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Creativity, Insight, and Learning

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LUIZ HENRIQUE SANTANA CONCEIÇÃO

Creativity, Insight, and Learning

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> “Quando eu vim do sertão, seu moço, Do meu Bodocó/ A malota era um saco e o cadeado era um nó/ Só trazia a coragem e a cara, viajando num pau-de-arara/ Eu penei, mas aqui cheguei!” (“Pau-de-arara”, Luiz Gonzaga)

> "Rien ne se perd, rien ne se crée, tout se transforme".
>
> Antoine-Laurent de Lavoisier, *Traité élémentaire de chimie*, 1789.

RESUMO

Conceição, L. H. S. (2021). *Insight and Acquired Stimulus Equivalence*. Tese de Doutorado não publicada. Programa de Pós-Graduação em Psicologia Experimental, Instituto de Psicologia, Universidade de São Paulo, São Paulo.

A aprendizagem é um fenômeno predito pelos princípios associativos pavlovianos. A resolução de problemas é produto desta aprendizagem tanto pelos processos de tentativa e erro, quanto de aprendizagem súbita e/ou emergente. Contudo, ainda há indefinição e falta de clareza nas bases associativas da resolução súbita (insight). Nesta tese, descrevemos uma tese previamente vista de soslaio pela literatura especializada a respeito do papel do processo de generalização mediada como mediador da emergência do fenômeno de insight em um modelo animal com roedores. Para tal, além da descrição teórica, foram realizados três experimentos que visaram testar propriedades distintivas do insight e posteriores a resolução de problemas em si (experimento 01), bem como as condições contextuais moduladoras da emergência do insight (experimentos 02 e 03). Os resultados demonstraram que o controle de estímulos previsto pela hipótese não foi totalmente contemplado no teste empírico. Ainda assim, sugere-se continuidade desta pesquisa na forma de um programa de testes das relações de controle de estímulos que são consequência da formulação aqui sustentada.

Palavras-Chave: insight, generalização mediada, equivalência de estímulos, resolução de problemas, criatividade.

ABSTRACT

Conceição, L. H. S. (2021). *Insight and Acquired Stimulus Equivalence*. Doctoral Thesis. Graduate Program in Experimental Psychology, Institute of Psychology, University of São Paulo, São Paulo.

Learning is a phenomenon predicted by Pavlovian associative principles. Problem solving is a product of this learning process both through trial and error and sudden and/or emergent learning. However, there is still uncertainty and lack of clarity in the associative bases of sudden solution (insight). In this thesis, we describe a thesis previously seen from the sidelines in the specialized literature regarding the role of the mediated generalization process as a mediator of the emergence of the phenomenon of insight in an animal model with rodents. To this end, in addition to the theoretical description, three experiments were carried out that aimed to test distinctive properties of insight and subsequent problem solving itself (experiment 01), as well as the modulating contextual conditions of the emergence of insight (experiments 02 and 03). The results showed that the stimulus control predicted by the hypothesis did not fully withstand the empirical test. Even so, it is suggested to continue this research in the form of a program of direct tests of the stimulus control relationships that are a consequence of the formulation supported here.

Keywords: insight, mediated generalization, stimulus equivalence, problem solving, creativity.

Table List

List of Figures

List of Tables

SUMMARY

CHAPTER 01

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1. Introduction

In certain ways, creativity, novelty and new behavior were topics discussed from the very beginning of Experimental Psychology. However, it was in the middle of 20th century that creativity became an object of scientific interest and were evaluated from an empirical standpoint by experimental psychologist (Byrne and Murray 2005; Dietrich 2018; Gilhooly 2016; Guilford 1950; Maier 1940). In the last five decades the studies from Experimental Psychology demonstrated that creativity was constrained to the organism experience and environmental contingencies, contrary to the view that preached it as innate and a free feature of human spirit (Birch 1945; Kounios and Beeman 2009, 2014; Vartanian 2009).

Innovative performances and ideas were proved to be dependent of changes in perception, attention, and learning (Birch 1945; Kounios and Beeman 2009, 2014; Vartanian 2009). The perceptual and learning basis of creativity are circumscribed to some environmental circumstances and are not exclusive human (Birch 1945; Keane 1989; Byrne and Murray 2005; Gilhooly 2016; Köhler 1917/1952; Kounios and Beeman 2009; 2014; Vartanian 2009). However, the experimental and theoretical development of the field is not unified. One line of research had invested on innovation and behavioral flexibility as defining characteristics of novel behavior in animals. The other line of research has focused on how creative behaviors emerge from learning processes.

We will argue here that that a complete view of creativity can only be gained when both lines of research are joined. We will also argue that the insightful problem-solving paradigm provides a suitable methodological framework for achieving this goal. Finally, we defend that there is a crucial dimension of creative behavior that are dependent from innovation and behavior flexibility. And this dimension can be investigated by insightful problem-solving.

2. New Behavior, Behavior Innovation and Behavioral Flexibility

Creative processes in non-human animals has been investigated in many ways, but in behavioural ecology and ethology it is specially explored as two phenomena, Behavioral innovation (BI) and Behavioral flexibility (BF). The first one deals with innovation defined as the capacity to generate novel behavior under the control of specific environmental circumstances (Griffin 2016; Griffin and Guez 2014; Huebner and Fichtel 2015; Kaufman and Kaufman 2015; Lefebvre 2013; Ramsey et al. 2007). Innovation itself is a phenomenon defined by the novelty of an action in a problem situation (Griffin 2016). For instance, if a rat in a conditioning box presses the lever that activate the mechanism of a water dipper for the first time – at random or as a result of the shaping procedure – this pressure is innovative because it is new and related to the contingencies inside the chamber (Griffin 2016; Griffin and Guez 2014; Huebner and Fichtel 2015; Kaufman and Kaufman, 2015; Lefebvre 2013; Ramsey et al. 2007).

First, one must define what novelty or new behavior is. Behavior repertoire refers to what an animal does and what it can potentially do as small variations of known stimulus-stimulus or stimulus-response relations (Catania, Ono & Souza, 2000; Kubina, Morrison & Lee, 2006). For a behavior to be considered new it has to fulfill at least one of two requirements: (1) It has to be a consequence of the formation of a new S-S relation;

and/or (2) It must show a new S-R relation. For instance, when a rat freeze on the presence of a sound after this sound was paired with an electric shock, this novel reaction to the sound expresses a new S-S relation (i.e., the sound acquired its eliciting function from being paired with the electric shock). If a lever is put inside the conditioning chamber and lever pressing can stop further electric shocks, the rat starts to press the lever more and more often whenever the electric shock occurs (i.e., a new S-R relation is learned where the shock serves as cue for lever pressing). If the rat always pressed the lever with its pawns until some point, but then suddenly starts to press it with its snout, can one consider it new behavior?

It is surely a new form (i.e., a new behavior topography of behavior) of a previous learned behavior. However, this new form is ultimately part of the same class of responses (i.e., lever press) under the discriminative control of the same stimulus (i.e., the lever). If the animal starts to jump upon an elevated platform to escape the electric shock instead of pressing the lever, not just the response is different – since it does not suppress the electric shock – but it also occurs under the presence of a new stimulus (i.e., the elevated platform). It is important to notice that this definition of novelty accounts for novelty within an individual lifetime. In this essay we focused on this individual instead of social processes to discuss the psychological basis of sudden novelty derived from individual development and learning.

Behavior Innovation is not a universal category. Innovation is a broad term that can describe novel behavior among an individual lifetime, a group or species history. Behavior innovation can be defined from changes in foraging, nesting, mating, migrating behavior or problem solving. And due to that, it is a term that does not rely on a single behavioral process. In one way, cats escaping from a puzzle box (Thorndike 1898) or an ape fabricating a tool (Köhler 1952), one can state that both behaviors are innovative.

However, these behaviors can be explained by different behavioral processes, trial and error and insight for instance (Thorpe, 1956).

Innovation is observed in several animal species, in captivity and in their natural environment, and it is influenced by ecological, developmental, idiosyncratic and social aspects of the animal's life (Griffin 2016; Quinn et al. 2016; Ramsey et al. 2007; Reader, Morand-Ferron and Flynn, 2016). Researchers usually study innovation by It is frequently accessed by tasks whose solution can usually be obtained by trial and error, and the focus of the analysis is on who innovates, who does not innovate, and what external variables explain these performance differences (Brubaker et al. 2017; Quinn et al. 2016; Reader, Morand-Ferron, and Flynn, 2016; Zandberg et al. 2017).

Trial-and-error solutions produce innovative responses in heuristic ways (i.e., based on their outcome) which can be explained by associative learning processes (Griffin et al. 2013; Griffin and Guez 2014; Huebner and Fichtel 2015; Lefebvre, Ducatez, & Audet, 2015; Ramsey et al. 2007). In other words, approaching animal cognition just from heuristic problem-solving narrows our understanding of the determinants of innovation by avoiding addressing the behavior processes that underlie problem-solving. For instance, the study of innovation could address the processes of variability that favors the occurrence of new behavior (Griffin 2016; Griffin and Guez 2014; Ramsey et al. 2007). Trial and Error procedures used with animals do not specify the task properties that facilitates the solution of a problem (Brady and Floresco, 2015; Lind et al., 2017). And both types of solutions still lack on explaining how the animal's attention shifts throughout the solution and how the configuration and nature of the interfere on an animal perception and formulation of a solution (i.e., the behavioral processes underlying behavior variability and novelty)

Trial and error procedures used with animals do not specify the task properties that facilitates the solution of a problem (Brady and Floresco 2015; Lind et al. 2017). Insightful problem-solving does not focus on the emergent processes necessary to produce new behavior that fits the solution in problem situations (Lu et al. 2017; Öllinger and Müller 2017). And both types of solutions still lack on explaining how the animal attention shifts throughout the solution and how the mechanics of a problem interfere on an animal perception and formulation of a solution (i.e., the behavioral processes underlying behavior variability and novelty).

On the other hand, the next phenomenon of BF, refers to an organism's potential to vary its behavior and to adjust it to changes in its environment (Audet and Lefebvre 2017; Barrett et al. 2018; Logan et al. 2014). BF studies usually invest in the observation of migratory species, whether by seasonal migration or migration resulting from the destruction of their habitats (Barrett et al. 2018; Felden et al. 2018; Rymer et al. 2013; Wong and Candolin 2015). Its measures frequently account flexibility differences in foraging habits; exploring new water sources; changing in mating or in offspring's nurture; and in tool use (Lefebvre 2013; Quinn et al. 2016; Ramsey et al. 2007).

Ecological studies on BF indicate that, at some extent, flexibility depends on processes of discrimination and generalization of stimuli as it depends on the capacity of the organism to react appropriately in the presence of a novel stimulus (Lu et al. 2017; Ruprecht et al. 2014). However, there are no consensus on which kind of relation between classes of stimuli are necessary and sufficient to define a pattern of behavior as flexible and/or innovative (Audet and Lefebvre 2017; Lea et al. 2020). From the presentation of problem-solving situations, researchers sought to observe whether the innovative performance of animals solving a problem could predict the animal's BF and vice versa (Griffin et al. 2013; Logan 2016a; Wright et al. 2010). The results of these observations revealed an apparent opposition between innovative performance and flexibility, that is, innovative animals were not very flexible, while those with greater BF were less innovative (Griffin et al. 2013; Logan 2016a; Wright et al. 2010).

However, those studies used asymmetric measures to compare the emergence of new behavior. While innovation has been directly measured by performance in a behavioral task (i.e., a problem situation), flexibility is usually assessed as characteristic of the organism as a whole, an idiosyncratic property defined by adaptation to a new habitat and occupation of a new niche (Audet and Lefebvre 2017; Quinn et al. 2016; Wright et al. 2010). Thus, BF ceases to be a descriptive measure of performance to become a qualifying measure of an internal characteristic of an organism do in a certain task (Audet and Lefebvre 2017; Logan 2016a).

In short, BF and Innovation are not correlated by definition, but there is no systematic evidence of their independence (Audet and Lefebvre 2017; Logan 2016a, b; Logan et al. 2014). It also does not explain the contextual and learning relations that modulates either the innovative or the flexible performances (e.g., interconnection, discrimination, generalization; see Griffin et al. 2013; Logan 2016a>; Lu et al. 2017; Ruprecht et al. 2014). In order to achieve this, it is necessary to define BF measures independently from those of innovation. The operational definition of these variables and their test would allow a functional and quantitative approach to animal creativity in terms of its behavioral characteristics and its determinants. However, for this it is necessary to define BF balancing its ecological validity and its operationalization (Audet and Lefebvre 2017; Logan 2016a).

An integrative approach should build an ecologically relevant and an operational measure of innovation and BF, as well as identify the stimulus control relations that take place in the production of both processes (Audet and Lefebvre 2017; Logan 2016a;

Neves-Filho et al. 2014). This type of measure cannot be constructed by the exclusive use of trial-and-error tasks, but significant elements of the innovation and flexibility studies can be improved if investigated from a Insightful problem-solving point of view.

3. Creativity, Problem-Solving and Insight

During its ontogeny, an organism acts on its physical and social environment developing its own history and idiosyncrasies (Bazer and Mizumori, 2017; Brady and Floresco 2015; Holekamp and Benson-Amram 2017; Sterelny 2016). Environmental conditions and adaptive processes shape the behavior to define patterns of action and habits. Habits are behaviors that are defined by their regularity, frequency, and predictability (Wood and Rünger 2016). However, these predictable behaviors begin with the occurrence of a novel and innovative response at some point. And it is the regularity and predictability of the circumstances that produce the innovation that may shed light on the behavioral basis of animal creativity.

All behaviors are controlled by functional relationships that affect the frequency and the context in which specific behaviors occur (Lattal 1995; Timberlake 2003). Contingencies describe predictable relationships between events, whether between stimuli (S-S) or between stimuli and responses (S-R) (Lattal 1995; Skinner 1938). These contingencies can describe known and regular relationships that produce the reoccurrence and maintenance of responses for enough time and/or in specific contexts (Lattal 1995; Skinner 1938, 1969; Timberlake 2003). This recurrence happens in predictable ways called Reinforcement Schedules, whose frequency and temporal distribution are formally describable (Ferster and Skinner 1997; Morgan 2010). However, before becoming familiar, every contingency presents itself as a problem situation (Davidson and Sternberg 2003; Newell and Simon, 1972), that is, a situation in which the behavior that gives access to a stimulus was never before performed by the organism (Skinner 1984).

In this way, we define problem or problem situation as a type of contingency that requires innovation to give access to stimulus or reinforcing situation (Skinner 1984; Boden 2004; Dostál 2015). Although the use of the term problem and problem situation is polysemic (Davidson and Sternberg 2003), its definition as a kind of behavioral contingency allows the identification of the functional relationships involved in any experimental task designed for the study of problem-solving and, by default, aids the investigation of the behavioral processes underlying creativity and emergence of novel behavior.

The Gestalt Psychologist Wolfgang Köhler (Köhler 1925/1952) was one of the pioneers in relate animal creativity to problem solving tasks. He investigated a group of chimpanzees exposed to different experimental problems. In one situation, a bunch of bananas was hanged on the ceiling out of reach of the apes. One ape, called "Sultan", stacked a set of boxes and thus managed to get the bananas by climbing these boxes. Köhler (1925/1952) called this kind of performance "einsicht", that was later translated as "insight" in the English edition of Köhler's book (Köhler 1925/1952).

To Köhler (1925/1952) insight was a kind of intelligent behavior that happens when a perceptual reorganization of the environment led to the solution of a problem, without new learning. Under this framework, the solution of the problem was considered a new behavior that emerges from the understanding of the relation between environment and objects properties (Fleck 2008; Keane 1989; Köhler 1925/1952). After Köhler (1925/1952) the term insight has been used to label different psychological processes Birch 1945; Köhler 1959; Shettleworth 2012; Tolman and Honzik, 1930) and its scope and conceptual importance varied over time.

Further in 20th century, Birch (1945) and later in the 1980s, Epstein and colleagues (Epstein et al. 1984) tested whether insight was dependent from previous learning. Epstein and colleagues tested whether four pigeons would solve the problem of box displacement after been trained in two different operant tasks (Epstein et al. 1984). One task was to push a box toward a green cardboard located in different positions in a chamber wall. The other was to climb the same box attached in the floor and peck a banana-toy hanging from the ceiling (analogous to Köhler's original bunch of bananas). Both behaviors were reinforced with grains delivered by an automatic dispenser. After those trainings, the pigeons were confronted to a new problem or test: the box was far away from the banana-toy and the green cardboard was not present. All pigeons solved the test by pushing the box toward the banana-toy, jumped on the box, pecked the banana-toy, and activated the grain dispenser (Epstein et al. 1984).

Epstein et al. (1984) also conducted variations of the trainings using different pigeons. Two pigeons learned to push the box to the green cardboard but not to climb and peck, two others learned to climb and peck but not to push towards the green cardboard, and two more pigeons learned to climb and peck and push directionless. None of these pigeons solve the problem when tested (i.e. pushed the box toward the banana-toy). In following publications, Epstein (1985; 1987; 1991; 2014; 2015) defined insight as the spontaneous and automatic interconnection or chaining of previously learned behavior.

Epstein and colleagues (Epstein 1985, 1987; Epstein et al. 1984; Epstein and Medalie 1983) have highlighted two features of insightful problem-solving. The first was the requirement to train the instrumental prerequisites behaviors in order to produce the new behavior. And a second feature called a "confusion period" that anticipates the sudden and fluid nature of insight. This "intuition" property was not directly defined or measured in Epstein's model. The latter feature is a topographic criterion pointed by Epstein to classify the solution as insight (Epstein et al. 1984; Epstein 1985, 1987). If a topographic criterion – such as the confusion period – is necessary in an insightful solution, it would be generally observed among different experiments. However, they were not replicated in other experiments of insight using similar procedures with non-human (Dicezare and Garcia-Mijares 2019; Neves-Filho et al. 2015, 2016; Neves-Filho 2010; Santos 2017) or in humans (Fleck and Weisberg 2013).

Another challenge to Epstein's proposal deals with the measurement of insight. If one animal solves the problem shortly after being introduced into the chamber and a second animal solves the same problem hours later, can we say that the two animals solved the problem through an insight? (Lind et al. 2017; Sio and Ormerod 2009). Some may argue that if the animal does not solve the task quickly and smoothly, the solution could be explained through the variability generated by behavioral extinction, and therefore we must not treat the solution as insight (Dicezare and Garcia-Mijares 2019; Neves-Filho et al. 2015, 2016a, b; Santos 2017). Nevertheless, even if extinction affects the behavioral variability, the behavioral origin of insight lies on the learning history previous to insight (Dicezare and Garcia-Mijares 2019; Neves-Filho et al. 2015, 2016a, b).

Ignoring the processes that took part in learning the prerequisite behaviors could lead to misinterpretation and incorrect analysis of insight. For example, Köhler's chimpanzee (Köhler 1925/1952) and Epstein's pigeons (Epstein et al. 1984) seem to behave similarly when faced with the same problem. If we just look at the test situation, we can describe the problem solving-behavior of the pigeons and the chimpanzee as an automatic chain of behavior composed by the following behavioral events: hanged bananas/toy (discriminative stimulus 1 –S1), boxes/box available in the environment (S2), stack/push the box (response 1 -R1), boxes/box under the banana (S3 or maybe S1S2), climb the boxes/box (R2) and pick banana /peck toy (R2). So, when one look into the problem situation solely, it could be mistakenly considered that Köhler (1925/1952) and Epstein et al. (1984) results are equivalent. However, when training history is considered, it is not possible to know whether stimulus functions were equivalent between both experiments due to Köhler’s lack of report on the previous learning histories of his chimps.

Adding training history to the analyses of Epstein et al. (1984) experiment give us a big picture of the contingencies operating during the problem-solving situation. The task “climb and peck the banana-toy” can be considered as an automatic chain of behavior that begins with the presence of the box (i.e. stimulus 01; S1) under the banana (S2). In the presence of both stimuli in this specific configuration climbing the box (i.e. response 01; R1) is followed by the proximity of the banana-toy (S2); pecking S2 (R2) results in food (i.e. the reinforcer). On the other hand, pushing the box towards the green cardboard (R3) begins with the presence of the box (S1) located far away from the green cardboard (S3). Thus, this task involves moving one stimulus toward another stimulus. So far, the analysis of the behavioral training conducted by Epstein and colleagues (Epstein et al. 1984) shows that: (a) the training of the two chains involves complex stimulus controls, since the responses are controlled by specific configurations of at least two stimuli of the environment; and (b) there are elements common to both tasks: S1 and the reinforcer.

The test described by Epstein et al. (1984) put the pigeons in a new setting: stimuli S1 and S2 of the climb and peck task are presented, but in a spatial arrangement similar to S1 and S3 in the pushing task (i.e., one is far from the other). In this new arrangement, the solution to the problem is to reduce the distance between S1 and S2; so, the behavior of pushing S1 must be under control of the distance between S1 and S2. When this distance is shortened enough to produce the configuration "box under the banana"S1S2, the problem can be considered as "solved" (Skinner, 1969) when the sequence of behaviors that follows the "solution" were learned during training (i.e., climbing the box and pecking the banana), according to Skinner's definition (1969) of a problem situation. Thus, the problem-solving observe in Epstein et al. (1984) indicate that the relationship between S1 and S3, learned in the training phase, was transferred to S2 without specific training. In other words, the performance of the pigeons in the test showed the emergence of a new relationship between S1 and S2, different from what was learned during training, but due to the relationship learned between S1 and S3. This kind of analysis was not possible to do from Köhler (1925/1952) experiment data and, due to that, is possible to compare the performance of Sultan with Epstein's pigeons, as Sultan's learning history was unknown or uncontrolled.

