks	33.07	66.93%	366	95.00%	78
43-9011.00	Computer Operators	33.10	66.90%	367	78.00%	275
31-1015.00	Orderlies	33.13	66.87%	368	n/a	n/a
19-3041.00	Sociologists	16.17	66.86%	369	5.90%	558
51-9061.00	Inspectors, Testers, Sorters, Samplers, and Weighers	33.14	66.86%	370	98.00%	33
21-1015.00	Rehabilitation Counselors	30.84	66.80%	371	0.94%	656
15-1199.05	Geographic Information Systems Technicians	33.26	66.74%	372	n/a	n/a
11-9031.00	Education Administrators, Preschool and Childcare Center/Program	30.82	66.73%	373	1.50%	632
25-2021.00	Elementary School Teachers, Except Special Education	30.23	66.62%	374	0.44%	683
33-3021.06	Intelligence Analysts	22.55	66.49%	375	n/a	n/a
43-9071.00	Office Machine Operators, Except Computer	33.54	66.46%	376	n/a	n/a
51-2023.00	Electromechanical Equipment Assemblers	33.56	66.44%	377	97.00%	55
29-1199.01	Acupuncturists	33.58	66.42%	378	2.00%	618
15-1142.00	Network and Computer Systems Administrators	31.45	66.28%	379	3.00%	594
51-3092.00	Food Batchmakers	33.74	66.26%	380	70.00%	318
35-2015.00	Cooks, Short Order	33.84	66.16%	381	94.00%	102
15-1151.00	Computer User Support Specialists	33.94	66.06%	382	n/a	n/a
11-9041.00	Architectural and Engineering Managers	22.80	65.94%	383	1.70%	625
21-1022.00	Healthcare Social Workers	31.96	65.80%	384	0.35%	695
43-9051.00	Mail Clerks and Mail Machine Operators, Except Postal Service	34.20	65.80%	385	94.00%	112
19-3093.00	Historians	21.72	65.76%	386	44.00%	420
53-6061.00	Transportation Attendants, Except Flight Attendants	34.40	65.60%	387	75.00%	291
51-3093.00	Food Cooking Machine Operators and Tenders	34.42	65.58%	388	61.00%	362
17-3029.08	Photonics Technicians	34.43	65.57%	389	n/a	n/a
17-2051.00	Civil Engineers	24.20	65.50%	390	1.90%	619
23-1011.00	Lawyers	20.52	65.49%	391	3.50%	588
27-1021.00	Commercial and Industrial Designers	30.61	65.48%	392	3.70%	584
31-1014.00	Nursing Assistants	34.55	65.45%	393	n/a	n/a
35-2013.00	Cooks, Private Household	34.65	65.35%	394	30.00%	462
29-2052.00	Pharmacy Technicians	34.65	65.35%	395	92.00%	141
11-9071.00	Gaming Managers	34.65	65.35%	396	9.10%	538
19-4011.02	Food Science Technicians	34.66	65.34%	397	n/a	n/a
19-1041.00	Epidemiologists	22.83	65.34%	398	20.00%	497
17-2041.00	Chemical Engineers	27.81	65.24%	399	1.70%	626
51-8011.00	Nuclear Power Reactor Operators	34.78	65.22%	400	95.00%	89
47-3014.00	Helpers--Painters, Paperhangers, Plasterers, and Stucco Masons	34.87	65.13%	401	94.00%	100
39-9032.00	Recreation Workers	32.36	65.09%	402	0.61%	674
31-9092.00	Medical Assistants	34.91	65.09%	403	30.00%	464
19-1029.01	Bioinformatics Scientists	23.35	65.08%	404	1.50%	637
17-2141.00	Mechanical Engineers	28.38	65.06%	405	1.10%	650
39-5012.00	Hairdressers, Hairstylists, and Cosmetologists	35.00	65.00%	406	11.00%	527

51-4071.00	Foundry Mold and Coremakers	35.01	64.99%	407	67.00%	333
47-2042.00	Floor Layers, Except Carpet, Wood, and Hard Tiles	35.04	64.96%	408	79.00%	265
25-1032.00	Engineering Teachers, Postsecondary	15.09	64.93%	409	n/a	n/a
51-6042.00	Shoe Machine Operators and Tenders	35.07	64.93%	410	97.00%	56
11-1011.00	Chief Executives	17.97	64.87%	411	1.50%	633
29-1125.01	Art Therapists	32.40	64.85%	412	n/a	n/a
25-2052.00	Special Education Teachers, Kindergarten and Elementary School	32.75	64.84%	413	n/a	n/a
37-1011.00	First-Line Supervisors of Housekeeping and Janitorial Workers	35.19	64.81%	414	94.00%	96
31-2022.00	Physical Therapist Aides	35.31	64.69%	415	61.00%	368
17-3029.02	Electrical Engineering Technologists	35.33	64.67%	416	n/a	n/a
49-2093.00	Electrical and Electronics Installers and Repairers, Transportation Equipment	35.37	64.63%	417	91.00%	149
25-1031.00	Architecture Teachers, Postsecondary	14.78	64.59%	418	n/a	n/a
11-9061.00	Funeral Service Managers	35.44	64.56%	419	n/a	n/a
25-2011.00	Preschool Teachers, Except Special Education	32.54	64.47%	420	0.74%	666
13-2021.01	Assessors	35.61	64.39%	421	90.00%	162
39-4011.00	Embalmers	35.75	64.25%	422	54.00%	395
35-3022.01	Baristas	35.76	64.24%	423	n/a	n/a
39-7012.00	Travel Guides	35.85	64.15%	424	5.70%	560
25-2023.00	Career/Technical Education Teachers, Middle School	35.86	64.14%	425	26.00%	474
31-9097.00	Phlebotomists	35.88	64.12%	426	n/a	n/a
25-1113.00	Social Work Teachers, Postsecondary	11.50	64.10%	427	n/a	n/a
17-3023.01	Electronics Engineering Technicians	35.97	64.03%	428	84.00%	229
51-9192.00	Cleaning, Washing, and Metal Pickling Equipment Operators and Tenders	36.02	63.98%	429	81.00%	258
27-4014.00	Sound Engineering Technicians	36.04	63.96%	430	13.00%	516
25-9031.00	Instructional Coordinators	23.42	63.88%	431	0.42%	687
33-9092.00	Lifeguards, Ski Patrol, and Other Recreational Protective Service Workers	36.16	63.84%	432	67.00%	330
35-2012.00	Cooks, Institution and Cafeteria	36.17	63.83%	433	83.00%	243
33-9021.00	Private Detectives and Investigators	36.24	63.76%	434	31.00%	460
25-1052.00	Chemistry Teachers, Postsecondary	15.13	63.70%	435	n/a	n/a
13-1074.00	Farm Labor Contractors	36.33	63.67%	436	97.00%	54
51-3022.00	Meat, Poultry, and Fish Cutters and Trimmers	36.38	63.62%	437	94.00%	110
17-3029.11	Nanotechnology Engineering Technologists	36.39	63.61%	438	n/a	n/a
51-2041.00	Structural Metal Fabricators and Fitters	36.41	63.59%	439	41.00%	428
29-2099.01	Neurodiagnostic Technologists	36.48	63.52%	440	40.00%	430
47-3015.00	Helpers--Pipelayers, Plumbers, Pipefitters, and Steamfitters	36.50	63.50%	441	57.00%	383
17-2141.01	Fuel Cell Engineers	30.90	63.50%	442	n/a	n/a
47-2142.00	Paperhangers	36.55	63.45%	443	87.00%	198