Epstein and colleagues (Epstein et al. 1984) experiment also showed that, even insight depends on operant conditioning. It is not a simple operant behavior though, as its occurrence could not be directly attributed to shaping or to stimulus generalization. Even so, it was demonstrated that insight can be induced by reinforcement learning (Kizilirmak et al. 2016), by the expectancy of a reward (Cristofori et al. 2018), by non-verbal cues (Neves-Filho et al. 2015; Santos 2017) and may even facilitate insight's occurrence (Hattori, Sloman & Orita, 201819; Schunn and Dunbar 1996) in a way that one can conclude that learning facilitates insight processes of stimulus discrimination and generalization must be somewhat relevant to insightful solutions.

At least in humans, insight is not considered a single cognitive process and it has been separated between the aha moment – an inner experience that were classically related to a breakthrough (Kounious and Beeman 2014) – and the sudden change in a behavioral performance (Sandkühler and Bhattacharya 2008). Since the former does not seem feasible for experimental measurement, the latter has been used for measure insight in animal research, where it is frequently defined as the sudden emergence of new behavior and new relationships between what the organism does and its environment. (Thorpe, 1956; Shettleworth 2012).

Finally, insightful problem-solving seems to be spread over a wide range of taxonomic classes and it has been observed in humans (Fleck and Weisberg 2013), pigeons (Cook & Fowler, 2014; Epstein et al. 1984; 1985), ravens (Heinrich 1995), crows (Taylor et al. 2010), parrots (Pepperberg 2015), elephants (Foerder et al. 2011), Grackles (Logan 2016a, b, c; Preiszner et al. 2016), capuchin monkeys (Delage 2011; Neves-Filho, Barros, Costa & Carvalho-Neto, 2016; Renner et al. 2017), mouses (Arnold & Newland, 2018), and rats (Dicezare and Garcia-Mijares 2019; Neves-Filho et al. 2015, 2016a, b). Then, any definition of insight should account this convergence.

So far, the empirical data on insight showed that it is a behavior that depends on learning, involve complex learning processes, that can be studied under experimental settings, and it is shown by a wide range of species. However, as pointed out by Shettleworth (2012), the experimental investigation of animal creativity is a scientific enterprise that depends on an operational definition that would be necessarily different from human investigations – at least at first – as it depends more on a behavioral measure and a focus on how contextual determinants would affect the occurrence of creativity and novel behavior. We think that research on innovation and behavior flexibility should be integrated to the insightful problem-solving paradigms in order to define and understand creativity performances in an ecological and evolutionary perspective.

4. Animal Creativity as Derived from BI and BF

Creativity is the cognitive function that allows an organism to adapt to new circumstances in appropriate and useful ways (Beghetto 2013; Beghetto & Kaufman, 2014; Guilford 1950; 1967; Glăveanu 2013). Task-appropriateness and novelty are the two elements that have been accepted among different theories of human creativity, as the Four-C's (Helfand et al. 2017; Kaufman and Beghetto 2013), Four P's (Rhodes, 1969) and Five A's (Glăveanu 2013), and the Investment Model of Creativity (Sternberg & Lubart, 1996), and the Componential Model of Creativity (Amabile, 1996). Even when the tasks used to measure creativity are different for humans than for animals, and for individuals than for groups (Beghetto 2007a, b; Dietrich 2018; Glaveanu 2011; Guilford 1950; Helfand et al. 2017). Problem-based models have been used as tools to measure task-appropriateness and novelty (Newell and Simon, 1972; Byrne and Murray 2005) and recent experiments in behavior innovation BI and BF had invested in such models to evaluate environmental determinants of new adaptative behavior (Quinn et al. 2016; Ruprecht et al. 2014; Sterelny 2016). Creativity can be observed in its novelty by two distinctive measures of BI behavior innovation and Bebehavior flexibility in its task-appropriateness by a conjunction of both.

BI occurs when an organism behaves, moves or acts in new ways to an environmental feature or in a specific scenario and this manner produce new effects, spatial configurations or any kind of real or virtual effects. As it depends on actions, BI shows that creativity is partially dependent from biological constrains, reinforcement history and attentional shifts (Audet and Lefebvre 2017; Barrett et al. 2018; Brubaker et al. 2017; Hattori et al. 2013; Lefebvre 2013). Therefore, in a specific organism, novelty is a function of its species phylogeny and its own individual ontogeny.

In parallel, behavior flexibility is the capacity to behave in an efficient manner when presented to a new set of environmental contingencies somewhat related to previous and familiar ones. BF experiments have shown that, at some extent, new behaviors can emerge from entirely new circumstances, apparently without specific shaping procedures, i.e. in a sudden and goal-directed manner (Dicezare and Garcia-Mijares 2019; Santos 2017). It means that flexibility is – at least partially – driven by contextual determinants and then maintained by reinforcement contingencies (Birch 1945; Brady and Floresco 2015; Strickland 1989). When analyzing both processes, Behavior Innovation explains how new responses emerge within a class of responses, while Behavior Flexibility explains how new stimuli can become part of a class of responses. Animal creativity can be defined as the behavior function that underlie novel behaviors within specific problem situations.

In this manner, animal creativity would be defined as novel and task-appropriate behavior. Its task appropriateness is driven by reinforcement schedule, and its novelty depends on the emergency of at least one new stimulus-stimulus relation or a production of a new discriminative class of stimuli (Skinner 1969, 1984). Trial-and-error strategies are heuristics solutions (Danek, Fraps & Müller, 2013; Davidson and Sternberg 2003; Newell & Simon, 1972; Öllinger, Jones & Koblich, 2008). Therefore, novel behavior is here produced by heuristic explorations such as through operant conditioning (e.g., through differential reinforcement and shaping).

The real challenge is about insightful problem-solving, as it depends on sudden and perceptual changes. Insight cannot be explained by shaping or other heuristic processes. Although it may be based on previous learning (Epstein et al. 1984; Neves-Filho et al. 2015; Santos 2017) and contextual variables, insightful problem-solving depend on creative processes as it depends on sudden changes of response topography (Behavioral Innovation) and new features of stimulus control (Behavior Flexibility). Insight is not in the problem, it is in the solution instead (Webb, Little & Cropper, 2016). The properties of the solution can be defined as insightful or not. Therefore, insight is an operational way to measure emergent patterns of novel and task-appropriate behavior.

On one hand, novel behavior in insight emerges directly from problem situations and cannot be explained through successive approximation of more and more specific responses. On the other hand, this does not mean that insight cannot be explained through associative processes and contextual relations (Maier 1940; Mednick 1962). The emergence of insight depends on the contextual control derived from contingencies of reinforcement present during previous training (Delage 2010; Epstein, Kirshnit, Rubin & Lanza, 1984; Epstein 1991; Neves-Filho et al. 2015, 2016a, b). This mean that insight can be defined as a joint feature of innovation and behavior flexibility.

In the Köhler's and Epstein's problem, described above (Köhler 1917/1952; Epstein, Kirshnit, Rubin and Lanza, 1984), the novel behavior is a behavioral chain of two responses where the first response of the chain depends on a novel discriminative stimulus, i.e. a new spatial distance between the displaceable box and a target. What defines insight in this scenario would be not just the occurrence of a BI, but also the flexible use of the displaceable box.

A cumulative corpus of evidence demonstrated that eye fixation in relevant stimuli differ for different types of solutions (Ellis et al. 2011; Knoblich et al. 2001; Kounios and Beeman 2009, 2014; Vartanian 2009). While heuristic solvers tend to have and increasingly higher levels of eye fixation of long durations, insightful solvers have an early drop of eye fixation after a couple of trials and shows lower levels of long duration's fixation and higher levels of short duration eye fixation (Ellis et al. 2011; Knoblich et al. 2001; Kounios and Beeman 2009, 2014; Vartanian 2009). These differences support the visual perception and attention peculiarities of insight and how differences in discriminative control may be enrolled in the genesis of insight, as formal properties of stimulus, transferences on stimuli function and the reinforcement value of a reward might affect the preferences or susceptibility for an organism to solve some problems in a creative way (Neves-Filho et al. 2015, 2016a, b).

There is data that support the role of developmental variables upon the occurrence of insight for individuals exposed to problem situations. However, a theoretical framework that may explain the behavioral role of these variables have to be built as many of them are only reported as correlations between the developmental variables and creative performance (Schooler et al. 1993; Zing et al., 2018). Still, there are studies showing that creativity is related to educational skills, engagement and motivation to solve a task (Kaufman and Beghetto 2009; Beghetto & Kaufman 2014; Canestrari et al. 2018; Kaufman, Beghetto & Watson, 2015), to social and cultural aspects are partially involved in group situations (Glaevenu 2011; Lee et al. 2012; Leung and Chiu 2010; Leung et al. 2008), and biological development and mental health (Kozbelt & Burmysheva, 2007; Lassig 2013; Buitenweg et al. 2017).

5. Final Thoughts

Creativity is a phenomenon that is hardly exclusive of humans. Adaptation is a natural feature among virtually all animal kingdom, especially when we consider animal behavior. Learning and memory are also behavioral functions that can assure active innovation among behavioral repertoire of individual organisms within a certain population. However, a creative trait represents an extension of this mentioned repertoire in a way that an animal may act in new ways, establishing new ecological relations considering that new actions (or behavioral responses) must happen in new circumstances, but to pursue a familiar goal and to reach familiar rewards or consequences.

Insight does not have to assume personality traits or personal characteristics (Hennessey and Ambelie 2010) as it can offer an empirical basis with multiple tasks to test whether any kind of innovation and behavioral flexibility is durable, stable and how an individual history can affect its idiosyncrasies when innovating. Therefore, it offers a pathway to explore innovation in a comparative and thus evolutionary way as it does not depend on such constructs such as abstract cognitive modules or computational networks that recurrently leads to dead alleys and theoretical fragmentation (Barsalou 2008; Hennessey and Ambelie 2010).

Finally, it is important to state that animal creativity in individual level is a particular feature of general animal creativity. Social animals can manifest behavioral innovation in individual level, by social learning and cultural transmission (Bandini and Harrison 2020; Koops 2020; Wild et al. 2020). Although it may occur in a different level (i.e., social level) it may also rely on more basic processes of individual (e.g. trial and error and insight) and social learning (e.g. modeling and imitation).

CHAPTER 02

Title: Reversal Learning as a feature of Insight

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1. Introduction

Insight is defined as the sudden solution of a problem (Statt, 1998; Matsumoto, 2009). It comprises the ability to discriminate relevant features of the environment and an abrupt decrease in the time to reach the solution to a problem (Hartman, 1931; Pechestein & Brown, 1939). Insight was once described as a different way to install an instrumental behavior (Delage & Carvalho-Neto, 2010). However, what makes insight a different instrumental/operant behavior is not clear.

The behavioral changes defined as insight learning do not come out of nothing. They are created from the *transference* of previous learning into new settings (Koffka, 1935; Köhler, 1938) or behavioral contingencies (Epstein, 1991; 2015). This transference was described in different ways. However – in broad terms – all the definitions rely on the generation of novel responses (i.e., behavior innovation) and flexible contextual control (i.e., behavior flexibility; Santana & Garcia-Mijares, 2021). Insight, as a feature of creativity, would be generated by the interconnection of previous learning into novel of behaviors (Epstein, 1991; 2015). If insight is but a product of interconnection, all its features should be explained by the contingencies of previous learning. A hypothesis that is still open to empirical test and proof.

Insight was defined as differences in learning curves. Reward or Reinforcement learning produces gradual changes in both increments in frequencies and subtractions of latency. Insight learning curves produces sudden changes in the form of abrupt increments in frequencies and decreases in latency. Insight is a behavioral phenomenon originally defined by these behavioral or performance distinctiveness. However, many other features were added to its observation and definitions throughout the years (Epstein, 2015; Osuna-Mascaró & Auersperg, 2021). The idea of fluidness as a feature associated to insight is not new but has been recently took into the focus of many efforts of investigating insight under the lens of the contingencies of reinforcement underlying it (Neves-Filho et al., 2015; Dicezare & Garcia-Mijares, 2019; Knaus, 2021).

Insight is not in the problem (Webb et al., 2016) and very few tasks became well accepted over the years as sources of insight-like solutions specially when focusing on insight in non-human animals (Shettleworth, 2012). Köhler Insight tasks (Köhler, 1917/1952; also described in Chapter 01) was the most influential tasks to approach insight phenomenon in non-human animals. Its influence is deep rooted in the science and teaching of psychological science despite almost all replications of said work had proved that Köhler's Insight is a product of instrumental learning (Windholtz, 1984). Recent findings demonstrated that what insight (an effective, fluid and directed way to solve a problem) can be produced by the combination of behavioral links into new chains of behavior. What evoke one set of behavior chain, or another remains unclear.

Part of this variation is a function of individual features such as mood behavior (Knaus, 2021), but a great part of it seems to depend on the arrangements of pre-testing training. The sequences of training (Neves-Filho et al., 2016, the proportionality of behavioral links trained (Neves-Filho et al., 2019), the spatial cues used during the training (Dicezare & Garcia-Mijares, 2019), the relation between behavior topography and mechanical costs of the response (Santos, 2017) are some of the variables reported as critical to produce insight or at least what one could call insight-like solutions.

Despite recent advances in the field, the investigation of insight in non-humans generally lack a control condition for non-insight solutions. This control for non-insight solutions was important to differentiate special features in the basic behavioral measures (i.e., differences in eye movement) and neural basis of insight in humans (Kounious & Beeman, 2014). Part of this lack can be explained due to the difficulty on characterizing what make an insight-like solution "insightful" enough.

When insight was demonstrated to rely on instrumental learning, the inner "novelty" attributed to insight learning faced the challenge to identify what is new and what is not in insight learning, and - of course - how this novelty is produced from familiar patterns of behavior. The behavioral processes underlying this feature is still unclear, although it was suggested that some kind of behavioral generalization may play a part when animals are acting toward certain and novel environments, objects or tools as they were trained to react to other previously trained stimuli (Koffka, 1935; Spence, 1937; Lazareva, 2012; Shettleworth, 2012).

A group of researchers recently reported a novel task to investigate Epstein's insight in non-human animals (Neves-Filho et al., 2015; 2016; Knaus, 2021). In their task, an acrylic chamber with two sides are separated by a barrier. The only way to crosse from one side to the other is by digging a tunnel using a passage covered by wood-chip bedding, usually used to cover captive rodents in their home-cages. The animals were proved to rely on instrumental training to solve this task. After being exposed to a training to dig the surface, and to climb a ladder that give access to a food reinforcer, animals were tested on a condition where they were expected to solve a problem by interconnecting the previous learned behavior into a sequence of digging-and-climbing to reach a food reward on the other side of the testing chamber. The findings about this experimental paradigm to investigate insight demonstrated an important contribution on producing insight in controlled behavioral experiments and on how to treat the measures of insight beyond the almost anecdotal description of Köhler's and Epstein's descriptions (Köhler, 1917/1952; Epstein et al., 1984).

This advances on the description and measurements of insight in non-human animals are important and they add to the theoretical mainframe that explains the behavioral nature of insight as a unique and distinctive way for an organism to behave (Webb et al., 2016; Osuna-Mascaró & Auersperg, 2021). However, there is a gap on the experimental paradigms that investigate insight that comprises the “pre-” and “post-” features of insight learning (Santana &Garcia-Mijares, 2021). The “Pre-insight” features comprise the learning determiners of insight, specifically, what can impair or hinder the emergence of insight solutions when one does not show insight-like solution despite been exposed to relevant instrumental training (Neves-Filho et al., 2020; Osuna-Mascaró & Auersperg, 2021). The investigation of this set of variables can offer tools to understand the behavioral processes underlying insight.

The post-insight-learning features comprise the behavioral changes that remain after the occurrence of original insight response (Santana &Garcia-Mijares, 2021). What is altered in one’s behavior after performing insight is difficult to keep track of for the ephemeral nature of insight phenomenon as a sudden change in performance (Statt, 1998; Matsumoto, 2009). The proper control and description of said processes can reveal what one can expect after observing insight-like behaviors and to discriminate what makes a behavior novel and distinctive enough to be called insight (Santana & Garcia-Mijares, 2021).

The relevance of the investigation of both “pre-“ and “post-“ components of insight-like behavior have a common relevance as they have the potential to shed light on on the learning determiners of insight (Osuna-Mascaró & Auersperg, 2021). Identifying which basic processes give rise to insight-like behavior may elucidate whether we need a behavior category under the label “insight” to begin with (Shettleworth, 2012; Osuna-

Mascaró & Auersperg, 2021). Demonstrating the associative learning basis of insight may elucidate that insight does not go beyond a pattern of behavior identified in some learning curves and that that is ultimately a product of pavlovian and instrumental learning that give rise to novel behavior (Osuna-Mascaró & Auersperg, 2021). Still, even in said situation, the *sui generis* configuration of processes underlying insight may be distinctive enough to separate insight from other generative processes of behavior (Shettlewroth, 2012; Epstein, 2015; Osuna-Mascaró & Auersperg, 2021)

In order to offer some novel *insights* on how insight learning can be tested for its distinctiveness, we dedicated this investigation to test the role of reversal learning as a metric to differentiate insight and non-insight behavior. Reversal Learning is broadly a term to describe how a reverse configuration of a pair of associate stimuli can emerge in an organism's repertoire without the necessity of specific training. This type of learning can be investigated in both pavlovian and instrumental learning and has been tested among different tasks, settings, and species (Bebus et al., 2016; Izquierdo et al., 2017). Reversal learning is considered evidence of behavioral flexibility and creativity in non-human animals (Izquierdo et al., 2017).

Reversal learning is observed in quick switches. In reversal learning tests (Costa et al., 2015; Izquierdo et al., 2017), variations on environmental conditions serve as cues that decrease the probability of reinforced actions and increase the chances to innovate with no gradual transition from one pattern of behavior (the reinforcement learning) to the other (the reversal learning). Since reversal learning is evidence for behavior flexibility (Santana & Garcia-Mijares, 2021), to add a reversal learning test into insight tests may offer a tool to track changes in behavior that go beyond the one occasion of insight in one testing session and may, otherwise, show whether one can notice further changes in behavior in after the traditional "insight".

Additionally, reversal learning paradigms may offer new tools to compare insight versus non-insight solutions by the means of contrast with "reinforcement learning" (Costa et al., 2015; Izquierdo, 2017). Among the literature of "reversal learning", "naive" or simply reinforcement learning is defined as behavioral responses that are a direct product of previous reinforcement, i.e., actions that are in form and function novel presentations of previously learning relations (Bebus et al., 2016). Reversal learning can be eased or impaired by training conditions (Jarvers et al., 2016; BEbus et al., 2016). Reward accessing conditions being the primary contingency affecting whether the typical "shifts" of reversal learning occur (Costa et al., 2015; Bebus et al., 2016; Izquierdo, 2017). Test the relation between reversal learning and insight require than a condition that may offer a control for when individuals do not solve by the means of a sudden "shift" as it is both observed in reversal and insight learning. Introduce a condition that increase responses directed toward the reward may impede the occurrence of insight behavior and, therefore, offer a comparison situation and a control group for non-insight solutions.

The ephemeral nature of behavior can make it difficult to identify the processes that determine it. However, it cannot prevent the testing of models and alternatives for the observation and control of behavioral phenomena. Therefore, the purpose of this experiment was twofold. On one hand, to test the effect of a broader form of training (one sessions, one reinforcer, right before the testing) as a disruptor for the observation of insight. This may offer tools to directly compare insight and non-insight solutions after comparable learning histories. The second aim was to evaluate whether this novel training session could reveal changes that go beyond the insight solution during the testing session. To test that, we used a reversal learning test (after the problem-solving test) to check on the behavioral differences between insight and non-insight group.

2. Methods

2.1. Animals

Twelve male Long Evans rats (*Rattus norvegicus*) from 90 to 150 days old and between 300-350g at the beginning of the experiment were used. The animals were kept under controlled conditions for temperature (23ºC±2ºC), humidity, and reversed light-dark cycle (12/12 hours with dark cycle starting at 7 a.m.). The animals were pair-housed with water under *ad libitum* regime. Two hours of food restriction before the behavioral sessions was used to increase animals' foraging and the appetitive value for food within sessions.

2.2. Materials and Equipment

a. Food Reward: Sweetened cereal flakes (Fruit Loops™) were used as rewards within training sessions, hereby referred as "food" or "reward".
b. Video recording and behavior: A video camera (Sea Wit® Webcam with Built-in Microphone A870 USB 2.0 HD 12.0MP) was used to film the behavioral sessions. The Behavioral Observation Research Interactive Software (BORIS® 7.9) was used to analyze the behavioral sessions.
c. Digging Chamber: A parallelepiped chamber (length= 45cm, width=60; height=60cm) was used. It was made of acrylic with two hatches (one on the side wall and the other on the bottom) filled with pine wood bedding, see Figure 1B. A piece of food was placed inside a vessel (a plastic bottle cap) and covered by the wood bedding under different depths.
d. Climbing chamber: Climbing training was undertaken in an adapted form of the home cage that included and an elevated platform made of wood and a metal ladder (height = 25cm; width = 8cm) that gives access to the platform, see Figure 1A.

e. Testing Chamber: An open field chamber was modified to support the test requirements. The chamber was divided between two sides of equal size (width=70, depth=35, height=80cm each side) by a glass barrier. The chamber floor was covered with pine wood bedding (depth=20cm) on both sides. An elevated platform (width=30cm, depth=15cm, height=20cm) and a metal ladder (the same model as the one used for the climbing training) were placed together on one side of the chamber during testing sessions (see Figure 1C).

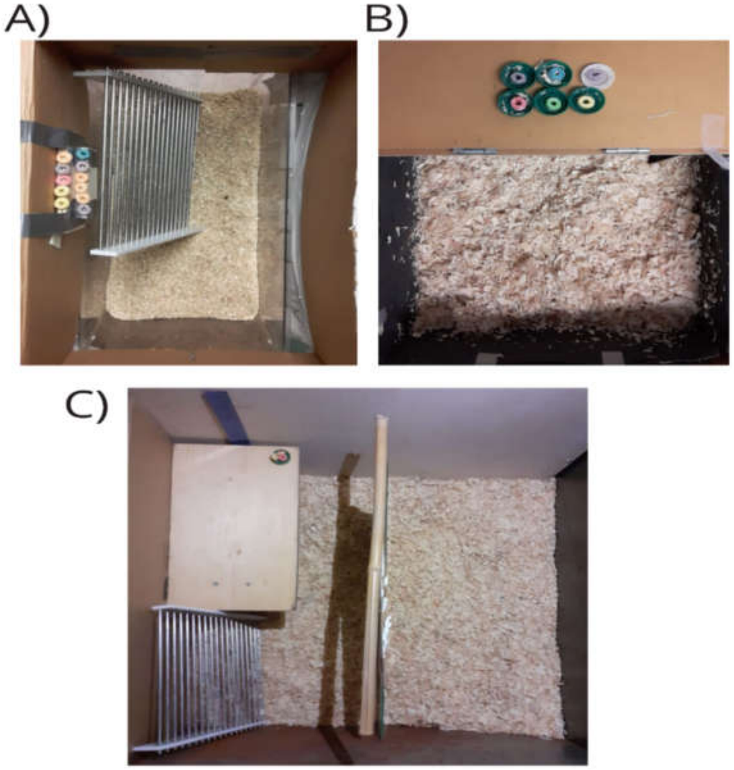


Figure 01. Experimental Apparatus. A) climbing chamber. B) digging chamber. C) testing chamber.

2.3. Experimental Design

At first, all animals were exposed to the same sequence of behavioral training and testing: a) Pre-testing; b) Behavioral training (for Climbing and Digging); d) direct test; and e) Reversal test. After that, animals were sorted to be in one of the two experimental groups (Non-Insight and Insight). The only difference between groups was that the non-

Insight group underwent a one session of *rewarded crossing without digging* right before the direct test. The sorting process was performed by attributing a number to each animal and by using a 'sorting()' function on Python 3.3 for a numeric list of items.

Table 01. Experimental Design for Experiment 01.

	Handling	Pre-Test	Digging Training	Climbing Training	*Rewarded crossing* (without digging)	Direct Test	Reversal Test
Insight	X	X	X	X		X	X
Non-Insight	X	X	X	X	X	X	X

Note: The "X" marks that the subjects in that group were exposed to that condition.

2.4. Procedures

All animals were tested on all three tests (pre-test, direct and reversal). All testing procedures were performed in a single session, in a single trial of up to ten minutes.

Pre-test: Each animal was placed on one side of the testing chamber opposite to the ladder (same as shown in Figure 2A) as a standard control condition for solving or not solving the task without instrumental training. To reach the food, the rat should dig and reach the connection between the two sides of the testing chamber. Digging to the other side would give the rat access to the ladder and so to the platform on which a bottlecap with a piece of food inside was placed.

Behavioral training: All animals received both training on climbing and digging.

Climbing: An instrumental shaping procedure was performed to train the animal on climbing a ladder to reach the food (reward). One piece of food would be placed on a small window-shaped platform (width=10cm; height=8cm) over the ladder at a time. Each trial consisted of a sequence of climbing up, grabbing the food, and climbing down the ladder. There was no inter-trial interval, despite the time for the experimenter to manually refill the platform. Rats could access up to 12 pieces of food per training session. Sessions would end after 15 minutes or after the rat had eaten all 12 pieces of food in a session, whichever came first. The criteria to end the climbing training would be to climb the ladder and eat at least 10 out of 12 pieces of food (>80%) per session and keeping this performance throughout three consecutive sessions.

Digging: A second instrumental shaping procedure was used to train the animal on digging toward the food in a modified skinner chamber (see Figure 1E) filled with wood chip bedding for rodents (depth=25cm). In each trial, four bottle caps were placed underneath the wood bedding under one of five different depths (0cm, 5cm, 10cm, and 15cm). Each bottle cap contained one piece of food. A trial consisted of digging toward every single one of these four bottlecap targets to reach the food. The experimenter would check whether the animals reached all the caps every three minutes refilling the caps every time until reaching the session limit of 12 pieces of food per session. Sessions could also be ended after 15 minutes if the animal did not reach the 12-piece limit. The shaping of digging required two stages of training. In the first, the animal should reach the bottle caps on the deepest depths at least 25% or 3 out of 12 trials (complexity criterion). Secondly, the animal should reach at least 80% of the targets (≥10) per session, during three consecutive sessions (stability criterion).

Rewarded Crossing (Without digging):After being trained on both behaviors, the were sorted between two groups and half of the rats (that would constitute the Non-Insight group, n=6) underwent one session of rewarded crossing without the need to dig to reach the other side of the chamber. This one session consisted of leaving the passage between the two sides open for the animal to cross. The passage was on the side where the ladder was. A bottlecap containing a piece of food was positioned between the two points (the passage and the ladder; ~12cm from the ladder and ~18cm from the barrier dividing both sides). Right after reaching and eating the food the sessions was ended and the animals prepared for the testing session.

Behavioral testing (post-training)

Direct Test: The test contained the same configuration as the one described on the pre-test but performed after all behavioral training was completed (Figure 02A).

Reversal Test: In the reversal test, the rats were placed on the platform inside the testing chamber (Figure 2B). Solving the reversal test consisted of reaching a bottlecap containing a piece of food on the other side of the testing chamber, opposite to the one where the animal was placed. To reach the food, each animal had to climb down the ladder, dig toward the other side of the chamber and reach the bottlecap containing food.

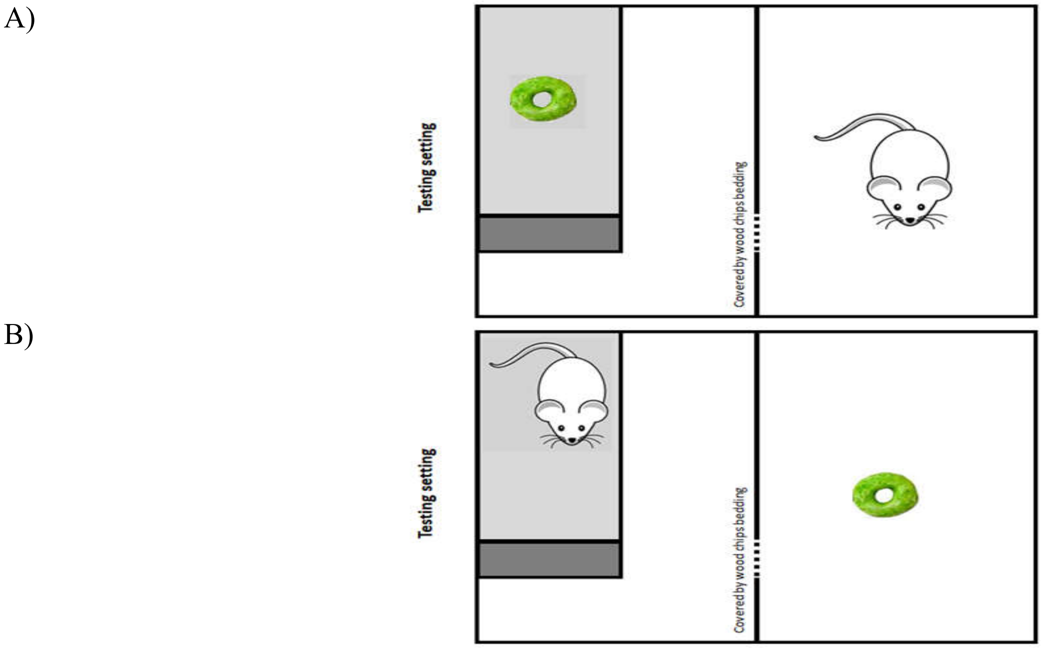


Figure 02: disposition of the chamber at the beginning of the testing sessions. A) Direct Test. B) Reversal test.

2.5. Data Analysis

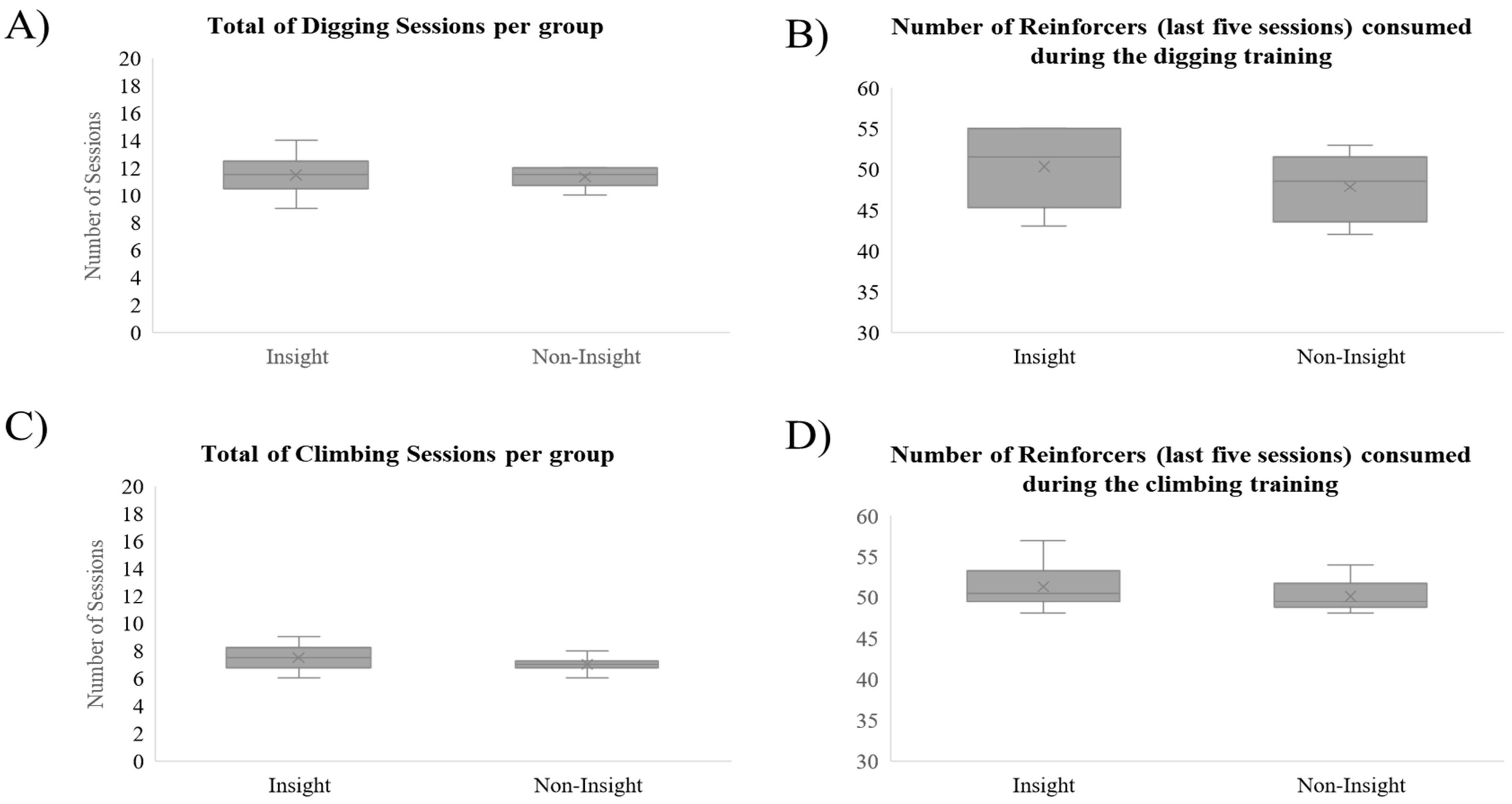
The analysis of training performance compared reinforcers accessed throughout the climbing and digging training between both groups (i.e., Non-Insight and Insight) to standardize the control for the number of reinforcers accessed per group per behavior trained. The performance of both groups (Non-Insight and Insight) was compared in the direct and reversal tests using a segmentation of the testing chamber in quadrants (for a parameter on their exploration), time to solution and relevant behavior such as crossing and/or digging. The groups were also compared in their accomplishments on each tests (whether they did or not solve the test correctly, i.e., whether they reached the food).

3. Results

3.1. Pre-Test and Behavior training

None of the animals solved the problem on the pre-test condition after reaching the time limit (10 minutes). After that, all animals underwent behavioral training for both digging and climbing behavior. Their individual performances are summarized in Table 2 in terms of the total sessions to reach stability and the number of reinforcers consumed in their last five training sessions in each behavior. The T-Test revealed that climbing behavior was faster to reach the stability criteria than the behavior of digging toward a target. The first was taught in less than eight sessions of training (M =7.25, SD = 0.67), while digging took more than eleven sessions (M = 11.41, SD =0.91), t = -9.54252, $p < .001$.

After the allocation of the animals in each group (insight and non-insight), an analysis of variance was performed to test whether there were differences between the experimental groups comprising the number of reinforcers accessed and consumed in their last five session in each behavioral training. The results are summarized in Figure 3. Regarding the number of reinforcers on the last five sessions of the digging training, no significant difference was observed between the insight group (M = 50.33, SD = 4.89) and the non-insight group (M = 47.67, SD = 3.93), f = 1.08, p > .32. When analyzing the sum of the reinforcers consumed in the last five sessions of the climbing training, we observed no difference between both groups (Insight: M = 51.33, SD = 3.08; Non-Insight: M = 50.17, SD = 2.14), f = 0.58, p > .46. Relevant differences in training could affect the testing results in the form of cue and reward control. The inexistence of statistical differences until this point is important to keep control of previous reinforcement learning in both groups.


A) Total of Digging Sessions per group

B) Number of Reinforcers (last five sessions) consumed during the digging training

C) Total of Climbing Sessions per group

D) Number of Reinforcers (last five sessions) consumed during the climbing training

Figure 3. Summary of data for the behavioral training. A) Number of sessions on digging; B) Sum of reinforcers consumed during digging in its last five sessions; C) Number of sessions on climbing; D) Sum of reinforcers consumed during climbing in its last five sessions.

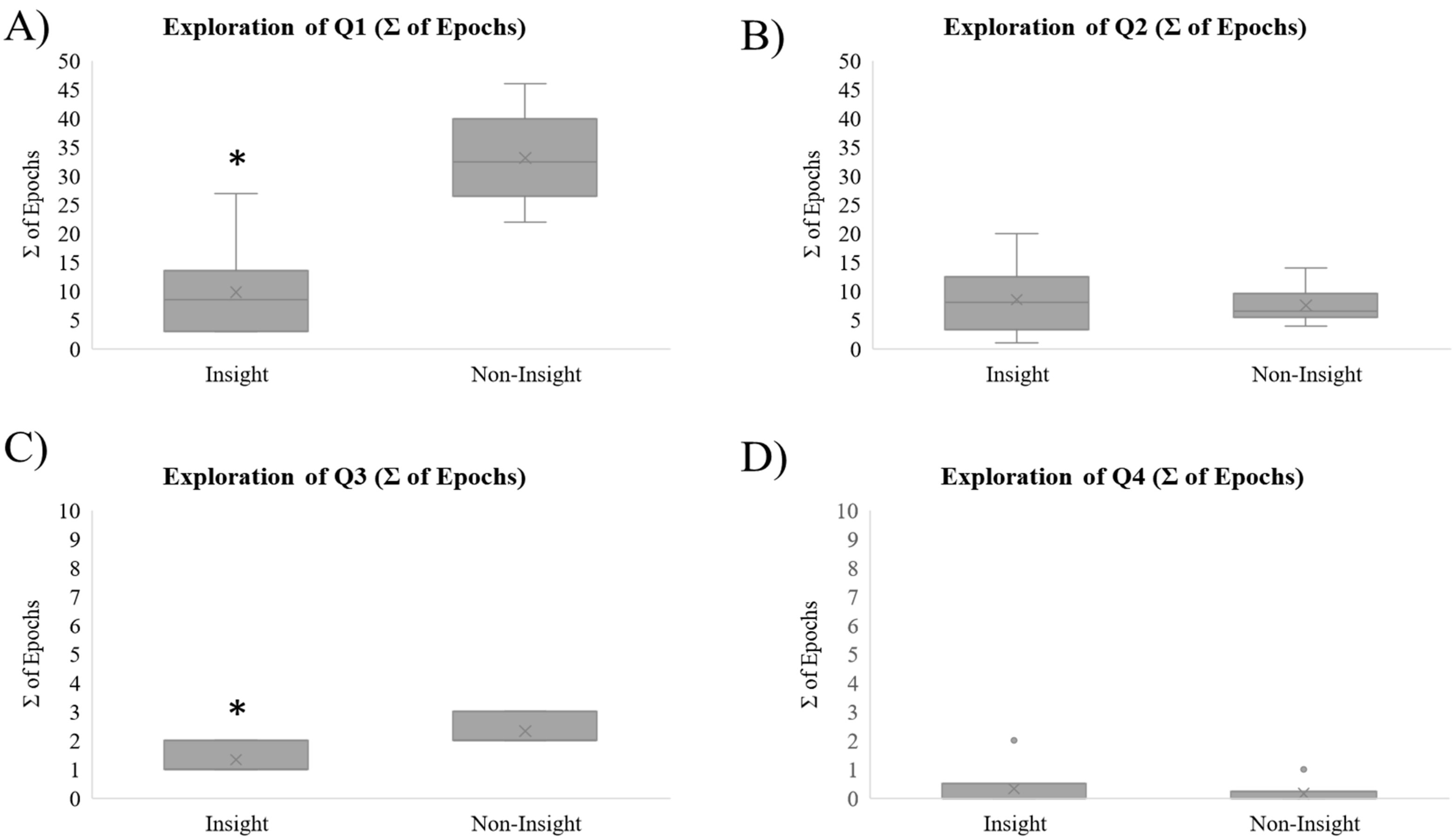


Figure 4. Summary of Data during the direct test. A) Exploration of Q1; B) Exploration of Q2; C) Exploration of Q3; D) Exploration of Q4.

Figure 4. Summary of Data during the direct test. A) Exploration of Q1; B) Exploration of Q2; C) Exploration of Q3; D) Exploration of Q4.

3.2. Insight, Learning and Problem-Solving

The only difference between the procedures to which insight and non-insight groups were exposed was a single short session of one trial where the non-insight group was exposed to a free crossing session where they could reach one piece of food (reward) after crossing without digging. The insight group did not undergo such session and moved directly to the testing session. All animals in the non-insight group reached the other side and consumed the food on the other side.

When under the testing session (the direct test), all twelve animals solved the problem by digging through crossing and climbing the ladder until the reach the food. Animals in insight group (M = 207s, SD = 53.33s) solved the task faster than animals in the non-insight group (M = 431s, SD = 75.02s), f = 26.3588, p < .001.

Animals in non-insight group spent more time in quadrant Q1 (M = 331,67s, SD = 68.13), incompatible with behavioral responses relevant to solutions (i.e., the digging toward a target and climbing behaviors) when compared to animals in insight group (M = 98,33s, SD = 57.22s), f = 21.55 and p < .001. Still, there was no difference between the time spent in both Q2 between insight (M = 85.40s, SD = 48.31s) and non-insight (M = 75.21s, SD = 23.27s), f = 0.10 and p > .74. The Non-insight group spent more time in Q3 (M = 23.11s, SD = 4.44s) than insight group (M = 13.43s, SD = 4.44s), f = 11.25 and p < .01, the quadrant where the ladder was placed. This seems to point toward a more explorative and less directional solution performed by the non-insight group when compared to insight group, as more the latter spent more time in both relevant (Q3) and irrelevant (Q1) quadrants. The non-insight group also performed more of the crossing and digging behavior (M = 3.83, SD = 0.56) when compared to the insight group (M = 2.67, SD = 0.89), t = 2.01 and p = .04. This feature adds to the idea that non-insight group performed a more explorative and less directional/fluid solution of the problem. Solutions performed by non-insight group was also more time demanding. They spent more time before reaching the solution than insight group. The testing session then revealed that the non-insight group were capable of solving the task as much as the insight group. However, non-insight group was slower and more explorative than insight group. The summary of group comparisons can be found in Figure 03. The exposure to the rewarded crossing before testing appear to be effective to produce differences in solution such as changing the exploration of the testing set. But both groups were still able to solve the problem of the direct test..