29-2099.05	Ophthalmic Medical Technologists	36.60	63.40%	444	n/a	n/a
31-2012.00	Occupational Therapy Aides	36.68	63.32%	445	27.00%	472
45-2021.00	Animal Breeders	36.70	63.30%	446	95.00%	84
51-2022.00	Electrical and Electronic Equipment Assemblers	36.73	63.27%	447	95.00%	82
43-5071.00	Shipping, Receiving, and Traffic Clerks	36.76	63.24%	448	98.00%	24
37-3011.00	Landscaping and Groundskeeping Workers	36.89	63.11%	449	95.00%	80
21-1093.00	Social and Human Service Assistants	36.90	63.10%	450	13.00%	518
41-1011.00	First-Line Supervisors of Retail Sales Workers	36.94	63.06%	451	28.00%	470
25-1054.00	Physics Teachers, Postsecondary	14.09	63.02%	452	n/a	n/a
11-9151.00	Social and Community Service Managers	29.26	62.94%	453	0.67%	670
23-1023.00	Judges, Magistrate Judges, and Magistrates	26.56	62.90%	454	40.00%	432
27-2041.01	Music Directors	34.22	62.81%	455	1.50%	631
33-9032.00	Security Guards	37.23	62.77%	456	84.00%	225
17-2151.00	Mining and Geological Engineers, Including Mining Safety Engineers	27.03	62.74%	457	14.00%	514
17-1011.00	Architects, Except Landscape and Naval	31.03	62.65%	458	1.80%	621
19-2032.00	Materials Scientists	26.53	62.64%	459	2.10%	616
29-1069.01	Allergists and Immunologists	24.78	62.60%	460	n/a	n/a
43-5052.00	Postal Service Mail Carriers	37.41	62.59%	461	68.00%	328
29-1062.00	Family and General Practitioners	20.96	62.58%	462	n/a	n/a
25-1071.00	Health Specialties Teachers, Postsecondary	23.25	62.51%	463	n/a	n/a
11-9051.00	Food Service Managers	37.49	62.51%	464	8.30%	541
51-9083.00	Ophthalmic Laboratory Technicians	37.52	62.48%	465	97.00%	47

43-5031.00	Police, Fire, and Ambulance Dispatchers	37.54	62.46%	466	49.00%	405
31-9096.00	Veterinary Assistants and Laboratory Animal Caretakers	37.69	62.31%	467	86.00%	208
29-2011.02	Cytotechnologists	37.70	62.30%	468	n/a	n/a
17-2131.00	Materials Engineers	27.82	61.94%	469	2.10%	615
25-9011.00	Audio-Visual and Multimedia Collections Specialists	38.07	61.93%	470	39.00%	433
39-3021.00	Motion Picture Projectionists	38.25	61.75%	471	97.00%	44
31-2011.00	Occupational Therapy Assistants	38.26	61.74%	472	2.80%	602
31-9091.00	Dental Assistants	38.31	61.69%	473	51.00%	400
51-2092.00	Team Assemblers	38.32	61.68%	474	97.00%	57
43-5111.00	Weighers, Measurers, Checkers, and Samplers, Recordkeeping	38.39	61.61%	475	95.00%	92
19-1042.00	Medical Scientists, Except Epidemiologists	22.43	61.52%	476	0.45%	682
17-3029.05	Industrial Engineering Technologists	36.60	61.51%	477	n/a	n/a
29-1122.01	Low Vision Therapists, Orientation and Mobility Specialists, and Vision Rehabilitation Therapists	38.52	61.48%	478	n/a	n/a
29-1141.01	Acute Care Nurses	38.55	61.45%	479	n/a	n/a
49-9091.00	Coin, Vending, and Amusement Machine Servicers and Repairers	38.56	61.44%	480	94.00%	106
21-1023.00	Mental Health and Substance Abuse Social Workers	30.98	61.43%	481	0.31%	699
35-2014.00	Cooks, Restaurant	38.59	61.41%	482	96.00%	62
29-1199.05	Orthoptists	30.05	61.32%	483	n/a	n/a
51-8012.00	Power Distributors and Dispatchers	38.76	61.24%	484	64.00%	348
39-6011.00	Baggage Porters and Bellhops	38.86	61.14%	485	83.00%	234
29-1181.00	Audiologists	31.29	61.09%	486	0.33%	698
35-1012.00	First-Line Supervisors of Food Preparation and Serving Workers	38.91	61.09%	487	63.00%	354
27-2023.00	Umpires, Referees, and Other Sports Officials	38.96	61.04%	488	98.00%	19
49-3022.00	Automotive Glass Installers and Repairers	39.07	60.93%	489	55.00%	390
47-2043.00	Floor Sanders and Finishers	39.15	60.85%	490	87.00%	194
33-3041.00	Parking Enforcement Workers	39.20	60.80%	491	84.00%	221
47-2141.00	Painters, Construction and Maintenance	39.24	60.76%	492	75.00%	292
51-9198.00	Helpers--Production Workers	39.30	60.70%	493	66.00%	338
11-9021.00	Construction Managers	37.52	60.69%	494	7.10%	549
13-1121.00	Meeting, Convention, and Event Planners	36.80	60.63%	495	3.70%	582
29-1023.00	Orthodontists	35.79	60.58%	496	2.30%	609
29-2051.00	Dietetic Technicians	39.43	60.57%	497	13.00%	520
41-2022.00	Parts Salespersons	39.43	60.57%	498	98.00%	27
51-9195.03	Stone Cutters and Carvers, Manufacturing	39.48	60.52%	499	90.00%	163
27-1026.00	Merchandise Displayers and Window Trimmers	39.52	60.48%	500	48.00%	412
51-9071.01	Jewelers	34.71	60.44%	501	95.00%	77
51-9194.00	Etchers and Engravers	39.59	60.41%	502	98.00%	21
51-9196.00	Paper Goods Machine Setters, Operators, and Tenders	39.60	60.40%	503	67.00%	334
31-1011.00	Home Health Aides	39.61	60.39%	504	39.00%	437
51-4034.00	Lathe and Turning Machine Tool Setters, Operators, and Tenders, Metal and Plastic	39.62	60.38%	505	84.00%	226
11-3071.02	Storage and Distribution Managers	39.68	60.32%	506	n/a	n/a
15-1143.01	Telecommunications Engineering Specialists	39.69	60.31%	507	n/a	n/a
53-7081.00	Refuse and Recyclable Material Collectors	39.76	60.24%	508	93.00%	118
29-2021.00	Dental Hygienists	39.80	60.20%	509	68.00%	324
49-3091.00	Bicycle Repairers	39.81	60.19%	510	94.00%	107
51-3021.00	Butchers and Meat Cutters	39.82	60.18%	511	93.00%	120
19-3091.01	Anthropologists	21.04	60.14%	512	0.77%	664
47-2121.00	Glaziers	39.90	60.10%	513	73.00%	301
25-1021.00	Computer Science Teachers, Postsecondary	21.18	60.00%	514	n/a	n/a
53-3022.00	Bus Drivers, School or Special Client	40.00	60.00%	515	89.00%	178
15-2021.00	Mathematicians	15.53	59.98%	516	4.70%	568
53-2031.00	Flight Attendants	40.05	59.95%	517	35.00%	453
17-2141.02	Automotive Engineers	33.95	59.92%	518	n/a	n/a
19-1029.03	Geneticists	28.79	59.83%	519	n/a	n/a