3.3. Reversal Learning:

The Chi-Square test revealed a significant difference between the solution of the reversal task (Chi-Square = 27.27, $p < 0.0001$; for one degree of freedom). Since the Non-insight group did not solve the reversal task in the present condition (where the reversal task was performed few minutes after the direct test), no direct comparison for "time to solution" could be performed. However, a comparison for the pattern of exploration was performed to track the general time spent on each quadrant of the testing chamber. The Non-Insight group explored more the Q3 (M = 178.30s, SD = 21.41s; f = 127.23 and $p < .001$) and Q4 (M = 411.7s, SD = 21.31; f = 81.09 and $p < .001$) quadrants than did the insight group (Q3: M = 52,63s, SD = 13,33s; Q4: M = 106.72s, SD = 53,34s). Only the insight group demonstrated responses of digging and crossing, a feature significantly different between the two groups on the reversal task. These results also indicate that the type of spatial exploration performed by the non-insight group was less directed to a target and more an exploration of the testing environment.

4. Discussion

4.1. Insight and the Rewarded Crossing as a distinct training

Our results indicate that the insight group were quicker and less explorative when solving the direct test than were the animals in the non-insight group. The control for other variables suggests that the crossing without digging session right before the direct test were capable of changing the way animals solve a problem. The exposition to the reward may affect the way organisms solve problems and, to the purpose of studying insight, seems to offer an alternative way to hinder insight solutions (Neves-Filho et al., 2020). This may help further studies to investigate on what kind of cues may control insight by facilitating or hindering insight-like solutions (Neves-Filho et al., 2020).

The fact that a single and short session may disrupt what has usually been called a "more sudden, fluid and direct" behavior (Epstein et al., 1984; Dicezare & Garcia-Mijares, 2019) may indicate that what has been called insight in non-human animals are a different way to install an operant (Delage & Carvalho-Neto, 2010) that is based in the transference of previous learned control exerted by classes of reinforcers and cues (Koffka, 1935; Shettleworth, 2012). One can argue for that interpretation by taking the fact that the solution, *per se*, of the problem were possible in both groups, what indicates that they both relied on the instrumental learning of digging and climbing to solve the problem.

A vast corpus of evidence have been pointing to that in both early (Koffka, 1935; Köhler, 1938; Thorpe, 1956; Epstein et al., 1984; Epstein, 1985; 1987) and recent findings (Neves-Filho et al., 2015; 2016; 2020) about insight learning. However, the way the solution was evoked may have been affected by the some of the differences on the conditions to which each group was exposed right before the direct test: one group of animals remaining on their home cage, the insight group; and the others being exposed to the rewarded session of crossing without digging.

The effect of said pre-direct test training remains unclear and needs further exploration. Still, for the purposes of supporting the development of a methodology to study insight with a control condition/group for non-insight solutions, our results seem to point toward a path for an inter-subject comparison of insight and non-insight solutions using a single training session as a distinction. Produce strong differences in short amount of time and trials is a quest when dealing with models that investigate insight in non-human animals since the procedures can be long and extremely hard to be replicated between different subjects due to the complexity of the target behaviors and the idiosyncrasies of the shaping procedures (Dicezare & Garcia Mijares, 2019; Santos, 2017). The results also point toward an acquired component of insight that can be tested in humans and non-humans by modifying behavioral experiments instead of using indirect comparisons or analogies such as the genetic traits of mood behavior (Knaus, 2021).

The fact that insight is usually studied using the same traditional variations of classic gestalt tasks (The Two String Problem and The Candle Problem in humans, and the Fishing Tool Manufacture and the Box piling/displacement in non-human animals) is also a challenge that seems important to surpass. If insight describe a behavioral phenomenon that is relevant in the big picture of behavioral sciences, insight need to be a investigated and described in terms of measures and processes that may shed light on what define and produce said phenomenon. Our results present a novel way to compare insight and non-insight solutions, shedding light on what appears to be a set of new variables to be explored: the cue- and reward- control that hinder or evoke insight before and during the test or problem-solving task.

4.2. Reversal Learning

Our results seems to support that instrumental learning play a critical role in the acquisition of units of behavior that are important to solve a problem that requires the combination or interconnection (Epstein, 1991; 2015) of said behaviors, like in Epstein's Insight. But the insightful features of said solution (i.e., the fluidity and directness of insight behavior; Epstein, 1991; 2015) seems to be a product of the pre-testing variables. This is due to the fact that all animals were capable of solving the direct test, despite the specific differences on the how they solved or, in other words, what may have controlled each type of solutions that animals in each group may have performed. Still, there appear to be later differences on the reversal learning that may reveal more about the processes underlying what make each group (insight and non-insight) different from one another.

The fact that the insight group were capable of solving the reversal test and the non-insight group have not may point toward a difference on how the cue-value may have changed for the non-insight group after been exposed to the rewarded crossing without digging. The possibility of crossing to the other side of the testing chamber and the access to the food reward right after that are the conditions that distinguish the instrumental training of insight and non-insight group. We understand that seems reasonable to assume that some parts of the learning that occurred in said session may have changed how animals in the non-insight group came to react when re-exposed to the chamber as presented in the direct and the reversal test setting. The specific processes underlying those differences remain unclear, but an investigation on how this learning may impact the reward and cue control during the direct test may shed light on whether the differences between insight and non-insight group are more or less related to the stimulus control processes operating between familiar parts of the testing setting (e.g., the ladder) or to the specificity of the rewarded crossing.

Epstein’s generative theory of creativity (Epstein, 1991; 2015) – as we understand it – would predict that the generation of insight come from combination of previous learning. Our findings demonstrated that combinations of behavior supported the solution of both insight and non-insight groups. However, differences on the training history may modify the combinations of behavior in such a way that said combinations can become distant from the properties that Epstein (1991; 2015) defined as inherent to insight-like solution (e.g., directionality, fluidness, for instance).

5. Conclusion

Epstein and his colleagues offered an innovative way to understand insight phenomenon by their demonstration of insight in pigeon. It reopened the path to study insight in non-human animals after decades of few investigations dedicated to that. Recent findings added to these preliminary investigations by offering new information on the intra-subject determiners of insight learning and by offering variations on the way to investigate insight in non-humans that does not require tool use in analogy to the original Köhler's findings (Köhler, 1917/1952).

The formulation of Epstein's Generative Theory tried to portrait insight as a specific type of behavior interconnection that supports the emergence of novel behavior, novel contextual control and, ultimately, novel ways for the organism to interact with its environment. Our findings indicate that Epstein's interpretation of insight was incomplete since it failed to predict the impact of how the broadening of instrumental training would affect the solution of a problem by producing effective solutions without insight-like behavior.

Further investigations may take into account how conditions contiguous to the testing may affect insight and how those effects may shed light on the stimulus control contingencies operating upon insight solutions. We hope that these findings may offer new tools to compare insight and non-insight solutions and to offer a new design to investigate the learning processes underlying insight and non-insight by understanding the reversal component of insight learning.

CHAPTER 03

Title: Insight and Mediated Generalization

1. Introduction

The aim of this essay is to present a mediated generalization explanation of how learning operates to produce novel behavior described as insight in animals (Kohler, 1917; Epstein, Kirshnit, Rubin & Lanza, 1984). In Gestalt terms, insight lies on the *transposition* (i.e., the transference or generalization) of previous knowledge to new environmental circumstances (Koffka, 1935). This *transposition* is essentially the use of previous learning in new environmental circumstances, as observed in *generalization*. To support our proposition, we review the evidence on insight in non-human animals from the 1910's to 2010's. Also, integrating these investigations with the development of the literature of Pavlovian processes supporting the emergence of new classes of equivalent stimuli.

In 1897, Ivan P. Pavlov demonstrated that some episodes of saliva secretion could be predicted based on environmental events that were previously associated with a stimulus that triggered a reflex response. In his *Lectures on the Work of Digestive Glands* (Pavlov, 1897), Pavlov used the salivary secretion as a quantitative parameter for the dogs' subjective reaction. After a few sessions of presenting the sound of a metronome before presenting food to a dog, Pavlov observed a systematic increase on the saliva secretion between the time of the sound and the presentation of the food. This increment in salivation persisted even when the sound was not followed by the food. Pavlov that linking up the food (i.e., a reflex-eliciting stimulus called an Unconditioned Stimulus, US) and the sound of a metronome (i.e., an initially neutral event). Making the sound a new condition (i.e., a new S called a Conditioned Stimulus, CS) under which the reflexive response (R) would also occur, even without the original triggering stimulus (Pavlov, 1897; 1927).

Because the sound acquired a new function as a condition promoting the reflex, Pavlov (1927) called the new behavior a Conditioned Reflex (actually, the correct translation from Russian should be "Conditional", but due to the mistranslation to "Conditioned", the latter term remains the most commonly-used one in English). It was the first quantitative demonstration of how systematic changes in behavior could be acquired and, so, how new behaviors could emerge from the interaction between physiology and the environment.

Pavlov's Conditioned Reflexes established a simple way to analyze an organism's behavior in terms of its most simple parts, the relation between a stimulus and its response, the S-R relation (Pavlov, 1927; Windholz, 1992; Boakes, 2003). The dog presented with the sound (CS) salivates (the conditioned response, CR) for the same reason it does when presented to the food (US), as both the food and the sound are stimuli related to eating. Salivation in the presence of the food is a response selected in the animal's phylogeny and adaptative to its homeostasis. Meanwhile, as the sound was systematically associated with the food, and therefore the food increased the amount of saliva secreted, the conditioned reflexes showed how learning mechanisms could evolve due to their beneficial effects on survival and reproduction (Windholz, 1992). Still, many questions remained unanswered on how these S-R relations would explain intelligent behavior.

Edward Lee Thorndike (1898; 1911) introduced a task and a measure to test animal intelligence in Problem-Solving situations. By putting animals in a puzzle-box, he observed what types of strategies they performed when trying to escape the box, and how the solution of the puzzle affected the time and frequencies of the effective and non-effective strategies throughout repeated behavioral sessions. Based on his findings, he argued for a general principle of behavior that he called the *Law of Effect*. The Law of Effect described that the effect of a behavioral response upon its environment, in terms of the appetitive or aversive nature of the outcome, would directly affect its latency and frequency of occurring in the same situation. In other words, pleasurable/appetitive effects lead to increments of frequency, while painful/aversive effects lead to decays of frequencies of behavior (Thorndike, 1927). Thorndike's Law of Effect brings two important features to the explanation of the behavior performed when solving a problem. Behavior is driven by hedonistic principles, that is, one should pursue desirable/pleasurable outcomes and avoid painful/hurtful ones. A second feature, derived from the first to some extent, is that the frequencies of behavior in the behavioral repertoire should fluctuate based on environmental circumstances and, specially, due to the variations of outcomes that a behavior could have. For instance, searching for an egg in an eagle's nest can produce a valuable source of nutrients for a young monkey, but it can also result in an altercation with the mother eagle, possibly resulting in the monkey's death. The hedonic value of *acquiring the eagle's eggs* drive the heuristics of looking for the egg in a trial-and-error basis.

Both Pavlov's and Thorndike's ideas illuminated some basic principles of learning. Classical and instrumental conditioning were both assimilated into many doctrines for learning theory (Kohler, 1925; Tolman, 1932). The Doctrine of Conditioned is a case in point (Tolman, 1937). This doctrine would assert that all learning processes are reducible to S-R relations and explained by the means of recency and frequency (i.e., by the *Law of Exercise*; Thorndike, 1898; 1911). For instance, Pavlov's dogs learned the function of a CS due to its previous association with a US, resulting in the CS being capable of eliciting a CR (i.e., the conditioned response of salivation in response to the sound of a metronome). The processing of these elementary units (i.e., S and R) within the nervous system would be driven by sensory and motor traits in the periphery and associated in the central NS, i.e., the representation of the relation between S and R would depend on higher hierarchical processes (Meyer, 1911; Watson, 1914; Kohler, 1925). The segmentation of psychological reality into elements (e.g., like the definitions of stimulus and response), and whose importance was defined from their repetition was appealing and led to further developments by Watson (1913; 1914), Guthrie (1935), Karl Lashley (1923), and others (see Hunter, 1932; and Lashley, 1923). Yet, it also started a feud that deeply affected the scientific community.

One can summarize this quarrel as twofold. On one hand, there is the Telephone-Switchboard Metaphor (TSM; Meyer, 1911; Tolman, 1948). Let us envisage an old Telephone central, when a telephone operator receives a call from Phone A requesting to reach Phone B, this operator must switch a plug to directly connect A and B. If, in a second call, A requests a call to Phone C, the plug must be moved from B to C in order to reach its correct address. In this metaphor, there is a strict one-to-one correspondence between an address (e.g., Phones A, B, and C) and their representation on the telephone switchboard, in a way that the only way to reach one of the numbers is to directly plug a cable inside a specific key on the board (Meyer, 1911; Tolman, 1948). In the Doctrine of Conditioned Reflexes, psychological associations are reducible to associations between S-R where specific S's are associated with specific R's by phylogeny and ontogeny.

Nevertheless, the use of conditioned reflexes as a conceptual paradigm for learning theory faced an early challenge on the use of S and R as categories of events (Bernstein, 1945/1998; 1967; Hull, 1943; Tolman, 1948). Yet, when one labels a controlled puff of air to the eye as a stimulus, variations in its intensity, latency, and frequency are traceable and measurable in a way that makes a category of stimuli "air puff" definable by its physical similarities (e.g., similar intensities, similar temperatures, etc.). However, when one observes a rat running in a maze without a ceiling, each part of the maze varies in illumination, spatial cues, and – occasionally – even in color, shape, and other local features. This led to the question of *what makes the maze a single stimulus?* In other words, what are the features that allow us to call two sets of conditions a repetition of the same stimulus (Hull, 1943; Tolman, 1937; 1948). The same can be said about the response. In the eyeblink reflex situation, the air puff generates a quick closure of the eyelids (i.e., the unconditioned eyeblink response). However, in Thorndike's puzzle-box, a cat can open the box by pulling a string with its front and rear pawns, or even with its teeth. It can use its full paw, or just a single claw to activate the puzzle-box mechanism, such as by lifting a latch and escaping. *Can all those different motor responses be called the same response R*? (Bernstein, 1945/1998; 1967; Skinner, 1938). In its original forms, stimulus and response are strict definitions that does not accord such use. They are useful as long as they are simply and objectively defined in one or few aspects (e.g., variations of frequency in a source of noise or variations of luminance in a beam of light).

The phenomenon of generalization brought to light a completely new field of investigation on the extension of the S-R relations formed after conditioning. Instead of a strict one-to-one identity, when a CS is paired with a US or when a response is followed by reinforcement, a myriad of S-S associations can emerge without ever having been directly learned. In other words, "every reinforcement mediates connections between a very great number of receptor and effector processes in addition to those involved in the reinforcement process" (Hull, 1943, p.183). Stimulus and response generalization revealed how new connections can be derived from previous learning in a more complex and indirect way than Pavlov’s one-to-one identity theory of learning (Pavlov, 1897; Meyer, 1911; Watson, 1914).

What implications does this hold for the definition of the response? One may think that The Doctrine of Trial-and-Error may offer a better account of this matter. When Thorndike (1898) put one of his cats in a puzzle-box, there were plenty of ways they could behave inside (i.e., they could emit responses R_1, R_2, R_3, …, R_n) at first. If R_3 is *to pull a string* that activates the mechanism that opens the latch, the *Law of Effect* states that escaping the box would produce satisfactory states like safety and freedom of movement, while the other possible responses (R_1, R_2, …, R) would not produce such a drive reduction and would have their frequencies reduced after some sessions on the puzzle box for their inefficiency (see the *Law of Exercise*, Thorndike, 1898; 1911). However, as stated before, what if a cat first pulled the string using its frontal and right pawn, and – in a second session – pulled the same string but now with its teeth. Can the teeth pulling be defined as caused by the drive reduction effect expected by the Law of Effect? Is that even the same behavior we are talking about?

The problem with strict definitions of S and R, such as the one just discussed, as they apply to learning new behaviors were pointed out by critics of the Conditioned Reflex Doctrine (Kohler, 1925; Koffka, 1935; Tolman, 1937; 1948), but what did Thorndike offer to deal with this challenge instead of specific S-R relations? The answer again is twofold. First, "every response or change in response of an animal is then the result of the interaction of its original knowable nature and the environment" (Thorndike, 1911, p. 256). This means that all actions performed by the animal are derived from the scope of actions nature has sculpted it to perform. The second feature is that the change in this original action is caused by the environment as the action can produce different outcomes that operate on animal behavior by the means of the Law of Effect (Thorndike, 1911).

The thing with hedonic drives is that it assumes that all behavior that is subject to non-reflexive control, is sensitive to sudden variations at the hedonic value of certain stimuli. A cat inside the puzzle-box can behave inside the box in different ways, but it would rather be exploring the environment instead of actively seeking to get out of it. By solving the puzzle-box, an association between the cats' action and its consequences is established in a way that, when the cat is put inside the box in the future, the puzzle-box would acquire aversive properties. The aversive box would then stamp-in the actions that allows the animal to escape from it, and stamp-out the actions that keeps the animal inside of it (Thorndike, 1911; Tolman, 1932). This account of how new behavior emerges from the exposure to a problem-solving situation assumes that all stimuli have or acquire hedonic value (appetitive or aversive) correlated to a single response, and that all new behaviors are intentional and, ultimately defined by its intentions or outcomes. .

2. The Insight

Gestalt Psychology was inaugurated in 1912 by the publication of Max Wertheimer's thesis *Experimentelle Studien über das Sehen von Bewegung* (translated to english as *Experimental studies on seeing movement*; Wertheimer, 1912). In this publication Max Wertheimer described the phi phenomenon. The phi phenomenon describes the psychophysical conditions that produce the illusion of movement between two or more visual stimuli. Although the phenomenon was discovered more than a century before Wertheimer's work (Wertheimer, 1912), he understood that this phenomenon was an evidence of how top-down processes can regulate our understanding of our environment by what he called a *Gestalt* perception. *Gestalt* is a German word for a unity of configuration. When applied to psychology, the phi phenomenon reveals that the way we react to the empirical world is by making sense of it by means of Gestalt segments, i.e., a grouped and bounded set of elements that affect behavior as a single unity. Instead of segmentation and reduction of stimuli and responses to tiny, meaningless physical parts, the Gestalt theory of perception is based on complex units composed by many, but meaningful, units. However, these many parts would, in fact, operate as a single field or configuration affecting behavior by its significance in terms of representation of the external world.

An important characteristic of gestalt perception is that it was conceived as a basic process. The idea of representation in analytical-introspectionist psychology was described as a higher process only accessible by consciousness and under the scrutiny of specific training (Wertheimer, 1912). Instead, the phi phenomenon reveals how the attribution of significance to a configuration or Gestalt was defined as a basic fundamental truth (Koffka, 1935). Another characteristic of gestalt perception is that – since it demonstrates the reaction to a set of stimuli as one configuration, Gestalt perception does not assume a physical-to-psychical one-to-one identity theory of reality (Tolman, 1933; Epstein & Hatfield, 1994). Physical-to-psychical identity theory is the assumption that for every sensory event in the empirical world, there is a mental representation of this event, one-to-one. And the assimilation of complex events and processes is required for the processing of every basic component of such event or process. For instance, this assumption argues that for one to understand that an earthquake is shaking a forest observable at the horizon, first it would be necessary to detect every tree on the foreseeable horizon.

The demonstration of phi phenomena showed that no isolated presentation of each stimulus could produce the perception of movement, and that it could only be perceivable when their presentation was made under a specific range of inter-stimulus timings such that the observer automatically perceives the two blinking stimuli as one stimulus in motion. In this scenario, interpreting the two flashing lights as a single moving light is a better interpretation of the event, since it maps onto real world perceptions produced by moving stimuli. This and related Gestalt phenomena reflect our understanding of these situations in terms of organization, symmetry, simplicity, and regularity. The illusion of movement is a feature ascribed to the *Law of Prägnanz* (Koffka, 1935; Köhler, 1967) or Good Figure.

Kurt Koffka and Wolfgang Köhler were subjects of some of Wertheimer's experiments and became important scientific partners and enthusiasts of gestalt principles (Hatfield, 2012). After spending almost seven years at the research station of the Prussian Academy of Sciences on the Island of Santa Cruz de Tenerife, Spanish territory off the coast of Africa, Wolfgang Köhler came back to German European territory and published his *Intelligenzprüfungen an Anthropoiden* (translated to English as *The Mentality of Apes*; Köhler, 1917) describing his observations on intelligence in great apes (e.g., chimps) when solving problems.