51-9051.00	Furnace, Kiln, Oven, Drier, and Kettle Operators and Tenders	40.26	59.74%	520	37.00%	448
33-9099.02	Retail Loss Prevention Specialists	40.39	59.61%	521	n/a	n/a
29-9011.00	Occupational Health and Safety Specialists	40.51	59.49%	522	17.00%	507
45-2092.01	Nursery Workers	40.58	59.42%	523	n/a	n/a

53-7063.00	Machine Feeders and Offbearers	40.79	59.21%	524	93.00%	123
51-9151.00	Photographic Process Workers and Processing Machine Operators	40.87	59.13%	525	99.00%	9
11-9013.01	Nursery and Greenhouse Managers	40.90	59.10%	526	4.70%	566
17-2161.00	Nuclear Engineers	25.60	58.97%	527	7.00%	550
51-9122.00	Painters, Transportation Equipment	41.11	58.89%	528	69.00%	321
53-6041.00	Traffic Technicians	41.13	58.87%	529	90.00%	166
19-4099.01	Quality Control Analysts	41.27	58.73%	530	61.00%	363
31-2021.00	Physical Therapist Assistants	41.31	58.69%	531	1.80%	620
51-7041.00	Sawing Machine Setters, Operators, and Tenders, Wood	41.31	58.69%	532	86.00%	210
35-3011.00	Bartenders	41.32	58.68%	533	77.00%	281
29-1199.04	Naturopathic Physicians	30.63	58.68%	534	n/a	n/a
53-6021.00	Parking Lot Attendants	41.37	58.63%	535	87.00%	193
29-9012.00	Occupational Health and Safety Technicians	41.39	58.61%	536	25.00%	480
51-3091.00	Food and Tobacco Roasting, Baking, and Drying Machine Operators and Tenders	41.47	58.53%	537	91.00%	155
29-2011.03	Histotechnologists and Histologic Technicians	41.50	58.50%	538	n/a	n/a
17-3023.03	Electrical Engineering Technicians	41.52	58.48%	539	n/a	n/a
51-4122.00	Welding, Soldering, and Brazing Machine Setters, Operators, and Tenders	41.54	58.46%	540	61.00%	361
51-9141.00	Semiconductor Processors	41.59	58.41%	541	88.00%	189
49-3093.00	Tire Repairers and Changers	41.70	58.30%	542	70.00%	319
39-5091.00	Makeup Artists, Theatrical and Performance	39.27	58.30%	543	1.00%	653
29-1081.00	Podiatrists	32.28	58.26%	544	0.46%	680
31-9099.02	Endoscopy Technicians	41.75	58.25%	545	n/a	n/a
47-3013.00	Helpers--Electricians	41.82	58.18%	546	74.00%	295
53-3031.00	Driver/Sales Workers	41.83	58.17%	547	98.00%	29
27-1012.00	Craft Artists	38.75	58.14%	548	3.50%	587
27-1013.00	Fine Artists, Including Painters, Sculptors, and Illustrators	37.52	58.13%	549	4.20%	572
15-2091.00	Mathematical Technicians	24.19	58.11%	550	99.00%	4
51-4193.00	Plating and Coating Machine Setters, Operators, and Tenders, Metal and Plastic	41.90	58.10%	551	92.00%	134
29-2033.00	Nuclear Medicine Technologists	41.90	58.10%	552	13.00%	523
49-2011.00	Computer, Automated Teller, and Office Machine Repairers	41.92	58.08%	553	74.00%	298
37-3012.00	Pesticide Handlers, Sprayers, and Applicators, Vegetation	41.99	58.01%	554	97.00%	49
21-1014.00	Mental Health Counselors	29.03	58.00%	555	0.48%	678
17-3021.00	Aerospace Engineering and Operations Technicians	42.09	57.91%	556	48.00%	413
51-6061.00	Textile Bleaching and Dyeing Machine Operators and Tenders	42.21	57.79%	557	97.00%	53
29-2053.00	Psychiatric Technicians	42.25	57.75%	558	4.30%	571
53-3021.00	Bus Drivers, Transit and Intercity	42.26	57.74%	559	67.00%	331
17-2021.00	Agricultural Engineers	40.36	57.74%	560	49.00%	408
19-2099.01	Remote Sensing Scientists and Technologists	32.73	57.73%	561	43.00%	422
51-4035.00	Milling and Planing Machine Setters, Operators, and Tenders, Metal and Plastic	42.27	57.73%	562	98.00%	25
11-9161.00	Emergency Management Directors	39.78	57.70%	563	0.30%	700
29-2012.00	Medical and Clinical Laboratory Technicians	42.31	57.69%	564	47.00%	415
53-1021.00	First-Line Supervisors of Helpers, Laborers, and Material Movers, Hand	42.43	57.57%	565	42.00%	424
17-3026.00	Industrial Engineering Technicians	40.53	57.44%	566	3.00%	595
25-4013.00	Museum Technicians and Conservators	42.57	57.43%	567	59.00%	377
27-2042.02	Musicians, Instrumental	40.51	57.37%	568	n/a	n/a
31-1013.00	Psychiatric Aides	42.64	57.36%	569	47.00%	416
29-1065.00	Pediatricians, General	28.57	57.34%	570	n/a	n/a
43-5021.00	Couriers and Messengers	42.68	57.32%	571	94.00%	104
25-1042.00	Biological Science Teachers, Postsecondary	20.76	57.30%	572	n/a	n/a
35-1011.00	Chefs and Head Cooks	42.75	57.25%	573	10.00%	534
11-9199.08	Loss Prevention Managers	40.62	57.25%	574	n/a	n/a
21-1094.00	Community Health Workers	42.81	57.19%	575	n/a	n/a
19-1012.00	Food Scientists and Technologists	40.85	57.09%	576	7.70%	545
47-2132.00	Insulation Workers, Mechanical	42.95	57.05%	577	64.00%	347
11-9081.00	Lodging Managers	40.89	56.98%	578	0.39%	691
31-9093.00	Medical Equipment Preparers	43.03	56.97%	579	78.00%	277
53-2022.00	Airfield Operations Specialists	43.05	56.95%	580	71.00%	315
49-2021.01	Radio Mechanics	43.07	56.93%	581	n/a	n/a
43-5041.00	Meter Readers, Utilities	43.08	56.92%	582	85.00%	218

27-4012.00	Broadcast Technicians	43.16	56.84%	583	74.00%	296
29-1024.00	Prosthodontists	43.19	56.81%	584	5.50%	562
23-1021.00	Administrative Law Judges, Adjudicators, and Hearing Officers	27.38	56.70%	585	n/a	n/a
49-9094.00	Locksmiths and Safe Repairers	43.42	56.58%	586	77.00%	283
11-3051.00	Industrial Production Managers	41.43	56.50%	587	3.00%	596
53-7062.00	Laborers and Freight, Stock, and Material Movers, Hand	43.57	56.43%	588	85.00%	220
11-3051.02	Geothermal Production Managers	43.58	56.42%	589	n/a	n/a
53-7073.00	Wellhead Pumpers	43.59	56.41%	590	84.00%	223
17-2199.11	Solar Energy Systems Engineers	41.44	56.36%	591	n/a	n/a
51-4062.00	Patternmakers, Metal and Plastic	43.65	56.35%	592	90.00%	164
45-2092.02	Farmworkers and Laborers, Crop	43.67	56.33%	593	n/a	n/a
53-6051.07	Transportation Vehicle, Equipment and Systems Inspectors, Except Aviation	43.70	56.30%	594	n/a	n/a