When Köhler first noticed one of his Chimps (named Sultan) piling a few boxes to reach a banana suspended out of reach above his enclosure, he called it *Einsicht*, the German word for intelligence, discernment, and knowledge, but was translated to English as "insight". Köhler's insight was defined as a sudden change in awareness of the solution to a problem. Köhler promulgated his findings as evidence against the narrowness of early associative psychology embodied by John Watson's behaviorism (Watson, 1913; 1914; 1924) and Thorndike's Law of Effect. In Kohler's view, insight was caused by shifts in *Gestalten* (the German plural of Gestalt) or the broad perception and representation of an environment. Insight would be an expression of one's comprehension of its environment in a way that it not just behaves, i.e., perceive and act upon its environment, but also comprehend the dynamic of its behavior and knowledge of why it is performing this behavior. This suggestion was made by Koffka ("we do not only act, but we know why we act"; Koffka, 1935, p.382) and Kohler ("Not only the result is experienced, but also very much of its 'why'"; Kohler, 1929, p. 372).

But these new results or acts do not arise from nothing. Instead, they come from the generalization from previous experience, a process very much favored by the Gestaltists. This transpositional feature of gestalt perception and of insight would be derived, according to Koffka (1935), from the fact that a current field (i.e., the gestaltic perception of a present environment) is comprised by broader fields or *Gesltalten*. Koffka (1922; 1925) used the term Gestalt-disposition to describe how tendencies of behavior emerge from gestalt perceptions. Koffka's reflection explained how generalization of perceptual features from one context to another could affect new behavior (Koffka, 1925; 1935). In other words, he tried to explain how perception could change behavior by modulating motivational features of behavior by transference from previous learning. The question that remains is whether gestalt psychology has ever demonstrated the conditions necessary to produce this generalization. The simple answer is no. Transfer of learning in a controlled setting, like those observed in Kohler's insight experiments with non-human primates, and the contingencies which facilitate the emergence of insight were never ultimately described.

During his time spent in research in the Canary Islands, Köhler (1917) performed many experiments with the chimpanzees that were kept in captivity in the research facility of the Prussian Academy of Sciences. Among these experiments, one became notorious for the importance of its findings and its implications to the theory of psychological science. The experiment involved the sudden combination of two sticks as evidence of tool fabrication and problem-solving in Apes (Kohler, 1917; Windholz, 1984; 1985). In his book on *The Mentality of Apes*, Kohler described how a chimp named Sultan combined two hollow sticks of wood into one longer stick, by inserting the narrower stick into the opening of the wider stick, to reach a piece of food that was out of reach of either stick along. The sudden combination of the tools – as described by Kohler (1917) – were explained as a sudden change in Sultan's field or gestalt perception; the insight.

The evidence of insight was latter replicated in total or in parts (Spence, 1938; Pechestein & Brown, 1939; Birch, 1945; Harlow, 1951; Schiller, 1952), but these replications revealed part of the learning constrains to the emergence of this insight solution in one hand, but failed to demonstrate the associative processes that led to the sudden changes of behavior on the other hand.

The impact of insight evidence on psychology and behavioral sciences was huge, due to its implications to learning theory. Tool fabrication is a means- ends phenomenon which demonstrates – to some extent – a comprehension of the dynamic of a certain environmental circumstance (Kohler, 1917; Tolman, 1933; Koffka, 1935). If this comprehension emerges abruptly from one's sudden change in perception. Köhler's put decades of S-R research based on William Ockham's Razor (or the *Principle of Parsimony*) and Morgan's Cannon (Morgan, 1903) in check for its implications for animal research.

In different species, the emergence of novel behaviors based on generalization of learning were described. Yet, such instances of generalization seemed to build off of a history of prior learning (Birch, 1945; Harlow, 1951), rather than resulting from the sudden change in behavior to the correct solution. Instead, behaviors in novel situation ran the spectrum from sudden to gradual emergence, varying from individual to individual (Spence, 1938; 1940).

In its early years, insight was considered a sudden shift in attention due to novel physical or symbolic representations (or *Gestalten*; Köhler, 1938). Epstein and his colleagues demonstrated that insight could be observed in pigeons, and that it involved an automatic chaining of directed behavior dependent on specific learning histories (Epstein, 1985; 1987; 2015; Epstein, Kirshnit, Lanza & Rubin, 1984).

Epstein and his colleagues taught two behaviors to pigeons (Epstein, Kirshnit, Rubin & Lanza, 1984). The firs behavior (Training 1) was to displace a box toward a green spot located on the wall of a conditioning chamber. This was done by reinforcing the pigeon with food every time they moved the box to the spot. The second behavior (Training 2) was to climb a box that was fixed to the ground and peck a plastic toy banana suspended above the box from the ceiling of the chamber. Each time the pigeon climbed on the box and pecked at the toy, it received the same kind of food reinforcement used during Training 1. After both trainings, the animals were exposed to a new environmental configuration, the problem. The new configuration consisted in the same box with the movable box, but instead of been far from the green spot, it was far from the suspended toy. That is, the green spot was absent and replaced by the suspended banana, so the stimulus that controlled pushing the box on Training 1, and its location was changed for the stimulus that controlled climbing in Training 2. All three pigeons spontaneously solved the task by moving the box toward the banana and then climbing the box and pecking at the banana (Epstein, Kirshnit, Lanza & Rubin, 1984). Just as Sultan did in Kölher's experiment (Kohler, 1917).

Epstein, et. al. (1984) conducted some variations of the training just described with different pigeons: (1) two pigeons went through Training 1, but no Training 2; (2) two went through Training 2, but no Training 1; (3) two learned to push the box to the spot (Training 1), and peck the toy, but not to climb the box; (4) two learned to climb the box and peck the toy (Training 2), and to push the box, but not to a specific target (i.e there was not spot or other stimulus to push the box “forward to”). None of the pigeons from those training solve the problem.

To explain his findings, Epstein et al. attributed the insight behavior to two behavioral processes: the functional generalization of the box as an object to reach higher locations, and the summation of responses modulating the directed displacement of the box (Epstein, Kirshnit, Lanza & Rubin, 1984).

Starting with the latter, summation of responses is the phenomenon in which the presence of two or more stimuli paired with the same reinforcer are capable of producing more robust performances (higher in frequency, magnitude and/or with lower latencies) (Wikler, 1973; Aydin & Pearce, 1997). Epstein, Kirshnit, Lanza and Rubin (1984) suggest that this process would play a role in insight by considering that the summation of pecking toward the banana (i.e., the cue) leads to a reduction of expectancy for the pecking the banana (i.e., the reinforcer) by getting progressively closer to the banana .

Neves-Filho and his colleagues adapted one of Köhler's experiments where capuchin monkeys were faced with a problem whose solution required them to link two tools and use the new combined one to reach a reward. The capuchin monkeys were able to solve the problem by the sudden creation of a new tool (Neves-Filho, Carvalho-Neto, Taytelbaum, Malheiros & Knaus, 2016). An investigation in rats by the same research group demonstrated the emergence of an automatic chain of digging and climbing toward a reward. Showing that the rats can perform insight in a problem situation where they lose visual contact with the target (Neves-Filho, Dicezare, Martins-Filho & Garcia-Mijares, 2016; Neves-Filho, Stella, Dicezare, & Garcia Mijares, 2015). These two findings demonstrate that no progressive closeness to the target is required to produce insight.

Epstein's first hypothesis is more challenging to explain. Epstein did not offer a definition for functional generalization (Epstein, 2015; Epstein, Kirshnit, Lanza & Rubin, 1984). However, in his use of the term, he cited Bruner, Goodnow, and Austin's (1956) book *A Study on Thinking*. In this book, functional generalization is said to be involved in fulfilling a task requirement by reacting to a new stimulus as one should react to a known stimulus (Bruner, Goodnow & Austin, 1956). Functional generalization differs from semantic generalization given that the latter is driven by similarities in two stimuli in their meaning. Both functional and semantic generalization definitions are supported by other sources of the time (Razran, 1939; 1961; Butler, 1964). Epstein (Epstein, 2015; Epstein, Kirshnit, Lanza & Rubin, 1984) did not explicate their use of the concept of functional generalization and how it explains his findings. Nevertheless, functional generalization is one among other labels referring to a behavioral process that might play a relevant role on Epstein's findings: secondary or mediated generalization (Hull, 1943; Urcuioli, 2008). Thus, we return now to elaborate on the process of stimulus equivalence and mediated generalization that we first raised a few paragraphs ago, and how it can apply to Epstein's insight task.

3. Mediated Generalization and Stimulus Equivalence

Secondary or mediated generalization (we'll use the term "mediated" for the remainder of the essay) consists of a process that arises from stimulus equivalence, first demonstrated by Clark Hull (Hull, 1943), Walter Shipley (Shipley, 1933; 1935), and many others. Mediated generalization can be contrasted with primary or simple generalization, which is mediated by physical similarity, such as when a pigeon that has been reinforced for pecking at a red light or horizontal line will generalize pecking to an orange light or an oblique line 10 degrees off from horizontal, but not generalize pecking to a blue light or vertical line (Sutherland & Mackintosh, 1971). Mediated generalization, on the other hand, is based on shared associations between two elements and an outcome (Hull, 1943; Urcuioli, 2008) or by relational learning (Wasserman & Castro, 2012, Katz & Wright, 2006; Zentall, Wasserman & Urcuioli, 2014). For instance, when a pigeon pecks a 3D object after having been trained to peck at a photograph of the same object, one can argue that this behavior indicate that the pigeons learned to behave under the control of what the photography is about instead of the photography itself (Herrnstein, Loveland & Cable, 1976). or mediated associations are the type of relations that describe this pattern of behavior where one can behave toward a new stimulus under the control of its function or an abstract concept derived from previous learning (e.g. the idea that the photography were 'pictures of" instead of the photography as an object itself; Herrnstein, Loveland, & Cable, 1976).

Mediated generalization is driven by functional similarities and it is implicated in a variety of behavioral phenomena. Mediated generalization has been demonstrated to modulate the occurrence of categorial learning for complex stimulus discrimination such as differentiating between paintings from cubism and impressionism (Watanabe, Sakamoto & Wakita, 1995). After been trained to discriminate paintings from Picasso from paintings from Monet, pigeons were capable to generalize the previous learning toward a new painting from both artists (i.e., primary or simple generalization). However, pigeons trained with Picasso's paintings as discriminative stimulus had high response ratios toward Braque's and Matisse's paintings (i.e., other artists with cubist paintings). Meanwhile, the ones trained under Monet's paintings as discriminative stimulus, responded toward Renoir's and Cezanne's paintings as well suggesting the formation of a categorial learning for the complex visual patterns of impressionist paintings (Watanabe, Sakamoto & Wakita, 1995).

In a two-item same/different task, where pigeons were exposed to a situation where they were supposed to peck a picture for 'same' and a white rectangle for 'different' after been exposed to a model stimulus, pigeons were capable to learn abstract categories such as 'same as model' or 'different from model' by generalizing previous learning from conditional discriminations to novel pairs of stimuli (Katz & Wright, 2006). Also, Investigations exploring different strategies used by pigeons to behave in matching to sample (MTS) tasks showed that they can mix logical 'if-then' with configural learning to solve the MTS task (Katz, Bodily & Wright, 2008).

4. Mediated Generalization and Insight

Epstein’s Insight relies on one’s capacity to abstract a functional category (e.g., move a box to a target, dig to reach the other side, join stick to reach further distances), and this functional or mediated relation seems to rely on mediated generalization such as other observations of semantic relations and categorial learnings (Watanabe, Sakamoto & Wakita, 1995; Katz, Bodily & Wright, 2008; Zentall, Wasserman & Urcuioli, 2014).

The idea that mediated generalization plays a role in how one discriminative stimulus (S_1) transfers its function to others (S_2) in Epstein’s insight task requires testing. It is necessary to test the contextual control that produces the emergence of insight. Testing the discriminative control underpinning insight can also offer a framework to understand why insight is a direct (i.e., it occurs under the control of a contingency, the ‘goal’ in a problem situation) and requires less behavior variability, when contrasted with trial-and-error strategies.

Investigations on insight as an automatic chain of directed behavior are based on evidence from three experimental paradigms, all of them converging on having mediated generalization as the emergent and novel feature of insight. The first one is the box displacement test I described when mentioning Epstein’s work. His findings were replicated in three species of bird, pigeons (Neves-Filho, Assaz, Dicezare, Knaus & Garcia-Mijares, 2020), rooks (Bird & Emery, 2009), and crows (Neves-Filho, Knaus & Taylor, 2019). Epstein's Insight is based on the automatic chain of two behaviors, that is, to displace the box toward the target and to climb it to reach the target (Epstein, 1985; 1987; Epstein, Kirshnit, Rubin & Lanza, 1984). After reframing Epstein's idea of functional generalization as mediated generalization, one needs to reanalyze the contingencies affecting birds' performing the test.

After been trained in two instrumental behaviors, the animals were exposed to the testing situation where they could produce a food reward if they displace the box inside the chamber to reach a target (Epstein, Kirshnit, Lanza & Rubin, 1984; Bird & Emory, 2009). A directed performance emerges, and the animals displace the box adjusting its trajectory toward the target they were supposed to peck to produce food (Epstein, Kirshnit, Lanza & Rubin, 1984; Bird & Emery, 2009). This directedness is one evidence for the emergent discriminative control played by the target upon the directed displacement. The emergence of this novel discriminative control is what is new in insight behavior. Perform the displacement toward a target is not new. After the box reaches the point right below the target, animals are also under familiar contingencies. The only thing the is new in Epstein's insight is that his pigeons could react to the target (the plastic banana shaped toy) as they previously reacted to the spot (i.e., by displacing the box toward it).

We argued that this emergence is caused by mediated generalization (Hull, 1943; Urcuioli, 2008). Mediated generalization consists of a transference of function between two stimuli after they have been paired with the same reinforcer (Urcuioli, 1996; Ward-Robinson & Hall, 1999). If a CS_1 is previously paired with CS_2, and CS_3 is paired with CS_2, then one can observe the emergence of a functional equivalence between CS_3 and

CS_1 (Hull, 1943; Shipley, 1933; 1935). In instrumental learning, if an S_1 was reinforced by the same consequence as S_2, then both can discriminate the same response interchangeability (Urcuioli, 2008; Zentall, Wasserman & Urcuioli, 2014). It is mine understanding that Epstein's findings represent an example of this kind of functional generalization in a situation involving instrumental learning.

The novel directional performance of insight behavior in Epstein's insight task emerges when a common reinforcer, controlling two discriminative stimuli (S_1: the box, Conditioned Reward: the spot; S_2: the box, Conditioned Reward: the target) makes S_1 and S_2 members of the same functional class of stimuli (Hull, 1943; Urcuioli, 2008). As members of the same class, any of the stimuli can function as both a conditioned reinforcer for the responses that produce them, and a discriminative stimulus for the contingencies where the other members of the class were trained (Skinner, 1953; Sidman, 2000). I suggest that the emergence of this equivalence class is what makes the 'box+target' to control the box displacement. This control is what defines the 'directed' component of insight.

A second relevant feature is the "automatic" in automatic chain of behavior. Insight is said to occur in a sudden or automatic way (Epstein, 2015; Kounious & Beeman, 2014). For instance, it is a feature that differentiate insight from trial-and-error attempts of problem-solving (Kounious & Beeman, 2014; Thorpe, 1956). Insight is a solution that come along with less behavior variability within the testing situation and a sudden shift in performance changing from 0 (no solution) or 1 (effective solution) (Epstein, 2015; Köhler, 1952; Kounious & Beeman, 2014). These differentiate insight curves from typical learning curves of instrumental conditioning, as the latter starts with more behavior variability and higher latencies to solution and progressively reduces both features throughout one's re-exposition to the same contingency (Bird & Emery, 2009; Köhler, 1952; Epstein, Kirshnit, Rubin & Lanza, 1984).

In Epstein's insight task, the mediated generalization may mediate the formation of a functional equivalent class of stimulus (Zentall, Wasserman & Urcuioli, 2014; Hull, 1943) containing the stimuli associated with the box during training (i.e., the spot and the banana). Stimulus equivalence is the feature of two or more stimuli to share same functional properties, i.e., to control the same behavioral response. The term took the center of the stage during the 1930's and 1940's among the investigations about secondary generalization (Shipley, 1933; 1935; Hull, 1939; 1943). After two Pavlovian conditionings in humans, pairing a light (A) with an eye wink (B) and this eye wink (B) with a finger withdraw (C), a test revealed that the light (A) elicited the finger withdraw (C) by which was called an implicit learning (Shipley, 1935), or simply secondary generalization (Hull, 1943). Evidence of emergent categorial learning in non-humans are vast and it can be produced by both classical and instrumental conditioning (Lin, Dumigan, Recio & Honey, 2017; Zentall, Wasserman & Urcuioli, 2014).

In Epstein's insight task, the test presented a new situation in which the presence of the banana toy can elicit the box displacement toward itself (Bird & Emery, 2009; Epstein, 1985; 1987; Epstein, Kirshnit, Rubin & Lanza, 1984; Neves-Filho, Assaz, Dicezare, Knaus & Garcia-Mijares, 2020). This shows that the banana toy acquired the same discriminative function as the spot (i.e., they are both members of a stimulus equivalent class controlling the directed box displacement). As both the box (A) and the spot (B) were paired with the same reinforcer (i.e., the food; C), they both share a common S-S relation, with both becoming part of a class of equivalent stimuli mediated by their conditioning (A-C and B-C) during the instrumental training. As analogous to what was observed in secondary generalization, insight reveals that this transitive relation (A-B) emerges without training due to its mediated or contingency history. Since this transference is mediated by a common reinforcer (i.e. food), it indicates that Epstein’s test is a test of transitivity.

Additionally, mediated generalization explains the results of Cook and Fowler (2014). Using the same box displacement task, Cook and Fowler (2014) added a second test after the insight test with two displaceable boxes (one useful for climbing and reaching the target, and the other useless for structural instability when climbing upon it). Their animals did not differentiate between boxes, moving one of them or the other interchangeably (Cook & Fowler, 2014). The mediated generalization hypothesis considers that in its first test, one can observe the emergence of the equivalence class of stimuli related to the reinforcer in the animals that solved the test accurately. In the second test, with two boxes (Cook & Fowler, 2014), the animals reacted to both boxes due to their physical similarities, that is, due to simple/primary generalization (Sutherland & Mackintosh, 1971). Cook and Fowler (2014) test with two boxes may not be evidence of means-end process, but it is evidence of primary generalization between the two boxes. The directional displacement and the further attempts of climbing the new box show that one reacts to it as it were the familiar box, revealing the emergence of an identity relation between the new and the old box, which is part of the evidence supporting the formation of an equivalent class (Zentall & Urcuioli, 1993; Urcuioli, 2013).

The final evidence supporting insight as function of stimulus equivalent classes refers to a reversable feature: symmetry. If trained under a condition where A predicts B, one must derive that when presented to B, A should come next. In matching to sample tasks, this feature is easily tested through conditional discriminations in which A is trained as a conditional stimulus for the discriminative stimulus B, and where the emergence of the response to A is tested as discriminative when exposed to B as its conditional (Sidman, 1994; 2000). This reversibility between A and B is called symmetry (Sidman, Rauzin, Lazar, Cunningham, Tailby & Carrigan, 1982; Zentall & Urcuioli, 1993) and has been vastly documented to spontaneously emerge under this kind of training not just in humans, but also in non-human animals and especially among pigeons (Urcuioli, 2015). The digging and climbing paradigm offer a way to test insights symmetry using a reversal learning test.

As stated above, the Epstein's test is a transitivity test. In the digging and climbing paradigm, this test consists of digging toward the opposite side of an experimental chamber, reaching a ladder, and climbing it to reach a platform where the food is. A situation where a rat is placed on the platform and the food is on the other side would request the animal to use the ladder to reach the nearest place where it can dig toward the opposite site and reaches the food. The interchangeability of these two situations is evidence for the symmetry of insight and it is still a process open to empirical test.

To state that Epstein's insight requires a stimulus equivalent class does not imply that the species in which this behavior was observed one should find stimulus equivalence of arbitrary stimulus-stimulus relations. The directional component of the instrumental trainings that all animals had to undergo before showing insight clarify the differences between these two types of stimulus equivalences. In one hand, conditional discriminations using matching to sample (MTS) paradigms were shown to produce arbitrary stimulus equivalence in humans and, at least partially, in non-human animals (Urcuioli, 2008; 2015). In the other hand, Epstein's insight requires a contingency based effect during the instrumental training for the mediated generalization to occur. For instance, the pigeons had to learn to displace a box to spot (original target), before they could displace it to a plastic toy (the new target). Even performing digging naturally, rats had to be trained in a condition where they were supposed to dig toward a target (i.e., a bottle cap with a piece of food) so they could dig toward a new target (i.e., reach the ladder on the other side of the chamber). This means that Epstein's insight seems to fit the three properties of stimulus equivalence: reflexivity, symmetry, and transitivity (Sidman, 1994; 2000; Urcuioli, 2008).