11-9032.00	Education Administrators, Elementary and Secondary School	32.72	56.24%	595	0.46%	681
25-1051.00	Atmospheric, Earth, Marine, and Space Sciences Teachers, Postsecondary	24.49	56.22%	596	n/a	n/a
53-1031.00	First-Line Supervisors of Transportation and Material-Moving Machine and Vehicle Operators	43.88	56.12%	597	2.90%	598
39-9011.01	Nannies	43.94	56.06%	598	n/a	n/a
19-1031.03	Park Naturalists	43.97	56.03%	599	n/a	n/a
25-2032.00	Career/Technical Education Teachers, Secondary School	42.18	56.00%	600	0.88%	658
29-1127.00	Speech-Language Pathologists	34.29	55.91%	601	0.64%	672
11-3051.01	Quality Control Systems Managers	44.10	55.90%	602	n/a	n/a
47-4011.00	Construction and Building Inspectors	44.14	55.86%	603	63.00%	353
33-9011.00	Animal Control Workers	44.23	55.77%	604	21.00%	493
45-2091.00	Agricultural Equipment Operators	44.23	55.77%	604	n/a	n/a
25-4012.00	Curators	38.32	55.75%	606	0.68%	669
51-9022.00	Grinding and Polishing Workers, Hand	44.26	55.74%	607	97.00%	50
39-9031.00	Fitness Trainers and Aerobics Instructors	44.31	55.69%	608	8.50%	539
27-4011.00	Audio and Video Equipment Technicians	44.41	55.59%	609	55.00%	387
51-9197.00	Tire Builders	44.42	55.58%	610	94.00%	98
51-4022.00	Forging Machine Setters, Operators, and Tenders, Metal and Plastic	44.47	55.53%	611	93.00%	116
45-2011.00	Agricultural Inspectors	44.69	55.31%	612	94.00%	95
53-6031.00	Automotive and Watercraft Service Attendants	44.71	55.29%	613	83.00%	236
51-4032.00	Drilling and Boring Machine Tool Setters, Operators, and Tenders, Metal and Plastic	44.74	55.26%	614	94.00%	113
53-6051.08	Freight and Cargo Inspectors	44.89	55.11%	615	n/a	n/a
17-2031.00	Biomedical Engineers	35.40	55.05%	616	3.70%	583
51-4052.00	Pourers and Casters, Metal	44.95	55.05%	617	87.00%	200
29-2099.06	Radiologic Technicians	44.96	55.04%	618	n/a	n/a
13-1041.02	Licensing Examiners and Inspectors	45.05	54.95%	619	n/a	n/a
51-5112.00	Printing Press Operators	45.06	54.94%	620	83.00%	237
25-1112.00	Law Teachers, Postsecondary	11.62	54.93%	621	n/a	n/a
29-1051.00	Pharmacists	38.42	54.91%	622	1.20%	649
51-8021.00	Stationary Engineers and Boiler Operators	45.13	54.87%	623	89.00%	174
19-4031.00	Chemical Technicians	45.16	54.84%	624	57.00%	384
17-2072.00	Electronics Engineers, Except Computer	43.36	54.82%	625	2.50%	605
19-1011.00	Animal Scientists	36.19	54.71%	626	6.10%	556
29-2031.00	Cardiovascular Technologists and Technicians	45.33	54.67%	627	23.00%	484
29-1125.02	Music Therapists	43.09	54.57%	628	n/a	n/a
53-7031.00	Dredge Operators	45.69	54.31%	629	92.00%	139
53-6011.00	Bridge and Lock Tenders	45.69	54.31%	630	97.00%	59
29-2054.00	Respiratory Therapy Technicians	45.78	54.22%	631	10.00%	529
51-6092.00	Fabric and Apparel Patternmakers	43.51	54.12%	632	0.49%	677
29-1122.00	Occupational Therapists	43.72	54.11%	633	0.35%	697
27-4021.00	Photographers	43.55	54.08%	634	2.10%	612
53-3033.00	Light Truck or Delivery Services Drivers	45.94	54.06%	635	69.00%	323
43-9031.00	Desktop Publishers	43.88	53.95%	636	16.00%	509
47-2071.00	Paving, Surfacing, and Tamping Equipment Operators	46.22	53.78%	637	83.00%	231
29-2035.00	Magnetic Resonance Imaging Technologists	46.22	53.78%	638	n/a	n/a
19-4021.00	Biological Technicians	43.29	53.73%	639	30.00%	465
51-4192.00	Layout Workers, Metal and Plastic	46.30	53.70%	640	84.00%	227

11-9199.09	Wind Energy Operations Managers	46.34	53.66%	641	n/a	n/a
51-4033.00	Grinding, Lapping, Polishing, and Buffing Machine Tool Setters, Operators, and Tenders, Metal and Plastic	46.39	53.61%	642	95.00%	79
49-2098.00	Security and Fire Alarm Systems Installers	46.39	53.61%	642	82.00%	253
51-6064.00	Textile Winding, Twisting, and Drawing Out Machine Setters, Operators, and Tenders	46.42	53.58%	644	96.00%	66
19-4011.01	Agricultural Technicians	46.42	53.58%	645	97.00%	38
51-4012.00	Computer Numerically Controlled Machine Tool Programmers, Metal and Plastic	46.43	53.57%	646	36.00%	450
11-3051.04	Biomass Power Plant Managers	45.21	53.56%	647	n/a	n/a
47-3012.00	Helpers--Carpenters	46.44	53.56%	648	92.00%	130
45-3021.00	Hunters and Trappers	46.51	53.49%	649	77.00%	278
47-2081.00	Drywall and Ceiling Tile Installers	46.54	53.46%	650	79.00%	270
11-9039.02	Fitness and Wellness Coordinators	44.60	53.45%	651	n/a	n/a
47-2041.00	Carpet Installers	46.60	53.40%	652	87.00%	199
11-9041.01	Biofuels/Biodiesel Technology and Product Development Managers	44.52	53.33%	653	n/a	n/a
49-9063.00	Musical Instrument Repairers and Tuners	46.70	53.30%	654	91.00%	158
17-2121.02	Marine Architects	41.34	53.26%	655	n/a	n/a
33-2022.00	Forest Fire Inspectors and Prevention Specialists	46.76	53.24%	656	4.80%	565
29-2032.00	Diagnostic Medical Sonographers	46.78	53.22%	657	35.00%	452
51-4061.00	Model Makers, Metal and Plastic	46.79	53.21%	658	93.00%	122
49-9045.00	Refractory Materials Repairers, Except Brickmasons	46.79	53.21%	659	82.00%	252
47-2131.00	Insulation Workers, Floor, Ceiling, and Wall	46.86	53.14%	660	83.00%	238
49-3052.00	Motorcycle Mechanics	46.88	53.12%	661	79.00%	268
29-1066.00	Psychiatrists	31.73	53.12%	662	n/a	n/a
29-1161.00	Nurse Midwives	43.63	53.06%	663	n/a	n/a
29-1041.00	Optometrists	40.87	53.06%	664	14.00%	515
29-1069.04	Neurologists	28.61	53.03%	665	n/a	n/a
51-4194.00	Tool Grinders, Filers, and Sharpeners	46.97	53.03%	666	88.00%	183
47-5071.00	Roustabouts, Oil and Gas	47.00	53.00%	667	68.00%	327
53-7033.00	Loading Machine Operators, Underground Mining	47.04	52.96%	668	50.00%	404