5. Possible critics and their counterarguments and evidence

To elucidate the explanatory power of this hypothesis, it is necessary to address some evidence that may seem to challenge it on a first glance. Neves-Filho, Knaus and Taylor (2019) found that crows combine up to six different behaviors in one chain to solve a problem, even when those trainings were structured with different rewards (i.e., food and access to new environment). If mediated generalization is mediating the stimulus equivalence through similar rewards, this evidence should contradict this hypothesis at a first sight. However, a closer look to Neves-Filho, Knaus and Taylor (2019) offer a better understanding on the intricacies of their training and its effect on crows' solutions.

Captive crows were trained in four types of behaviors: stone dropping, operating a cloth door, choosing between two boxes, and opening the cloth door to gain access to a new environment (i.e., crossing between cages), in this sequence (Neves-Filho, Knaus & Taylor, 2019). The first three were trained using food as a reward. The fourth was trained using the access to a second environment by a similar door mechanism used during the training of "operating a cloth door" behavior. This variant reinforcer was already a conditioned reinforcer related to the food and, thus, it shared a conditioning history with it (Neves-Filho, Knaus & Taylor, 2019). Therefore, the early stages of the "crossing between cages" training was already counting with a transference of stimulus function to perform as a conditioned reinforcer. This way crows' emergent performance fits the mediated generalization just as Epstein's pigeons (Epstein, 1985; 1987), but using a training that assumes a well-known conditioned transference of function between a reinforcer and its discriminative stimulus (Hull, 1943; Skinner, 1953; Lin, Dumigan, Recio, & Honey, 2017).

Two other tasks were used to test Epstein's insight in non-human animals. The first task is the tool manufacturing of a rack out of two components (Köhler, 1952; Neves-Filho, Carvalho-Neto, Taytelbaum, Malheiros & Knaus, 2016). This task is a variation of Köhler's seminal work on insight (Köhler, 1952) and it consists of two separate trainings, the use of a short rack to reach a piece of food inside a small vessel placed in a certain distance D from one side the animal's cage wall, and a second behavior of connecting two sticks (rewarded with food) (Neves-Filho, Carvalho-Neto, Taytelbaum, Malheiros & Knaus, 2016). The test consisted of putting the food far enough so the monkey could not reach it using neither the rack nor the stick (Neves-Filho, Carvalho-Neto, Taytelbaum, Malheiros & Knaus, 2016). Instead, they could combine one stick and the rack to extend the range of the rack and thus reach the food (Neves-Filho, Carvalho-Neto, Taytelbaum, Malheiros & Knaus, 2016).

Regarding generalized tool use in an tool-based insight test, the mediated generalization hypothesis predicts that, the instrumental training produces a new class of stimulus created by combining previous tool-uses in one class of stimulus (Hull, 1943; Urcuioli, 1996; 2008). In this case, animals behave toward the rack as if it were another stick (transference of function). By using the rack as it were just another stick (Neves-Filho, Carvalho-Neto, Taytelbaum, Malheiros & Knaus, 2016), one is connecting response is being partially under the control of one stick (trained relation) and the rack (emergent relation). The test reveals the formation of a stimulus equivalent class between the rack and the sticks. The new combined tool is used for its functional similarities with the rack.

The last and most recent task exploring insight does not require tool use, and it consists of rats crossing a barrier by digging under a barrier to get from one compartment of a chamber to another that contains a ladder that provides access to a food reward (Araújo, Prata-Oliveira, Nascimento-Júnior, Pessoa-Neto, Monteiro & Tatmatsu, 2020; Teixeira, Maciel, Silva, Oliveira & Tatmatsu, 2020; Neves-Filho, Dicezare, Martins-Filho & Garcia-Mijares, 2016). After being trained on digging toward food, and to climb a ladder toward food, animals are tested in a new chamber to assess the emergence of insightful behavior that combines both of those behaviors. In this paradigm, the ladder that was trained to control the climbing behavior acts as a conditioned reinforcer and appears to elicit digging behavior during the insight test (Neves-Filho, Dicezare, Martins-Filho & Garcia-Mijares, 2016). Recent investigations showed even stronger evidence supporting the role of the ladder controlling the position where the digging is produced during insight test by changing the position of the ladder and finding changes in the typical position of the digging (Knaus et al., 2021). This results appear to support that there is a transference of learning that facilitates the ladder to partially control digging behavior. The processes underlying this transference remain open to further evidence, test and debate.

6. Final Thoughts

The modulation of insight by mediated generalization expands the range of empirical exploration of Epstein's insight task due, moving the theoretical and empirical debate from focusing on sequences of behavior (Araújo, Prata-Oliveira, Nascimento-Júnior, Pessoa-Neto, Monteiro & Tatmatsu, 2020; Neves-Filho, Dicezare, Martins-Filho & Garcia-Mijares, 2016) to the measurement of acquired equivalence and behavioral variability, and on how the formation of a stimulus equivalence class can expand the behavioral repertoire of the subject (Araújo, Prata-Oliveira, Nascimento-Júnior, Pessoa-

Neto, Monteiro & Tatmatsu, 2020; Cook & Fowler, 2014; Neves-Filho, Knaus & Taylor, 2019).

Finally, this hypothesis advances our definition of and conceptual understanding of insight behavior. This new framework can spur further investigation of the differences in contextual control that can emerge from insight. Further tests exploring the conditions that favor the emergence or hinders insight should lead to a better characterization of how prior training history predicts behavior on the insight task must be done. A non-exhaustive list of these tests comprises investigations on the role of the directional component of the instrumental learning have on the stimulus equivalence formation, and the role of concurrent discriminative stimuli on the observation of insight.

The mediated generalization hypothesis also moves the discussion away from topographical (i.e. structural) characteristics of behaviors (e.g. to speculate about whether the pigeon or the rat need to experience a period of confusion prior to the emergent solution (Epstein, Kirshnit, Lanza & Rubin, 1984; Neves-Filho, Stella, Dicezare & Garcia-Mijares, 2015) to a functional approach of insight based on the test of its basis in psychological mechanisms, such as associative learning, associative generalization, and principles of reward. This final contribution offers a better comparative mainframe for understanding insight and may shed light on its use as tool in education.

Chapter 04

Title: Reinforcement Learning, Cue-control and Insight

Introduction

Problem-solving is a task or situation that gives access to a reward when performing one or few specific responses (Thorpe, 1956; Dunbar, 1998). Insight is one way of solving a problem without spending time and energy exploring the environment and the conditions of a problem (Thorpe, 1956; Dunbar, 1998). Instead, it is a sudden and direct way to solve a problem (Epstein, 2015; Köhler, 1952; Kuo & Knoblich, 2007). However, insight is a term that does not describe a unique behavioral process (Dunbar, 1998).

Among different tasks, Köhler observed how chimpanzees performed in problem situations. Many of Köhler's subjects solved the problems that they were subjected to using trial and error strategies (Köhler, 1917). Very few of his animals performed the solutions in a sudden and direct way. Köhler called this sudden and goal-directed change as insight behavior. Köhler considered the apes insight performance as product of a sudden shift on their 'configural representation' of their environment (Köhler, 1952). In other words, Köhler considered that the chimpanzes created a new Gestalten perception (i.e., a new representation of its environment highlighting its relevant features; Köhler, 1938).

Further investigations revealed that apes performing in Köhler's tests depend on developmental variables (e.g., on age and play behavior; Schiller, 1952) and on previous learning history (Birch, 1945; Harlow, 1951). In other animals, variations of Köhler's tests showed that insight in problem solving-situations can occur in multiple taxa (e.g., pigeon (Bird & Emery, 2009), crows (Cook & Fowler, 2014; Neves-Filho, Knaus & Taylor, 2019), elephants (Foerder, Galloway, Barthel, Moore III, Reiss, 2011), capuchin monkeys (Neves-Filho et al., 2014), and rats (Neves-Filho et al., 2015). However, insight is deeply rooted in individual learning history and in the cue-control presented in the problem situation in all these species.

On its early days, Epstein's insight (Epstein et al., 1984) was based upon a tool use task that adapted the task used by Köhler with his apes in the Canary Islands (Köhler, 1917/1952). A pigeon had to move a box toward a target, climb upon it and reach the target to activate the feeder inside a modified operant chamber (Epstein, Kirshnit, Lanza, & Rubin, 1984). What Epstein findings revealed is that this insight behavior does not simply emerge through trial and error, but it relies on a specific learning history (Epstein, Kirshnit, Lanza, & Rubin, 1984; Epstein, 1985; 1987; 2015). After been trained on moving the box toward a target located at various places and after learning to climb that box a peck a plastic hanging from the top of the box (when the box was placed below it), the pigeons were placed in a situation where the box was put far from the plastic toy (Epstein, Kirshnit, Lanza, & Rubin, 1984). After a while, the pigeons push the object towards the plastic toy, and when it reached the place right below the toy, they climbed the box and pecked the toy. This performance was described as insight behavior by Epstein and colleagues (Epstein, Kirshnit, Lanza, & Rubin, 1984; Epstein, 1985; 1987).

For thirty-three years, Epstein's insight was only investigated through the box displacement task (Epstein, Kirshnit, Lanza, & Rubin, 1984; Epstein, 1985; 1987; 2015). However, in 2015, Neves-Filho and colleagues demonstrated the same process using a simpler task that does not require tool use (Neves-Filho, Stella, Dicezare & Garcia-Mijares, 2015; Neves-Filho, Dicezare, Martins-Filho & Garcia-Mijares, 2016). Rats, placed in a modified hamster chamber, were presented with a task where the animals have to dig into wood shavings, find and go through a crack in a wall, go to and climb a ladder, and walk on a platform to gain access to the reinforcer. (Neves-Filho, Dicezare, Martins-Filho & Garcia-Mijares, 2016).

In brief, Neves and colleagues (Nees et al., 2016) evaluated the effects of successive and concomitant training on the recombination of digging and climbing repertoires. In this investigation, the authors found that concomitant training in the two instrumental behaviors facilitated the emergence of insight into a scenario that required digging into an reachable underground tunnel when the animals excavated the shavings covering the tunnel. These results demonstrated that, although based in behaviors that are commonly observed in rats (i.e., digging and climbing), the solution of the digging and climbing task is dependent upon behavioral training (Neves-Filho, Dicezare, Martins-Filho & Garcia-Mijares, 2016)

Later, a variation of the testing chamber was used to offer a better understanding of the allocation of the digging response along the testing session (Knaus et al, in preparation). However, there was still an open question around the role of the ladder in controlling the digging response and the impact of a different training session (crossing without digging) upon the pattern of solution of the digging-and-climbing problem. Those two manipulations may shed light on the stimulus control operating when contrasting insight and non-insight solutions.

In the second chapter we demonstrated how insight-like solutions can facilitate the emergence of reversal learning in a variation of Knaus and colleagues' task (in preparation). Rats were trained to dig toward a piece of food placed underground, and to climb toward a ladder to reach an elevated piece of food. One group, called insight, were trained in just climbing and digging behavior. Meanwhile, a second group called non-insight received and extra training of rewarded crossing without digging. After training, animals from the insight group were place in the test chamber, while animals from the non-insight group were placed in a modified test chamber, and just then, in the test chamber. The Testing chamber consisted in a modified open chamber divided into two sides. The animals were put in one side where they could reach one underground tunnel to reach the second side and then climb a platform to reach a food reward.

After testing, all animals were exposed to a reversal test. The reversal test chamber consisted in the same environment as the direct test, but animals were put on the other side of the chamber (in an elevated platform that gave access to Quadrants 3 and 4, instead of quadrants 1 and 2). As they were placed in the opposite side of the ladder, animals had to walk down the ladder, reach quadrant 3 and then dig toward the other side to reach the food.

Results from our first experiment (reported in the chapter 01) showed that the non-insight group solved the test after spending more time and by more exploration of the environment when compared to the insight group. They also could not solve the reversal learning test they were exposed to after the direct test. Therefore, the non-insight group showed a non-directed solution of the test and showed no flexibility in a reversal test (ibdem), a performance incompatible with what one would expect from insight behavior. That leads to the question of what the animals of the non-insight group learned in the modified test chamber that disrupt the emergence of insight.

In the present investigation we tested two variations of Knaus and colleagues in preparation) task based on digging and climbing behaviors. In the first experiment we tested the role of the presence/absence of the ladder as critical stimulus controlling the occurrence of the insight behavior, instead of controlling the position of the ladder on the problem-solving set (Knaus et al, in preparation). The second experiment tested whether the reward in the special session (the crossing without digging session) was a feature capable of hindering reinforced and insight-related behaviors during the problem-solving testing.

2. General Method

2.1. Animals and Environment

Twenty male Long Evans rats (*Rattus norvegicus*). From 90 to 150 days old and between 300-350g at the beginning of the experiment, was used in this experiment. The animals were kept under controlled conditions for temperature (23±2), humidity, and reversed light-dark cycle (12/12 hours with dark cycle starting at 7 a.m.). The animals were pair-housed with water under *ad libitum* regime. Two hours of food restriction before the behavioral sessions was used to increase animals' foraging and the appetitive value for food within sessions.

2.2. Materials and Equipment

2.2.1. *Food Reward*

Sweetened cereal flakes (Fruit Loops™ or Cheerios™) used as rewards within training sessions. Individual preferences between the two options was assessed during the handling procedure described below.

2.2.2. *Video recording and behavior analysis*

A video camera (Sea Wit® Webcam with Built-in Microphone A870 USB 2.0 HD 12.0MP) was used to film the behavioral sessions. The Behavioral Observation Research Interactive Software (BORIS®) was used to analyze behavioral training and testing.

2.2.3. *Digging Chamber*

For digging training, a parallelepiped chamber (length= 45cm, width=60; height=60cm) was used. It is made of acrylic with two hatches (one on the side wall and other on the bottom) filled with pine wood bedding, see Figure 1B. A piece of food (the cereal) was placed inside a vessel (a bottle lid constructed of plastic) and covered by the wood bedding under different depths.

2.2.4. *Climbing Chamber*

The training of climbing took place within an ALESCO™ acrylic-made home cage adapted with an elevated platform with an attachable rectangular metal ladder (height = 25cm; width = 15cm), see Figure 1A. Climbing the ladder would give access to a platform with the food.

2.2.5. *Testing Chamber*

An open field chamber was modified to support the test requirements. The chamber was divided between two sides of equal size (width=70, depth=35, height=80cm each side) by a glass barrier. The chamber floor was covered with pine wood bedding (depth=20cm) in both sides. An elevated platform (width=30cm, depth=15cm, height=20cm) and a metal ladder (the same model as the one used for the climbing training) was placed together on one side of the chamber during testing sessions (see Figure 1C).

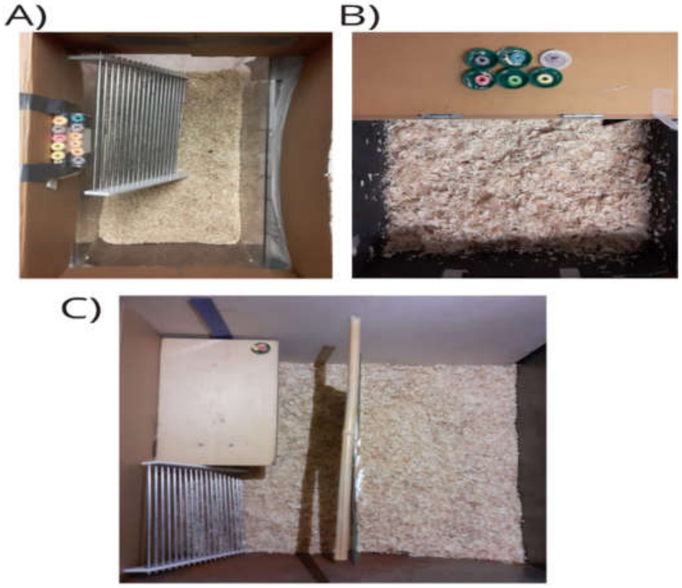


Figure 5. Experimental Apparatus. A) climbing chamber. B) digging chamber. C) testing chamber (reproduced from the Experiment 01.

2.3. General Procedures

2.3.1. Behavioral testing 01 (Pre-test)

Pre-test: each animal was placed on one side of the testing chamber opposite to the ladder (right side of figure 1C). To reach the food, the rat should dig and reach the connection between the two sides of the testing chamber. Digging to the other side would give it access to the ladder and so to the platform on which a bottlecap with a piece of food inside it was placed.

2.3.2. Behavioral training

All animals received both trainings on climbing and digging. After been trained on both behaviors, they were sorted between two groups and half of animals underwent one rewarded crossing (without digging) training session before doing the direct test.

a. Climbing: an instrumental shaping procedure was performed to train the animal on climbing a ladder to reach the food (reward). One piece of food was placed on a small window-shaped platform (width=10cm; height=8cm) over the ladder at a time. Each trial consisted of climbing up and grabbing the food. There was no inter-trial interval, despite the time for the experimenter to manually refill the platform. Animals were able to access up to 12 pieces of food per training session, one per trial. Sessions would end after 15 minutes or after the animal have eaten all 12 pieces of food in a session, whichever came first. The criteria to end the climbing training was to climb the ladder and eat at least 10 out of 12 pieces of food (>80%) per session and keeping this performance throughout three consecutive sessions.

b. Digging: a second instrumental shaping procedure was used to train the animal on digging toward the food in a modified skinner chamber filled with wood chip bedding for rodents (depth=25cm). In each trial, four bottlecaps was placed underneath the wood bedding under one of five different depths (0cm, 5cm, 10cm, and 15cm). Each bottlecap contained one piece of food. A trial consisted of digging toward every single one of this four bottlecap targets to reach the food. The experimenter checked whether the animals reached all the caps every three minutes refilling the caps every time until reaching the session limit of 12 pieces of food per session. Sessions could also be ended after 15 minutes if the animal did not reach the 12-piece limit. The shaping of digging required two stages of training. In the first, the animal should reach the bottlecaps on the deepest depths at least 25% or 3 out of 12 trials (complexity criterion). Secondly, the animal should reach at least 80% of the targets (≥10) per session, during three consecutive sessions (stability criterion).

2.3.3. Behavioral Testing (post-test)

The behavioral testing (i.e., the post-test) was different for each experiment and it is descripted in its correspondent session (i.e., specific procedures) below on Experiment 02 and Experiment 03.

Experiment 02: Ladder presence and cue-control in insight.

Aims

Test the role of the presence of the ladder as cue for crossing and digging.

Procedures and Experimental Design

In this experiment, one group was exposed to a testing situation in the presence of the ladder (Ladder group, n=6), and other to the absence of it (No-Ladder group, n=6). The environment was the same as the pre-testing set, except for the manipulation of the presence of the ladder. The chamber was set in two sides separated by the glass barrier. The tunnel between sides were covered by the wood chip bedding.

Results

Pre-test and Behavioral Training

No animals solved the problem-solving situation in the pre-test phase. After the training, animals were separated in two groups, called Ladder and No-Ladder groups. The comparison between group showed no significant differences between the Ladder (M = 15.67, SD = 1.33) and the No-Ladder (M = 15.50, SD = 2.50) groups for the number of digging sessions, f = .67, p > .43. No difference in the between group comparison was observed for the number of reinforcers accessed in the last five sessions of digging behavior whatsoever (Ladder: M = 52.33, SD = 2.33; No-Ladder: M = 53.31, SD = 3.83), f = .25, p > .62. There was no observed difference between groups for the number of sessions of climbing sessions (Ladder: M = 6.83, SD = .89; No-Ladder: M = 6.17, SD = 0.89), f = .85, p > .37. And, finally, the Ladder (M = 56.17, SD = 3.50) and No-Ladder group (M = 55.67, SD = 3.33) had no significant differences for the number of reinforcers in the climbing session, f = .04, p > 0.83. This absence of difference is important to keep eventual differences on the training sessions under control when explaining insight and eventually non-insight solution of the testing problem. The summary of training results is summarized in figure 6.