49-2097.00	Electronic Home Entertainment Equipment Installers and Repairers	47.06	52.94%	669	65.00%	342
29-1125.00	Recreational Therapists	45.10	52.92%	670	0.28%	702
45-4023.00	Log Graders and Scalers	47.08	52.92%	671	97.00%	48
51-2031.00	Engine and Other Machine Assemblers	47.26	52.74%	672	82.00%	254
47-2151.00	Pipelayers	47.32	52.68%	673	62.00%	358
51-9199.01	Recycling and Reclamation Workers	47.36	52.64%	674	92.00%	131
19-2042.00	Geoscientists, Except Hydrologists and Geographers	44.32	52.53%	675	63.00%	357
51-4031.00	Cutting, Punching, and Press Machine Setters, Operators, and Tenders, Metal and Plastic	47.51	52.49%	676	78.00%	276
45-2093.00	Farmworkers, Farm, Ranch, and Aquacultural Animals	47.51	52.49%	677	n/a	n/a
51-4111.00	Tool and Die Makers	47.52	52.48%	678	84.00%	230
17-2199.07	Photonics Engineers	38.96	52.44%	679	n/a	n/a
15-2041.01	Biostatisticians	33.90	52.41%	680	n/a	n/a
47-4099.03	Weatherization Installers and Technicians	47.60	52.40%	681	n/a	n/a
51-9082.00	Medical Appliance Technicians	47.65	52.35%	682	45.00%	419
49-9043.00	Maintenance Workers, Machinery	47.70	52.30%	683	86.00%	204
51-6062.00	Textile Cutting Machine Setters, Operators, and Tenders	47.70	52.30%	684	95.00%	91
53-2021.00	Air Traffic Controllers	43.69	52.28%	685	11.00%	525
47-2053.00	Terrazzo Workers and Finishers	47.78	52.22%	686	88.00%	184
51-7031.00	Model Makers, Wood	47.83	52.17%	687	96.00%	67
47-2051.00	Cement Masons and Concrete Finishers	47.84	52.16%	688	94.00%	108
49-2091.00	Avionics Technicians	47.84	52.16%	689	70.00%	317
11-3051.03	Biofuels Production Managers	46.34	52.14%	690	n/a	n/a
47-2161.00	Plasterers and Stucco Masons	47.88	52.12%	691	84.00%	228
47-5051.00	Rock Splitters, Quarry	47.94	52.06%	692	96.00%	70
19-4051.02	Nuclear Monitoring Technicians	47.95	52.05%	693	n/a	n/a
49-3053.00	Outdoor Power Equipment and Other Small Engine Mechanics	47.97	52.03%	694	93.00%	125
51-9195.07	Molding and Casting Workers	47.99	52.01%	695	n/a	n/a
37-1012.00	First-Line Supervisors of Landscaping, Lawn Service, and Groundskeeping Workers	47.99	52.01%	696	57.00%	380
25-2059.01	Adapted Physical Education Specialists	48.04	51.96%	697	n/a	n/a
39-4031.00	Morticians, Undertakers, and Funeral Directors	48.09	51.91%	698	20.00%	496

47-3011.00	Helpers--Brickmasons, Blockmasons, Stonemasons, and Tile and Marble Setters	48.19	51.81%	699	83.00%	240
51-9032.00	Cutting and Slicing Machine Setters, Operators, and Tenders	48.20	51.80%	700	86.00%	207
53-7041.00	Hoist and Winch Operators	48.20	51.80%	701	65.00%	340
29-1128.00	Exercise Physiologists	46.54	51.79%	702	n/a	n/a
47-4031.00	Fence Erectors	48.21	51.79%	703	92.00%	135
53-7051.00	Industrial Truck and Tractor Operators	48.27	51.73%	704	93.00%	115
29-2034.00	Radiologic Technologists	48.33	51.67%	705	23.00%	485
25-1011.00	Business Teachers, Postsecondary	21.23	51.61%	706	n/a	n/a
51-9195.05	Potters, Manufacturing	46.71	51.56%	707	n/a	n/a
47-2073.00	Operating Engineers and Other Construction Equipment Operators	48.44	51.56%	708	95.00%	86
51-7021.00	Furniture Finishers	48.46	51.54%	709	87.00%	196
51-4072.00	Molding, Coremaking, and Casting Machine Setters, Operators, and Tenders, Metal and Plastic	48.53	51.47%	710	95.00%	83
51-6091.00	Extruding and Forming Machine Setters, Operators, and Tenders, Synthetic and Glass Fibers	48.63	51.37%	711	88.00%	185
51-4081.00	Multiple Machine Tool Setters, Operators, and Tenders, Metal and Plastic	48.76	51.24%	712	91.00%	151
47-4091.00	Segmental Pavers	48.76	51.24%	713	83.00%	239
29-1123.00	Physical Therapists	48.80	51.20%	714	2.10%	613
29-2056.00	Veterinary Technologists and Technicians	48.81	51.19%	715	2.90%	597
29-9099.01	Midwives	45.44	51.10%	716	5.50%	561
19-2041.02	Environmental Restoration Planners	47.14	51.08%	717	n/a	n/a
47-2044.00	Tile and Marble Setters	48.93	51.07%	718	75.00%	293
47-2171.00	Reinforcing Iron and Rebar Workers	49.22	50.78%	719	90.00%	169
29-9091.00	Athletic Trainers	49.23	50.77%	720	0.71%	668
47-4021.00	Elevator Installers and Repairers	49.24	50.76%	721	39.00%	435
53-3041.00	Taxi Drivers and Chauffeurs	49.25	50.75%	722	89.00%	172
25-1041.00	Agricultural Sciences Teachers, Postsecondary	31.11	50.75%	723	n/a	n/a
49-9031.00	Home Appliance Repairers	49.30	50.70%	724	72.00%	306
29-2091.00	Orthotists and Prosthetists	44.80	50.66%	725	0.35%	696
51-9041.00	Extruding, Forming, Pressing, and Compacting Machine Setters, Operators, and Tenders	49.34	50.66%	726	93.00%	119
47-1011.00	First-Line Supervisors of Construction Trades and Extraction Workers	49.43	50.57%	727	17.00%	504
51-9023.00	Mixing and Blending Machine Setters, Operators, and Tenders	49.49	50.51%	728	83.00%	241
53-7071.00	Gas Compressor and Gas Pumping Station Operators	49.50	50.50%	729	91.00%	154
47-3016.00	Helpers--Roofers	49.51	50.49%	730	72.00%	308
25-9021.00	Farm and Home Management Advisors	43.98	50.45%	731	0.75%	665
49-9012.00	Control and Valve Installers and Repairers, Except Mechanical Door	49.57	50.43%	732	63.00%	356
51-7042.00	Woodworking Machine Setters, Operators, and Tenders, Except Sawing	49.60	50.40%	733	97.00%	58
19-4099.02	Precision Agriculture Technicians	49.60	50.40%	734	n/a	n/a
47-2072.00	Pile-Driver Operators	49.61	50.39%	735	82.00%	249
17-3029.09	Manufacturing Production Technicians	49.62	50.38%	736	n/a	n/a
47-2061.00	Construction Laborers	49.63	50.37%	737	88.00%	191
51-9193.00	Cooling and Freezing Equipment Operators and Tenders	49.69	50.31%	738	93.00%	129
49-9096.00	Riggers	49.71	50.29%	739	89.00%	176
51-9111.00	Packaging and Filling Machine Operators and Tenders	49.79	50.21%	740	98.00%	22
47-2022.00	Stonemasons	49.79	50.21%	741	89.00%	179
51-5113.00	Print Binding and Finishing Workers	49.89	50.11%	742	95.00%	85
11-9199.07	Security Managers	48.28	50.07%	743	n/a	n/a
29-2061.00	Licensed Practical and Licensed Vocational Nurses	50.03	49.97%	744	5.80%	559
51-4021.00	Extruding and Drawing Machine Setters, Operators, and Tenders, Metal and Plastic	50.08	49.92%	745	91.00%	143
29-2011.00	Medical and Clinical Laboratory Technologists	50.13	49.87%	746	90.00%	170
51-9191.00	Adhesive Bonding Machine Operators and Tenders	50.15	49.85%	747	95.00%	81
17-3029.03	Electromechanical Engineering Technologists	50.19	49.81%	748	n/a	n/a
19-1031.02	Range Managers	48.68	49.64%	749	n/a	n/a
11-9013.03	Aquacultural Managers	50.40	49.60%	750	n/a	n/a
49-9062.00	Medical Equipment Repairers	50.41	49.59%	751	27.00%	471
29-1011.00	Chiropractors	47.65	49.57%	752	2.70%	603
39-2011.00	Animal Trainers	50.51	49.49%	753	10.00%	533
29-1126.00	Respiratory Therapists	50.60	49.40%	754	6.60%	553
29-1071.00	Physician Assistants	44.34	49.36%	755	14.00%	513
49-3051.00	Motorboat Mechanics and Service Technicians	50.71	49.29%	756	66.00%	335

49-9052.00	Telecommunications Line Installers and Repairers	50.85	49.15%	757	49.00%	406
53-7011.00	Conveyor Operators and Tenders	50.95	49.05%	758	93.00%	126
33-3021.02	Police Identification and Records Officers	50.96	49.04%	759	n/a	n/a
49-3021.00	Automotive Body and Related Repairers	50.99	49.01%	760	91.00%	145
13-1041.06	Coroners	48.39	48.96%	761	n/a	n/a
51-7032.00	Patternmakers, Wood	51.04	48.96%	762	91.00%	144
47-2231.00	Solar Photovoltaic Installers	51.07	48.93%	763	n/a	n/a
49-2021.00	Radio, Cellular, and Tower Equipment Installers and Repairers	51.15	48.85%	764	93.00%	121
51-1011.00	First-Line Supervisors of Production and Operating Workers	49.73	48.81%	765	1.60%	630
29-1069.09	Preventive Medicine Physicians	25.76	48.66%	766	n/a	n/a
29-2055.00	Surgical Technologists	51.40	48.60%	767	34.00%	456
49-2095.00	Electrical and Electronics Repairers, Powerhouse, Substation, and Relay	51.44	48.56%	768	38.00%	442
49-9098.00	Helpers--Installation, Maintenance, and Repair Workers	51.53	48.47%	769	79.00%	269
51-9121.00	Coating, Painting, and Spraying Machine Setters, Operators, and Tenders	51.56	48.44%	770	91.00%	152
19-2041.00	Environmental Scientists and Specialists, Including Health	43.72	48.43%	771	3.30%	590
27-4031.00	Camera Operators, Television, Video, and Motion Picture	51.64	48.36%	772	60.00%	371
11-3051.06	Hydroelectric Production Managers	51.68	48.32%	773	n/a	n/a
45-4022.00	Logging Equipment Operators	51.72	48.28%	774	79.00%	266
27-2022.00	Coaches and Scouts	49.91	48.19%	775	1.30%	645
51-9195.04	Glass Blowers, Molders, Benders, and Finishers	51.82	48.18%	776	n/a	n/a
33-9093.00	Transportation Security Screeners	51.83	48.17%	777	n/a	n/a
47-2181.00	Roofers	52.00	48.00%	778	90.00%	168
51-8013.00	Power Plant Operators	52.10	47.90%	779	85.00%	217
29-1069.02	Dermatologists	44.55	47.89%	780	n/a	n/a
37-2021.00	Pest Control Workers	52.13	47.87%	781	66.00%	339
51-8031.00	Water and Wastewater Treatment Plant and System Operators	52.19	47.81%	782	61.00%	364
25-1072.00	Nursing Instructors and Teachers, Postsecondary	39.04	47.80%	783	n/a	n/a
19-1021.00	Biochemists and Biophysicists	36.79	47.77%	784	2.70%	604
19-3039.01	Neuropsychologists and Clinical Neuropsychologists	27.01	47.76%	785	0.43%	686
47-2021.00	Brickmasons and Blockmasons	52.32	47.68%	786	82.00%	248
53-6051.01	Aviation Inspectors	52.33	47.67%	787	90.00%	165
51-4121.06	Welders, Cutters, and Welder Fitters	52.33	47.67%	788	94.00%	105
17-2199.06	Microsystems Engineers	45.17	47.51%	789	n/a	n/a
49-9011.00	Mechanical Door Repairers	52.59	47.41%	790	91.00%	156
45-4011.00	Forest and Conservation Workers	52.61	47.39%	791	87.00%	201
17-3029.04	Electronics Engineering Technologists	52.62	47.38%	792	n/a	n/a
33-3021.05	Immigration and Customs Inspectors	52.83	47.17%	793	n/a	n/a
29-1141.04	Clinical Nurse Specialists	52.84	47.16%	794	n/a	n/a
29-1069.05	Nuclear Medicine Physicians	39.01	47.15%	795	n/a	n/a
49-9071.00	Maintenance and Repair Workers, General	52.89	47.11%	796	64.00%	351
47-5042.00	Mine Cutting and Channeling Machine Operators	52.89	47.11%	797	59.00%	376
45-1011.08	First-Line Supervisors of Animal Husbandry and Animal Care Workers	52.90	47.10%	798	n/a	n/a
49-2096.00	Electronic Equipment Installers and Repairers, Motor Vehicles	52.91	47.09%	799	61.00%	369
19-4091.00	Environmental Science and Protection Technicians, Including Health	52.98	47.02%	800	77.00%	284
19-1013.00	Soil and Plant Scientists	45.10	46.80%	801	2.10%	617
17-2199.09	Nanosystems Engineers	42.19	46.74%	802	n/a	n/a
29-1069.06	Ophthalmologists	44.06	46.68%	803	n/a	n/a
19-2043.00	Hydrologists	45.86	46.56%	804	1.40%	643
29-1124.00	Radiation Therapists	53.53	46.47%	805	34.00%	455
47-5021.00	Earth Drillers, Except Oil and Gas	53.71	46.29%	806	85.00%	215
29-1131.00	Veterinarians	50.88	46.25%	807	3.80%	581
47-2211.00	Sheet Metal Workers	53.78	46.22%	808	82.00%	250
13-1199.01	Energy Auditors	53.88	46.12%	809	23.00%	487
51-2091.00	Fiberglass Laminators and Fabricators	53.92	46.08%	810	93.00%	128
51-6093.00	Upholsterers	54.11	45.89%	811	39.00%	436
33-2021.01	Fire Inspectors	54.20	45.80%	812	48.00%	414
17-3027.01	Automotive Engineering Technicians	54.28	45.72%	813	n/a	n/a
51-4191.00	Heat Treating Equipment Setters, Operators, and Tenders, Metal and Plastic	54.29	45.71%	814	91.00%	147