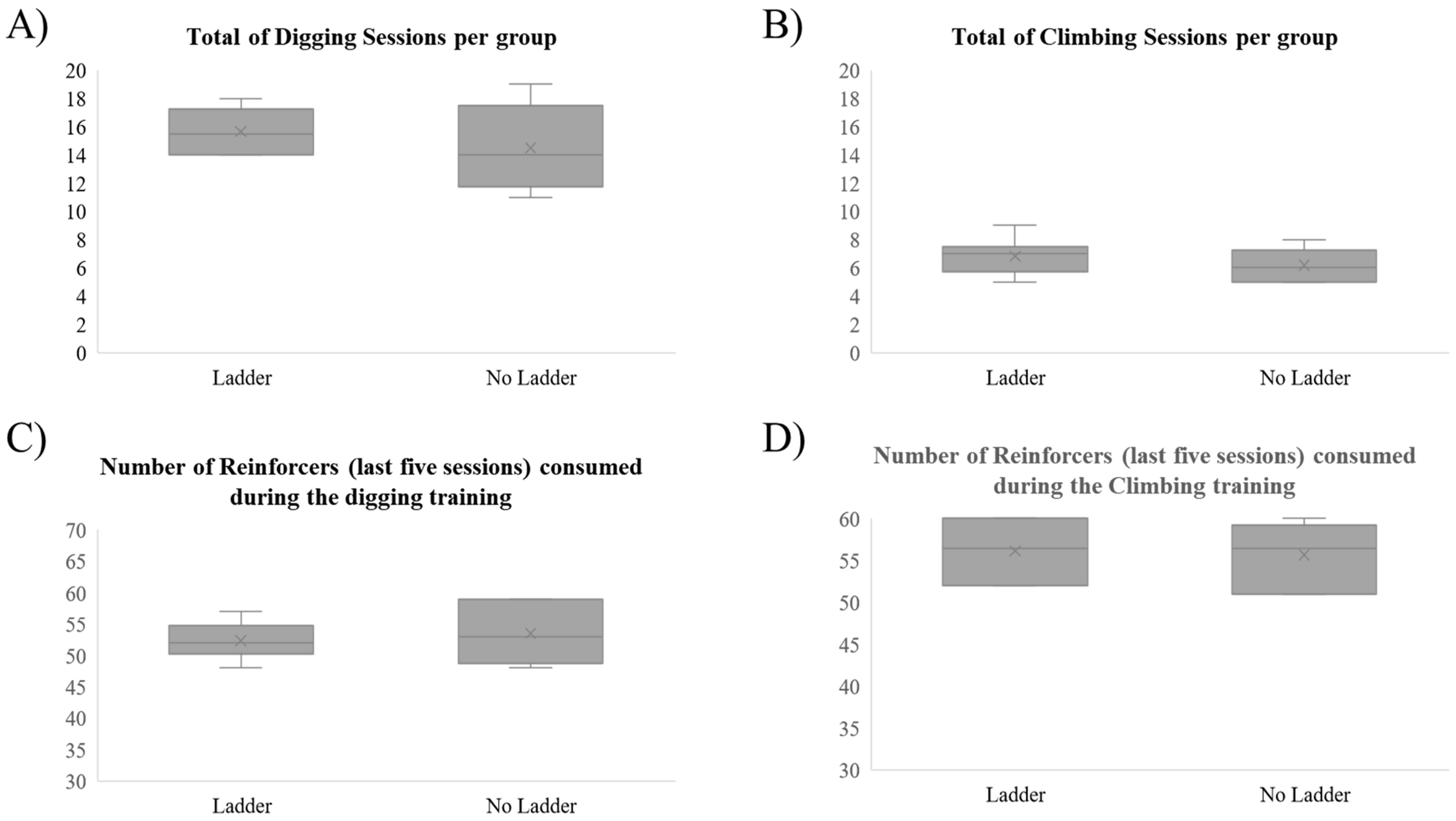


Figure 6. Summary of data for the behavioral training. A) Number of sessions on digging; B) Number of sessions on climbing; C) Sum of reinforcers consumed during digging in its last five sessions; D) Sum of reinforcers consumed during climbing in its last five sessions

Testing the Ladder as cue for evoking previous learning

Test the possibility that the ladder plays a role on evoking behaviors that may have been directly or indirectly associated with the ladder is a quest for understanding the cue-/contextual control operating on insight solution. The mediated generalization hypothesis predicts that more of the behaviors related to the ladder would be produced under its presence and less of said behavior would occur in its absence. Our findings indicate that no significant difference was observed for exploratory behavior. There was no difference for animals in the Ladder group (M = 36.00, SD = 14.80) and the No-Ladder group for the exploration of Q1, f = 0.73, p > .40. There was also no difference between groups for Q2 (Ladder: M = 11.80, SD = 7.36; Non-Ladder: M = 12.17, SD = 3.50; f = .06, p > .81), Q3 (Ladder: M = , SD = ; Non-Ladder: M = , SD = ; f = , p >), and Q4 (Ladder: M = 3.20, SD = 7.36; Non-Ladder: M = 9.17, SD = 7.50; f = 2.04, p > .18). Even when comparing the exploration of an elevated platform accessed by climbing the ladder or by jumping upon it (for the No-Ladder group), no significant difference was observed (Ladder: M = 7.81, SD = 12.48; Non-Ladder: M = 6.33, SD = 6; f < .001, p > .98). In summary, the ladder had no impact on the exploration of the testing chamber. These results are summarized in figure 7

The general comparison on whether animals in ladder and non-ladder group crossed to the other side – using a Chi-Square comparison – revealed that there was no significant difference between groups (Chi-square = 3.0857, p = .078983, one degree of freedom). When specifically comparing the number of crossing and digging behavior altogether, no difference was observed when comparing the ladder (M = ,1,17 SD = .56) and non-ladder group (M= 2.33, SD = 1.22), f = 2.88, p > .12. This comparison is pictured in figure 7C. This result seems to indicate that the ladder per se did not increment the frequency of digging or crossing behavior. The specifics of individual performance, describing position and relevant behavior (i.e., digging and crossing) is summarized in Appendix C.

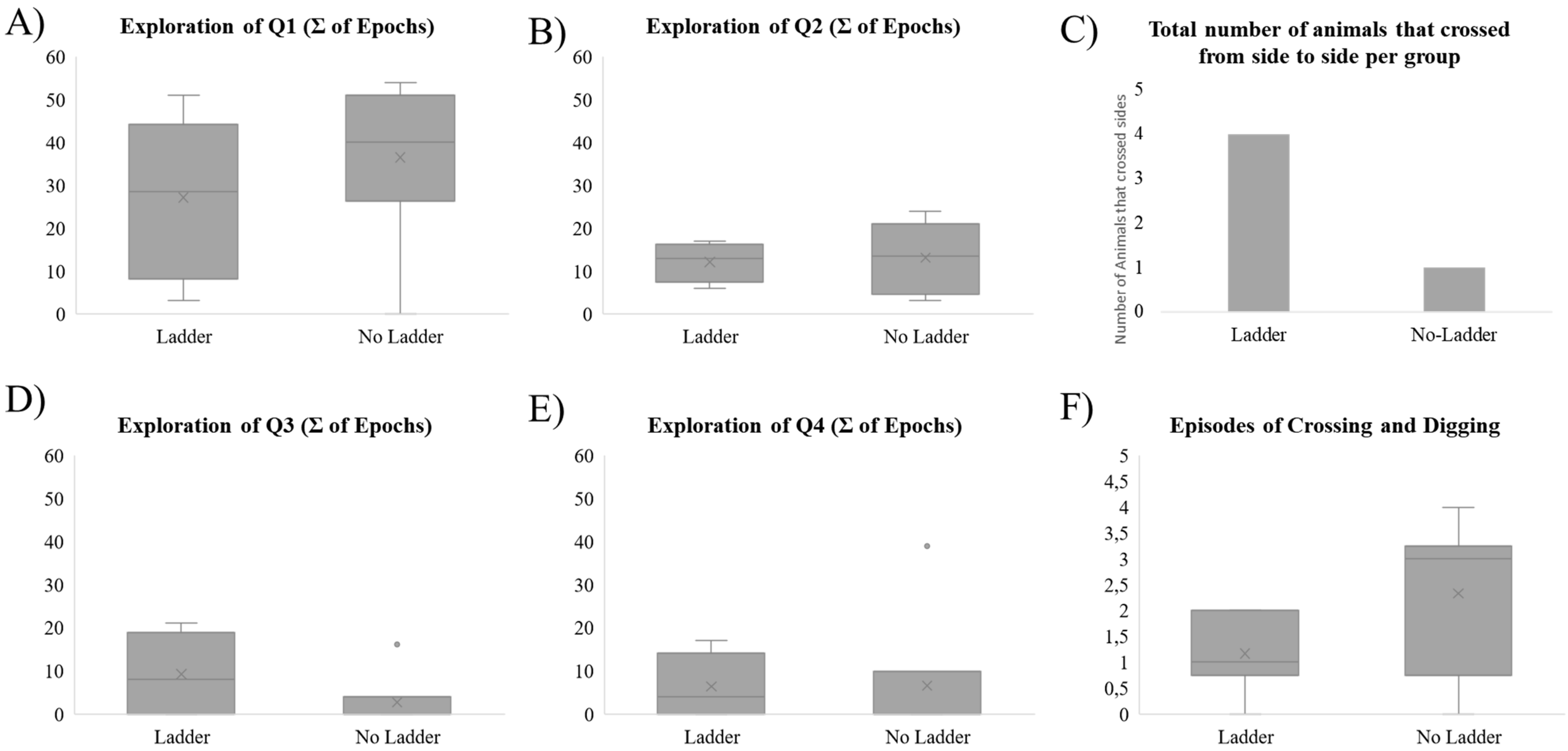


Figure 7. Summary of Data during the test. A) Exploration of Q1; B) Exploration of Q2; C) Number of animals that crossed between sides; D) Exploration of Q3; E) Exploration of Q4; F) Episodes of Crossing and Digging.

Experiment 03

Reward and Non-Reward Crossing and the Climbing and Digging Problem-Solving.

Aims

The purpose of this experiment was to track the role of the contingency between the reward and the crossing (without digging) before the testing upon the behaviors related to the solution of the problem.

Procedures and Experimental Design

After finishing the two basic trainings of climbing and digging behavior, animals were sorted in two groups (Rwd and Non-Rwd Crossing). The Rwd Crossing was exposed to a situation where each animal underwent a single and short session of crossing without digging. The animals were placed between quadrants Q1 and Q2 and the tunnels connecting Q2 and Q3 were set open to cross to the other side. A piece of food was placed between the tunnel passage and the ladder on Q3. After crossing and reaching the food, the Rwd Crossing group had this session ended. The same procedure was performed for animals in Non-Rwd group, but without any offer of food, leaving the passage opened and the sessions being ended after the animals crossed with all paws from Q2 to Q3. The general experimental design is summarized on Table 03 and the schematics of the rewarded crossing session is represented in figure 8.

Table 03.

Behavioral procedures and experimental design

	Pre-test	Climbing	Digging	Rwd Crossing (without digging)	Direct Test
Rwd Crossing	Y	Y	Y	Y	Y
Non-Rwd Crossing	Y	Y	Y	N	Y

Note: Climbing and Digging training will be performed simultaneously. Two training sessions per day, one on each behavior. Their order of training will be alternated daily, i.e., if climbing happened on one morning, the other began on the other.

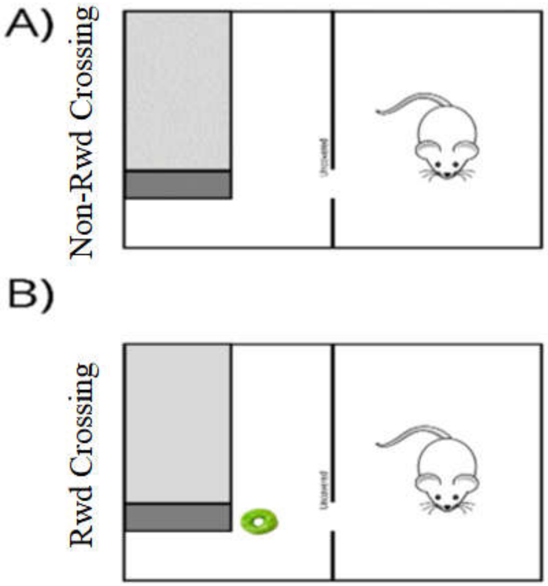


Figure 8. Schematics of the testing sets. A) Non-Rwd Crossing. B) Rwd-Crossing.

Results

First, the report on this experiment includes the results of only four animals per group. This makes analysis of variances between group factors inappropriate and limits the range of inferential statistics applied here. The short number of animals investigated here is directly related to restrictions of acquisition of novel animals established during the COVID-19 pandemic. Otherwise, the results were reported as other previous findings discussed in the doctoral thesis.

Common Instrumental Training

The control for instrumental learning is important when investigating insight and problem-solving. In this experiment, we found no evidence for differences on digging sessions between Rwd Crossing (M = 15.00, SD = 2.00) and Non-Rwd Crossing (M = 16.25, SD = 1.38), t = 0.78, p = .23. The same can be said when comparing the number of climbing sessions between Rwd Crossing (M = 6.50, SD = 1.00) and Non-Rwd Crossing (M = 7.5, SD = .50), t = -1.41, p = .10. When comparing the number of reinforcer accessed, no differences were found between both groups for digging (Rwd Crossing: M = 49.50, SD = 2.50; Rwd Crossing: M = 50.75, SD = -.51, t = .31) and climbing behaviors (Rwd Crossing: M = 54.00, SD = 5.00; Rwd Crossing: M = 51.25, SD = 2.75; t = .72 and p = .24). The digging behavior demanded more sessions to reach the stability criteria when comparing the number of sessions between all animals in both the digging (M = 15.63, SD = 1.62) and climbing behavior (M = 7.00, SD = .75), t = 9.97415, p < .00001. The general results are summarized in figure 9.

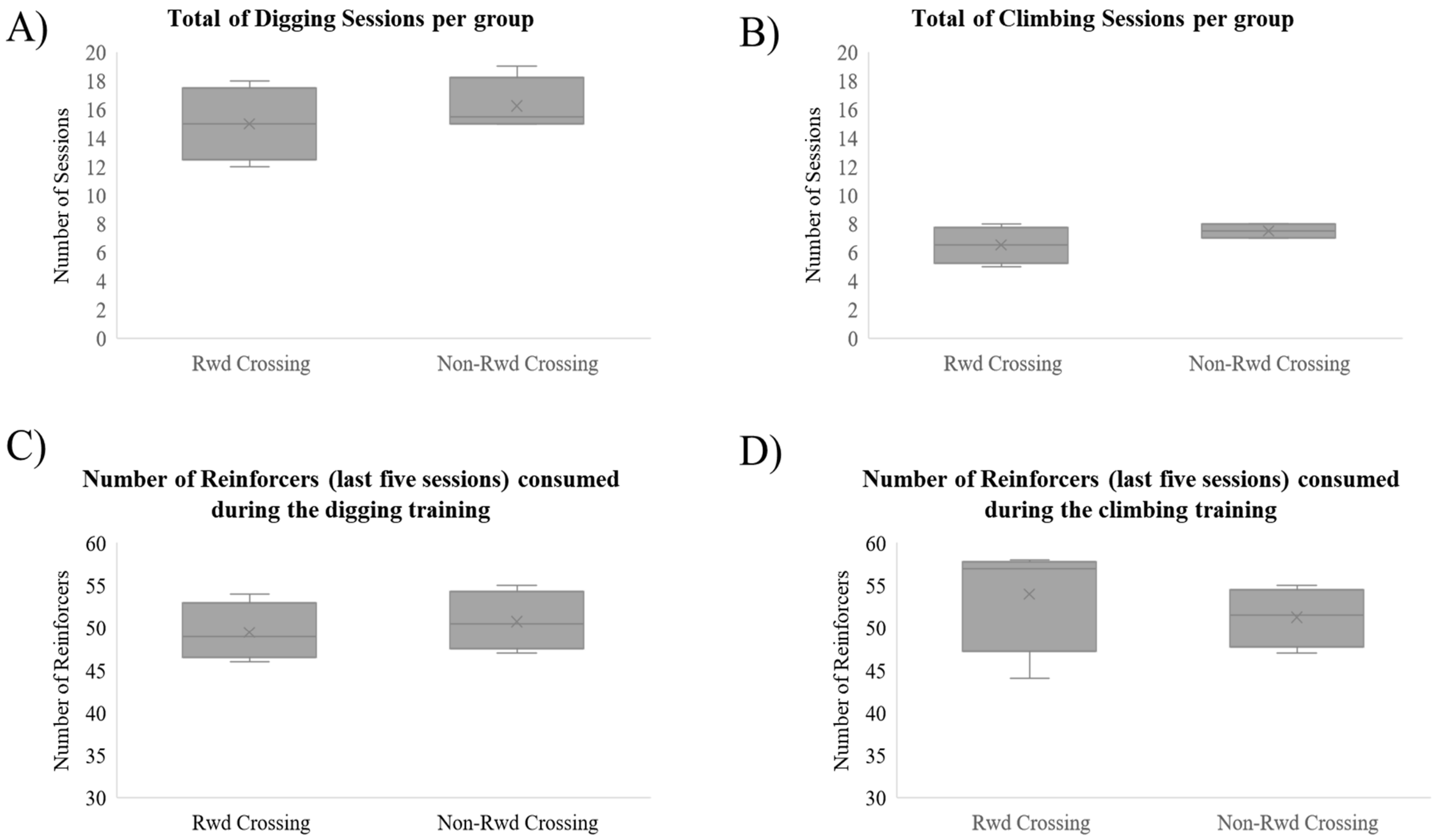


Figure 9. Summary of data for the behavioral training. A) Number of sessions on digging; B) Number of sessions on climbing; C) Sum of reinforcers consumed during digging in its last five sessions; D) Sum of reinforcers consumed during climbing in its last five sessions

Testing after crossing

When observing the exploratory behavior of both Rwd and Non-Rwd groups, there was no significant differences between them on any of the quadrants of the experimental chamber. There was no difference in exploration of Q1 (Rwd: M = 12.00, SD = 16.00; Non-Rwd: M = 7.75, SD = 4.13, t = .38, p > 35), Q2 (Rwd: M = 6.50, SD = 4.50; Non-Rwd: M = 7.50, SD = 2.50, t = -0.28, p > .39), Q3 (Rwd: M = 13.75, SD =6.87 ; Non-Rwd: M = 13.50, SD = 3.5, t = .04, p = .48), or Q4 (Rwd: M = , SD = ; Non-Rwd: M = , SD = , t = 1.25, p > .12p =). There was a significant difference in the exploration of the elevated platform, with the Rwd group (M = 2, SD = 2) exploring more of this part than Non-Rwd group (M = 18.25, SD = 7.75), t = -3.24, p = .009. The summary of this results is reported in figure 8. This comes in direct contrast with the expectation of non-Rwd group to be less explorative. However, the short number of subjects limits the generalization of this interpretations but may point toward the necessity of a more specific manipulation and control of how the crossing training affects testing performances and what kind of reinforcement or discriminative control it produces or affect. The general individual performances are summarized in attachment D.

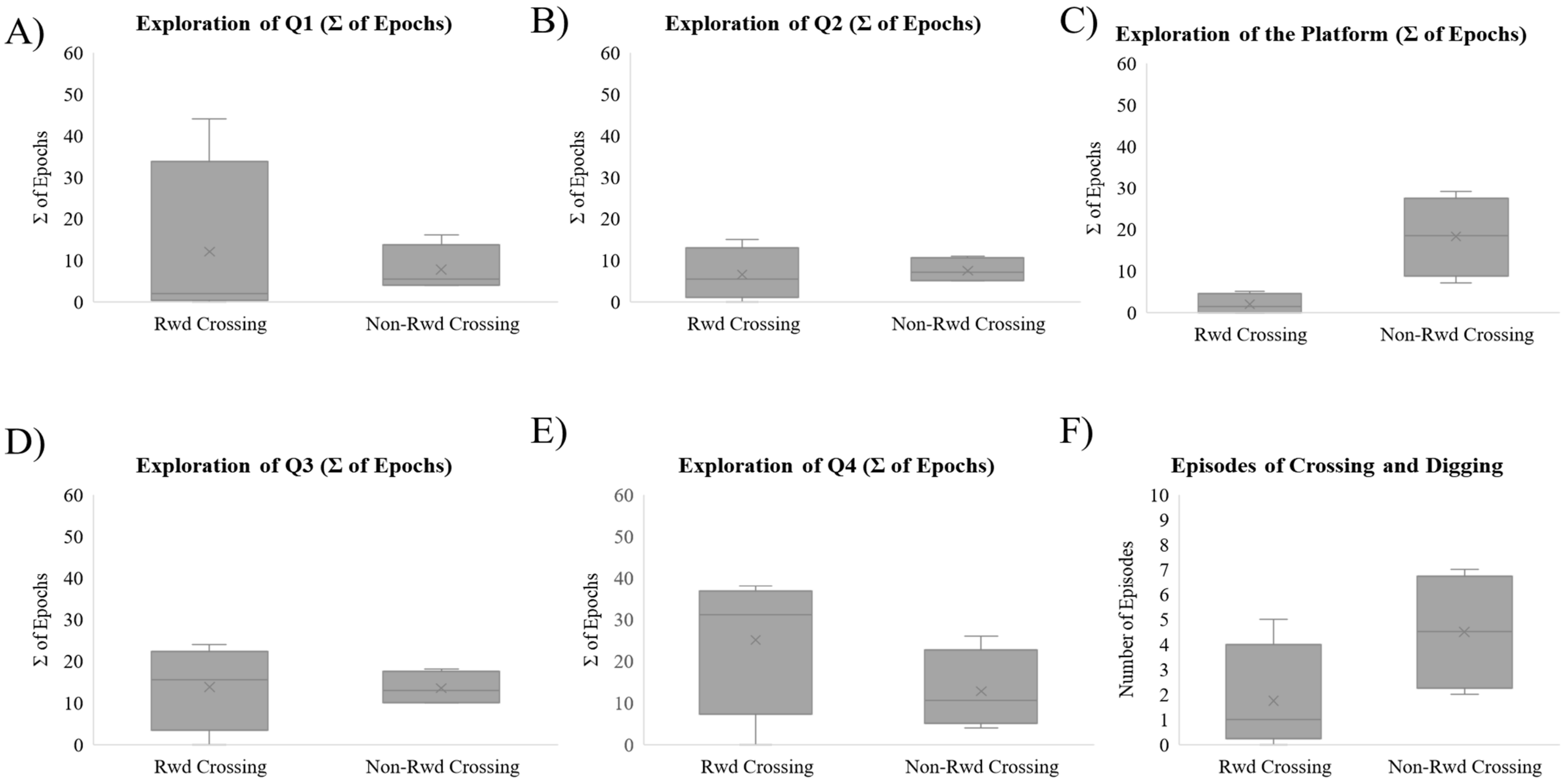


Figure 10. Summary of Data during the direct test. A) Exploration of Q1; B) Exploration of Q2; C) Exploration of the Platform; D) Exploration of Q3; E) Exploration of Q4; F) Episodes of Crossing and Digging.