51-4051.00	Metal-Refining Furnace Operators and Tenders	54.31	45.69%	815	92.00%	142

53-4021.00	Railroad Brake, Signal, and Switch Operators	54.39	45.61%	816	83.00%	245
17-1022.01	Geodetic Surveyors	52.30	45.35%	817	n/a	n/a
51-8091.00	Chemical Plant and System Operators	54.66	45.34%	818	85.00%	216
53-7072.00	Pump Operators, Except Wellhead Pumpers	54.68	45.32%	819	90.00%	161
17-3031.01	Surveying Technicians	54.69	45.31%	820	96.00%	68
51-9012.00	Separating, Filtering, Clarifying, Precipitating, and Still Machine Setters, Operators, and Tenders	54.78	45.22%	821	88.00%	186
19-4041.02	Geological Sample Test Technicians	54.80	45.20%	822	n/a	n/a
13-1041.04	Government Property Inspectors and Investigators	54.89	45.11%	823	n/a	n/a
49-3092.00	Recreational Vehicle Service Technicians	54.97	45.03%	824	59.00%	374
29-1064.00	Obstetricians and Gynecologists	48.19	44.98%	825	n/a	n/a
19-2031.00	Chemists	48.76	44.94%	826	10.00%	530
51-7011.00	Cabinetmakers and Bench Carpenters	55.11	44.89%	827	92.00%	137
47-4051.00	Highway Maintenance Workers	55.12	44.88%	828	87.00%	192
53-3011.00	Ambulance Drivers and Attendants, Except Emergency Medical Technicians	55.17	44.83%	829	25.00%	476
51-2011.00	Aircraft Structure, Surfaces, Rigging, and Systems Assemblers	55.30	44.70%	830	79.00%	267
33-3021.03	Criminal Investigators and Special Agents	55.43	44.57%	831	n/a	n/a
29-1069.08	Physical Medicine and Rehabilitation Physicians	48.12	44.49%	832	n/a	n/a
47-2152.02	Plumbers	55.59	44.41%	833	n/a	n/a
27-1027.00	Set and Exhibit Designers	53.59	44.34%	834	0.55%	676
29-1069.03	Hospitalists	44.82	44.17%	835	n/a	n/a
17-3024.00	Electro-Mechanical Technicians	55.83	44.17%	836	81.00%	259
17-2199.08	Robotics Engineers	49.63	44.13%	837	n/a	n/a
17-3025.00	Environmental Engineering Technicians	55.90	44.10%	838	25.00%	478
51-9011.00	Chemical Equipment Operators and Tenders	55.91	44.09%	839	76.00%	287
51-8092.00	Gas Plant Operators	55.91	44.09%	840	78.00%	274
29-1071.01	Anesthesiologist Assistants	55.93	44.07%	841	n/a	n/a
17-2199.01	Biochemical Engineers	48.99	43.96%	842	1.40%	640
47-4071.00	Septic Tank Servicers and Sewer Pipe Cleaners	56.10	43.90%	843	83.00%	235
19-1020.01	Biologists	45.79	43.83%	844	n/a	n/a
49-3023.02	Automotive Specialty Technicians	56.22	43.78%	845	n/a	n/a
47-2011.00	Boilermakers	56.22	43.78%	846	68.00%	326
17-3029.12	Nanotechnology Engineering Technicians	56.36	43.64%	847	n/a	n/a
51-4023.00	Rolling Machine Setters, Operators, and Tenders, Metal and Plastic	56.53	43.47%	848	83.00%	232
33-1011.00	First-Line Supervisors of Correctional Officers	56.71	43.29%	849	2.50%	607
51-9021.00	Crushing, Grinding, and Polishing Machine Setters, Operators, and Tenders	56.79	43.21%	850	97.00%	51
29-1069.10	Radiologists	48.99	43.18%	851	n/a	n/a
19-1023.00	Zoologists and Wildlife Biologists	51.34	43.13%	852	30.00%	463
53-7021.00	Crane and Tower Operators	56.88	43.12%	853	90.00%	167
11-9013.02	Farm and Ranch Managers	56.93	43.07%	854	n/a	n/a
47-4041.00	Hazardous Materials Removal Workers	57.08	42.92%	855	53.00%	396
17-3027.00	Mechanical Engineering Technicians	57.19	42.81%	856	38.00%	440
51-8099.03	Biomass Plant Technicians	57.31	42.69%	857	n/a	n/a
47-2031.01	Construction Carpenters	57.34	42.66%	858	72.00%	305
53-4041.00	Subway and Streetcar Operators	57.43	42.57%	859	86.00%	209
49-3031.00	Bus and Truck Mechanics and Diesel Engine Specialists	57.52	42.48%	860	73.00%	299
27-2032.00	Choreographers	52.84	42.45%	861	0.40%	690
47-1011.03	Solar Energy Installation Managers	57.61	42.39%	862	n/a	n/a
49-9021.02	Refrigeration Mechanics and Installers	57.61	42.39%	863	n/a	n/a
53-4031.00	Railroad Conductors and Yardmasters	57.74	42.26%	864	83.00%	244
53-4012.00	Locomotive Firers	57.74	42.26%	865	93.00%	124
17-3029.07	Mechanical Engineering Technologists	57.85	42.15%	866	n/a	n/a
19-1029.02	Molecular and Cellular Biologists	43.12	42.00%	867	n/a	n/a
47-2152.01	Pipe Fitters and Steamfitters	58.04	41.96%	868	35.00%	454
17-3029.06	Manufacturing Engineering Technologists	54.90	41.88%	869	n/a	n/a
29-1151.00	Nurse Anesthetists	53.13	41.86%	870	n/a	n/a
27-2021.00	Athletes and Sports Competitors	58.17	41.83%	871	28.00%	469
47-5012.00	Rotary Drill Operators, Oil and Gas	58.26	41.74%	872	53.00%	397
49-9051.00	Electrical Power-Line Installers and Repairers	58.28	41.72%	873	9.70%	537

51-4041.00	Machinists	58.33	41.67%	874	65.00%	345
17-2111.01	Industrial Safety and Health Engineers	52.32	41.51%	875	2.80%	600
29-1069.07	Pathologists	38.82	41.47%	876	n/a	n/a
29-1171.00	Nurse Practitioners	53.52	41.44%	877	n/a	n/a
45-1011.07	First-Line Supervisors of Agricultural Crop and Horticultural Workers	58.57	41.43%	878	n/a	n/a
29-1063.00	Internists, General	37.85	41.42%	879	n/a	n/a
47-4061.00	Rail-Track Laying and Maintenance Equipment Operators	58.60	41.40%	880	89.00%	175
19-4051.01	Nuclear Equipment Operation Technicians	58.81	41.19%	881	85.00%	214
53-4013.00	Rail Yard Engineers, Dinkey Operators, and Hostlers	58.88	41.12%	882	91.00%	150
53-7121.00	Tank Car, Truck, and Ship Loaders	59.20	40.80%	883	72.00%	307
47-4099.02	Solar Thermal Installers and Technicians	59.24	40.76%	884	71.00%	313
45-4021.00	Fallers	59.29	40.71%	885	76.00%	285
49-2092.00	Electric Motor, Power Tool, and Related Repairers	59.29	40.71%	886	76.00%	286
19-1031.01	Soil and Water Conservationists	55.69	40.70%	887	1.60%	628
37-3013.00	Tree Trimmers and Pruners	59.31	40.69%	888	77.00%	282
47-2031.02	Rough Carpenters	59.32	40.68%	889	n/a	n/a
45-1011.06	First-Line Supervisors of Aquacultural Workers	59.41	40.59%	890	n/a	n/a
27-2031.00	Dancers	54.90	40.58%	891	13.00%	524
19-1032.00	Foresters	57.94	40.57%	892	0.81%	660
53-3032.00	Heavy and Tractor-Trailer Truck Drivers	59.52	40.48%	893	79.00%	272
19-3091.02	Archeologists	53.51	40.39%	894	n/a	n/a
17-3029.01	Non-Destructive Testing Specialists	59.70	40.30%	895	24.00%	482
53-1011.00	Aircraft Cargo Handling Supervisors	59.70	40.30%	896	6.60%	554
47-5081.00	Helpers--Extraction Workers	59.83	40.17%	897	37.00%	445
19-4093.00	Forest and Conservation Technicians	59.96	40.04%	898	42.00%	425
13-1041.01	Environmental Compliance Inspectors	53.30	39.85%	899	8.00%	544
49-3043.00	Rail Car Repairers	60.24	39.76%	900	88.00%	182
29-1061.00	Anesthesiologists	54.92	39.74%	901	n/a	n/a
47-5013.00	Service Unit Operators, Oil, Gas, and Mining	60.45	39.55%	902	93.00%	127
49-9021.01	Heating and Air Conditioning Mechanics and Installers	60.54	39.46%	903	65.00%	341
49-9097.00	Signal and Track Switch Repairers	60.68	39.32%	904	90.00%	160
19-1022.00	Microbiologists	52.05	39.26%	905	1.20%	647
17-2199.04	Manufacturing Engineers	57.47	39.11%	906	n/a	n/a
33-3012.00	Correctional Officers and Jailers	61.01	38.99%	907	60.00%	372
33-3021.01	Police Detectives	61.06	38.94%	908	34.00%	457
47-5041.00	Continuous Mining Machine Operators	61.28	38.72%	909	54.00%	394
53-5021.02	Mates- Ship, Boat, and Barge	61.38	38.62%	910	n/a	n/a
29-1141.03	Critical Care Nurses	59.59	38.54%	911	n/a	n/a
49-9099.01	Geothermal Technicians	61.73	38.27%	912	50.00%	403
29-2099.07	Surgical Assistants	62.04	37.96%	913	n/a	n/a
33-3031.00	Fish and Game Wardens	62.04	37.96%	914	8.00%	543
29-1069.12	Urologists	55.12	37.92%	915	n/a	n/a
19-2012.00	Physicists	37.00	37.81%	916	10.00%	528
17-1022.00	Surveyors	62.24	37.76%	917	38.00%	441
49-9081.00	Wind Turbine Service Technicians	62.25	37.75%	918	n/a	n/a
19-4092.00	Forensic Science Technicians	60.54	37.67%	919	0.95%	654
49-3041.00	Farm Equipment Mechanics and Service Technicians	62.62	37.38%	920	75.00%	289
29-1141.00	Registered Nurses	58.58	37.32%	921	0.90%	657
49-2022.00	Telecommunications Equipment Installers and Repairers, Except Line Installers	62.69	37.31%	922	36.00%	449
45-3011.00	Fishers and Related Fishing Workers	62.71	37.29%	923	83.00%	247
53-5031.00	Ship Engineers	62.81	37.19%	924	4.10%	574
49-1011.00	First-Line Supervisors of Mechanics, Installers, and Repairers	62.00	37.16%	925	0.30%	701
47-5061.00	Roof Bolters, Mining	62.99	37.01%	926	49.00%	407
51-8099.04	Hydroelectric Plant Technicians	63.87	36.13%	927	n/a	n/a
49-9041.00	Industrial Machinery Mechanics	63.88	36.12%	928	67.00%	329
33-2021.02	Fire Investigators	63.92	36.08%	929	n/a	n/a
53-4011.00	Locomotive Engineers	64.43	35.57%	930	96.00%	65
29-1069.11	Sports Medicine Physicians	56.66	35.51%	931	n/a	n/a
51-8099.01	Biofuels Processing Technicians	64.52	35.48%	932	86.00%	212

33-3051.03	Sheriffs and Deputy Sheriffs	64.76	35.24%	933	n/a	n/a
51-8093.00	Petroleum Pump System Operators, Refinery Operators, and Gaugers	64.97	35.03%	934	71.00%	314
33-3052.00	Transit and Railroad Police	65.17	34.83%	935	57.00%	381
49-2094.00	Electrical and Electronics Repairers, Commercial and Industrial Equipment	65.31	34.69%	936	41.00%	426
53-5022.00	Motorboat Operators	65.41	34.59%	937	62.00%	360
17-2121.01	Marine Engineers	62.80	34.53%	938	1.00%	652
53-7032.00	Excavating and Loading Machine and Dragline Operators	65.82	34.18%	939	94.00%	101
51-4011.00	Computer-Controlled Machine Tool Operators, Metal and Plastic	65.92	34.08%	940	86.00%	205
47-2111.00	Electricians	65.94	34.06%	941	15.00%	511
47-5031.00	Explosives Workers, Ordnance Handling Experts, and Blasters	66.14	33.86%	942	48.00%	411
17-3024.01	Robotics Technicians	66.17	33.83%	943	n/a	n/a
45-1011.05	First-Line Supervisors of Logging Workers	67.02	32.98%	944	57.00%	385
33-1012.00	First-Line Supervisors of Police and Detectives	67.56	32.44%	945	0.44%	685
47-5011.00	Derrick Operators, Oil and Gas	68.62	31.38%	946	80.00%	263
49-3023.01	Automotive Master Mechanics	68.93	31.07%	947	59.00%	373
49-3011.00	Aircraft Mechanics and Service Technicians	69.17	30.83%	948	71.00%	316
49-9092.00	Commercial Divers	69.37	30.63%	949	18.00%	501
29-1022.00	Oral and Maxillofacial Surgeons	65.92	30.33%	950	0.36%	694
53-5011.00	Sailors and Marine Oilers	70.31	29.69%	951	83.00%	242
47-2221.00	Structural Iron and Steel Workers	71.00	29.00%	952	83.00%	246
49-9044.00	Millwrights	71.22	28.78%	953	59.00%	378
29-1021.00	Dentists, General	67.83	28.73%	954	0.44%	684
33-1021.02	Forest Fire Fighting and Prevention Supervisors	72.08	27.92%	955	n/a	n/a
49-3042.00	Mobile Heavy Equipment Mechanics, Except Engines	72.63	27.37%	956	40.00%	431
53-5021.01	Ship and Boat Captains	73.79	26.21%	957	27.00%	473
29-2041.00	Emergency Medical Technicians and Paramedics	75.03	24.97%	958	4.90%	564
33-3051.01	Police Patrol Officers	75.17	24.83%	959	9.80%	536
49-9095.00	Manufactured Building and Mobile Home Installers	75.87	24.13%	960	18.00%	500
53-5021.03	Pilots, Ship	76.93	23.07%	961	n/a	n/a
53-2012.00	Commercial Pilots	77.16	22.84%	962	55.00%	389
29-1067.00	Surgeons	74.66	17.90%	963	n/a	n/a
33-2011.01	Municipal Firefighters	83.48	16.52%	964	17.00%	506
33-1021.01	Municipal Fire Fighting and Prevention Supervisors	84.36	15.30%	965	0.36%	693
33-2011.02	Forest Firefighters	84.70	15.30%	966	n/a	n/a
53-2011.00	Airline Pilots, Copilots, and Flight Engineers	91.85	7.63%	967	18.00%	499