General Discussion

Insight & Cue Control

It is impossible to approach the phenomenology of insight in non-human animals (Shettleworth, 2012). What one can do is to investigate the behavioral processes underlying the insight phenomenon as generally described by the sudden solution of a problem. Epstein's findings shed light on the reinforcement learning basis supporting insight. It revealed how specific reinforcement contingencies can bring insight to light or to hinder it. Further investigations explored more on the instrumental basis of insight by the means how to produce it by interconnecting previous learning to produce novel behavior. The development of this research enterprise had started to approach a path of exploring the stimulus control relations underlying insight. The demonstration that some parts of the environment become part of what control some behavioral responses not directly related to said stimulus (Knaus et al., 2021) gave rise to the question about how this new stimulus would gain its new function.

The mediated generalization hypothesis (described in chapter 03) intended to describe a process that would explain how the ladder would gain a discriminative function to the digging behavior without been directly related to any digging training. This hypothesis led to two assumptions tested by those two last experiments. The first concerns the idea that the absence of the ladder would be enough to not evocate the occurrence of crossing and digging in a situation where the connection between both sides were not available visually and no food reward was presented on the other side. The second assumption concerns the disruptive role of the rewarded crossing (without digging) upon the cue control exerted by the ladder.

Our findings demonstrated that the absence of the ladder was not enough to extinguish the occurrence of crossing and digging behavior. Its presence also had no significant impact on producing more digging and crossing behavior, a different result from Knaus and colleagues (2021). This may indicate that the ladder may play a function orienting digging towards it when the food is directly involved in the problem set, but its presence would not be enough to increase the frequency of digging in general.

The comparison of two different sets of training (one with a free rewarded crossing and the other with an non-rewarded crossing) demonstrated that almost no difference on exploration and in the digging-crossing association was noticeable, except for the difference on the exploration of the elevated platform. Due to the limitations on the number of subjects that were exposed to this experiment, the conclusions taken from this experiment may wait for further investigations. However, they may indicate a path to investigate the cue control operating on insight problem solving in sets with and without the use of reinforcement learning (by the use of the rewarded crossing).

Insight, Mediated Generalization and Learning transferences

Insight is said to rely on some type of transference of previous learning into novel behavior (Epstein et al., 1984; Shettleworth, 2012). The mediated generalization hypothesis was developed as a way to test this transference through this phenomenon. Mediated generalization can describe how instrumental responses can interchangeably appear in the presence of two sets of stimuli not directly paired, but individually paired to the same reinforcer.

Knaus and colleagues' (in preparation) findings were promising on showing the acquisition of a cue-function to the ladder in controlling digging behavior. The distinctions of the reversal learning demonstrated by insight and non-insight group (performed in chapter 02) also support the idea that some kind of distinction separates insight and non-insight solutions. Still, our findings do not offer a final answer to this query as we did not control for the directional component of the digging during the testing condition (justified by the aim of investigating the general cue-control of the ladder). Also, we did not observed a full extinction of the digging in the absence of the ladder, indicating that may there be other components of the testing setting that may evoke crossing and/or digging that – even in low rates – may be enough to produce exploration without the direct purpose of seeking a reward or a cue on the problem solving set.

After reaching these findings, an experimental design focusing on a multiple baseline that includes progressively more complex scenarios for the testing conditions could be explored in order to test for the minimum, desirable and best conditions for evoking insight-like solutions and, therefore, to test the conditions that facilitate or hinders the learning transferences that may underlie insight. Some variations of the trained used by Dicezare & Garcia-Mijares (submitted), may offer a better understanding on how the specific features of the testing condition may improve or disrupt insight solution. These seems now to be a best way to have complementary findings on the predictive power of mediated generalization as a primary process supporting insight solutions

CONCLUSIONS

1. The hypothesis of how mediated generalization could explain the transposition/transference/generalization was described. This hypothesis states that a class of stimuli united by the same reinforcer could interchangeably serve the function of cue for the same response.
2. Experiment 01 demonstrated that reversibility is a feature of insight, and it serves as evidence for the novel contextual control that emerges in insight learning.
3. Experiment 02 demonstrated that the absence of the ladder was not enough to extinguish the crossing and also not sufficient to increase the exploration of the testing setting as would be expected in an non-insight solution.
4. Experiment 03 demonstrated that reward was not enough to explain the differences between insight and non-insight solutions (described in chapter 02).
5. The accuracy and generality of the mediated generalization hypothesis remain up to empirical proof. However, it may serve as a path to test transferences of learning that may underly insight learning.

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Zentall, T.R., Urcuioli, P.J. Emergent Relations in the Formation of Stimulus Classes by Pigeons. *Psychological Record, 43*, 795–810 (1993). https://doi.org/10.1007/BF03395913.

APPENDIX A – APPROVAL FOR ETHICAL USE OF ANIMALS IN RESEARCH

INSTITUTO DE PSICOLOGIA
www.ip.usp.br

Comissão de Ética no Uso de Animais
Universidade de São Paulo

CERTIFICADO

Certificamos que a proposta intitulada "Resolução Criativa de Problemas e Flexibilidade Comportamental em um Ambiente Modificado e com Solução Alternativa em ratos", protocolada sob o CEUA nº 7796210318, sob a responsabilidade de **Miriam Garcia-Mijares** *e equipe; Luiz Henrique Santana Conceição* - que envolve a produção, manutenção e/ou utilização de animais pertencentes ao filo Chordata, subfilo Vertebrata (exceto o homem), para fins de pesquisa científica ou ensino - está de acordo com os preceitos da Lei 11.794 de 8 de outubro de 2008, com o Decreto 6.899 de 15 de julho de 2009, bem como com as normas editadas pelo Conselho Nacional de Controle da Experimentação Animal (CONCEA), e foi **aprovada** pela Comissão de Ética no Uso de Animais da Instituto de Psicologia da Universidade de São Paulo (CEUA/IPUSP) na reunião de 29/08/2018.

We certify that the proposal "Creative Problem Solving and Behavioral Flexibility in a Modified Environment and with an Alternative Solution in rats", utilizing 16 Heterogenics rats (16 males), protocol number CEUA 7796210318, under the responsibility of **Miriam Garcia-Mijares** *and team; Luiz Henrique Santana Conceição* - which involves the production, maintenance and/or use of animals belonging to the phylum Chordata, subphylum Vertebrata (except human beings), for scientific research purposes or teaching - is in accordance with Law 11.794 of October 8, 2008, Decree 6899 of July 15, 2009, as well as with the rules issued by the National Council for Control of Animal Experimentation (CONCEA), and was **approved** by the Ethic Committee on Animal Use of the Psychology Institute - Universidade de São Paulo (CEUA/IPUSP) in the meeting of 08/29/2018.

Finalidade da Proposta: Pesquisa (Acadêmica)

Vigência da Proposta: de 05/2018 a 01/2021　　Área: Psicologia Experimental

Origem:	Biotério do Instituto de Ciências Biomédicas da USP						
Espécie:	Ratos heterogênicos	sexo:	Machos	idade:	60 a 90 dias	N:	16
Linhagem:	Wistar			Peso:	250 a 350 g		

INSTITUTO DE PSICOLOGIA
www.ip.usp.br

Comissão de Ética no Uso de Animais
Universidade de São Paulo

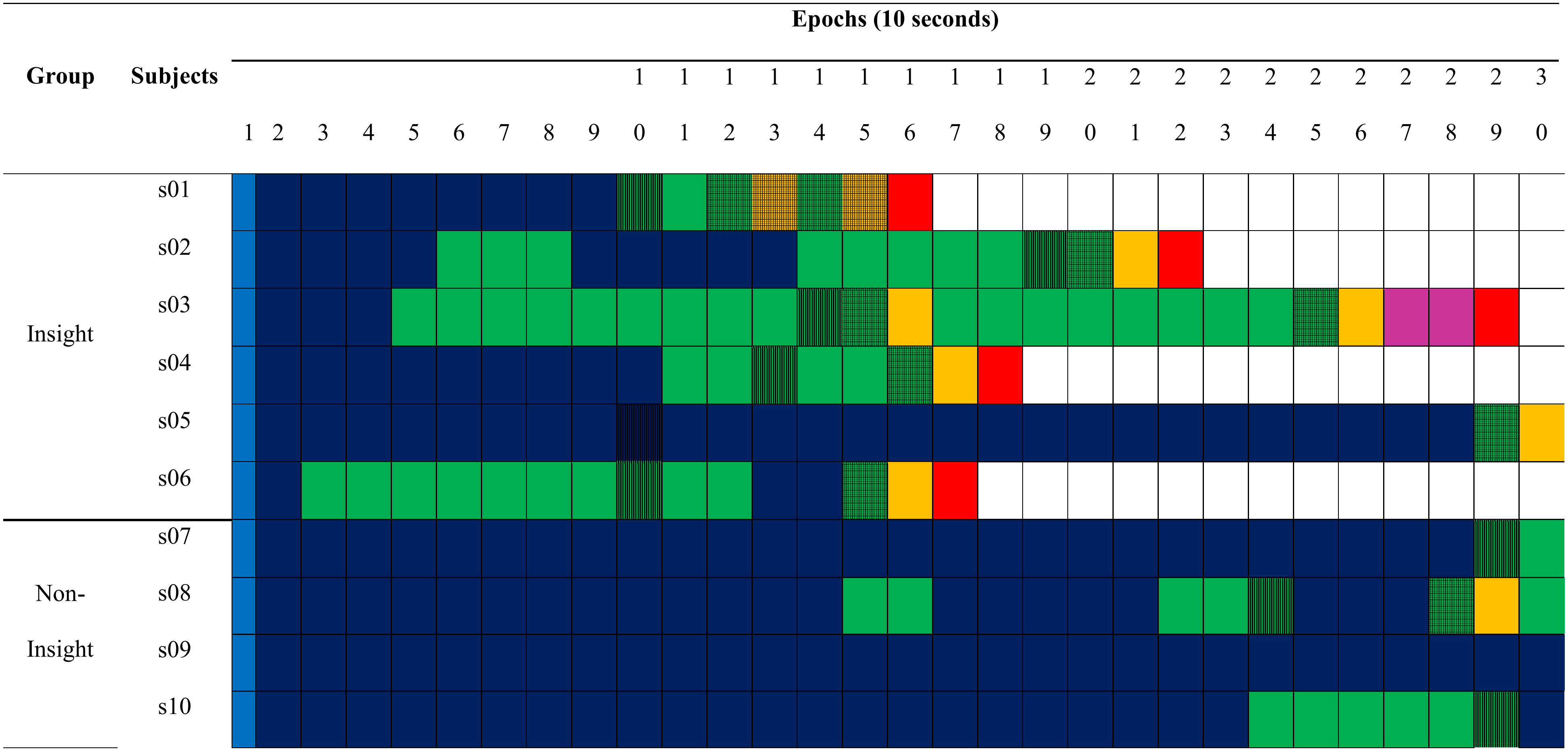
Profa.Dra. Miriam Garcia Mijares
Presidente em Exercício da Comissão de Ética no Uso de Animais
Instituto de Psicologia da Universidade de São Paulo

Em processo de indicação
Vice Presidente
Instituto de Psicologia da Universidade de São Paulo

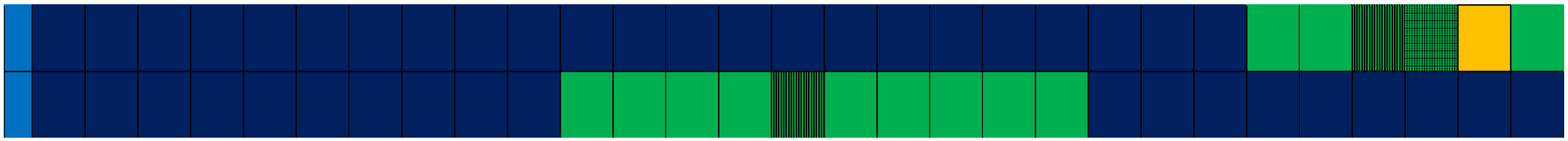
APPENDIX B – Individual Solutions of the Direct and Reversa lTests of Experiment 01 (Chapter 02).

Table 2.

Time series for Position and Relevant Behavior during the Direct Test (part 01)



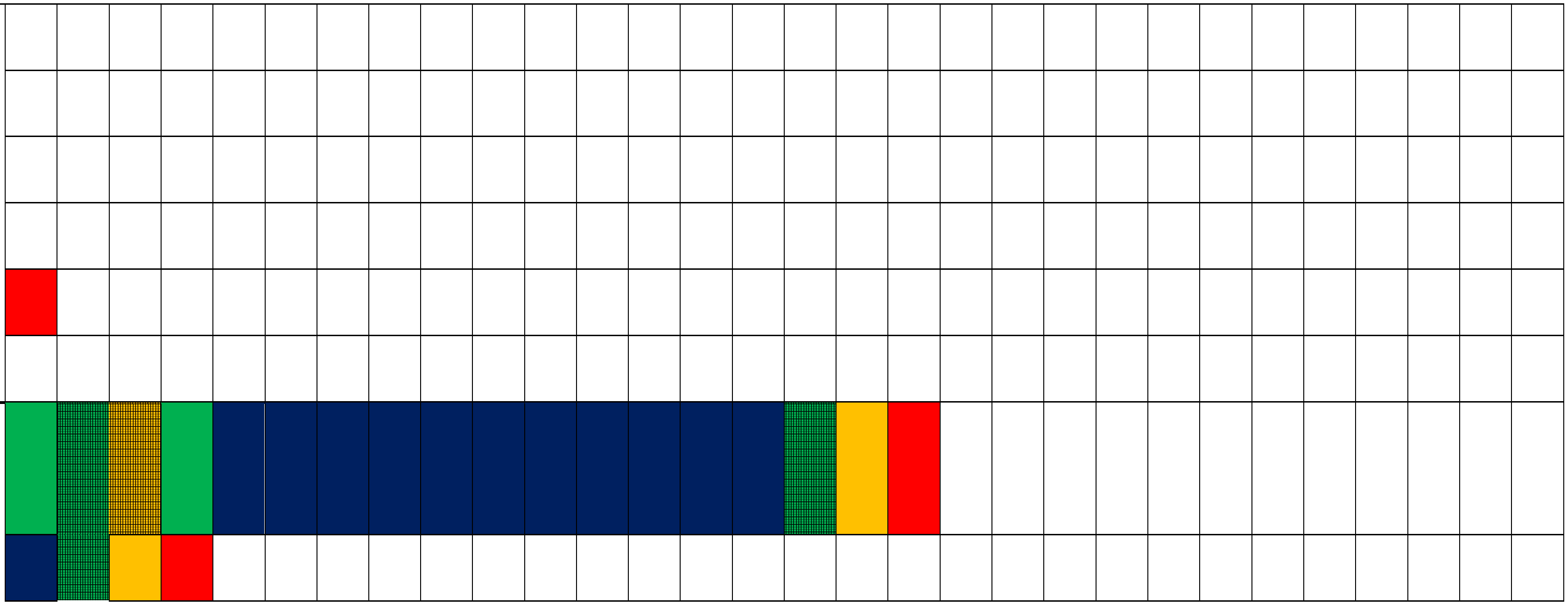
Group	**Subjects**	**Epochs (10 seconds)**																													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Insight	s01	🟦	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	▥	🟩	▦	▨	▦	▨	🟥	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜
	s02	🟦	⬛	⬛	⬛	⬛	🟩	🟩	🟩	⬛	⬛	⬛	⬛	⬛	🟩	🟩	🟩	🟩	🟩	▥	▦	🟨	🟥	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜
	s03	🟦	⬛	⬛	⬛	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	▥	▦	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	▦	🟨	🟪	🟪	🟥	⬜
	s04	🟦	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟩	🟩	▥	🟩	🟩	▦	🟨	🟥	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜
	s05	🟦	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	▤	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	▦	🟨
	s06	🟦	⬛	🟩	🟩	🟩	🟩	🟩	🟩	🟩	▥	🟩	🟩	⬛	⬛	▦	🟨	🟥	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜
Non-Insight	s07	🟦	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	▥	🟩
	s08	🟦	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟩	🟩	⬛	⬛	⬛	⬛	⬛	🟩	🟩	▥	⬛	⬛	⬛	▦	🟨	🟩
	s09	🟦	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛
	s10	🟦	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟩	🟩	🟩	🟩	🟩	▥	⬛



s11	🔹	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟩	🟩	▥	▦	🟨	🟩
s12	🔹	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟩	🟩	🟩	🟩	▥	🟩	🟩	🟩	🟩	🟩	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦

Table 4.

Time series for Position and Relevant Behavior during the Direct Test (part 02)



Group	Subjects	Epochs (10 seconds)																												
		31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Insight	s01																														
	s02																														
	s03																														
	s04																														
	s05	🟥																													
	s06																														
Non-Insight	s07	🟩	▦	▩	🟩	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	▦	🟨	🟥												
	s08	🟦	▦	🟨	🟥																										

s09	⬛	▥	⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟩	▩	🟨	🟪	▦	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟩	▩	🟨	🟥				
s10	⬛	⬛	⬛	⬛	⬛	▩	🟨	▦	▩	🟨	🟥																			
s11	⬛	⬛	⬛	⬛	⬛	⬛	▩	🟨	🟥																					
s12	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟩	▩	▦	🟩	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	▩	🟨	🟥						

Table 5

Time series for Position and Relevant Behavior during the Reversal Test (part 01)

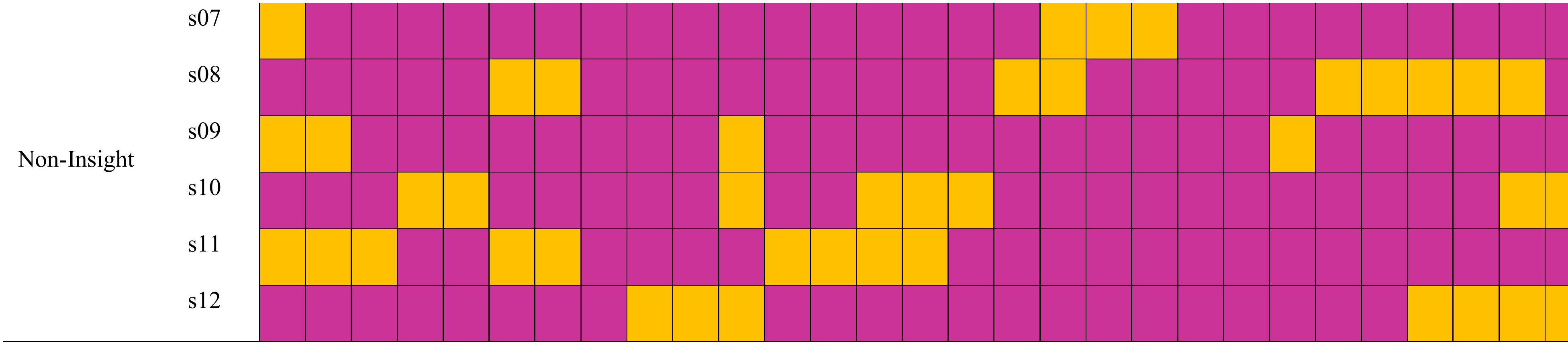
Group	Subjects	Epochs (10 seconds)																										
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Insight	s01	🟦	🟪	🟪	🟨	🟨	🟪	🟪	🟪	🟨	▦	🟩	🟥																
	s02	🟦	🟪	🟪	🟪	🟪	🟪	🟨	🟨	🟨	▦	🟥																	
	s03	🟦	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟨	▧	🟨	🟨	🟨	🟨	🟪	🟪	🟪	🟪	🟪	🟨	🟨	🟪	🟪	🟪	🟪	🟪	🟪
	s04	🟦	🟪	🟪	🟨	🟨	🟪	🟪	🟨	🟨	🟪	🟪	▦	🟥															
	s05	🟦	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟨	🟨	▦	🟩	🟥											
	s06	🟦	🟪	🟪	🟨	🟪	🟪	🟨	🟪	🟨	🟨	🟨	🟪	🟪	🟪	🟪	🟪	🟪	▦	🟩	⬛	🟩	🟥						
Non-Insight	s07	🟦	🟪	🟪	🟨	🟨	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟨	🟨	🟨	🟪	🟪	🟪	🟨	🟪	🟪	🟪	🟨	🟨	🟨	🟨	🟨	🟨
	s08	🟦	🟪	🟪	🟪	🟪	🟨	🟨	🟨	🟨	🟨	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟨	🟪	🟨	🟨	🟨	🟨	🟨	🟨	🟪

	s09	🟦	🟪	🟪	🟪	🟨	🟨	🟨	🟨	🟪	🟪	🟪	🟪	🟨	🟨	🟨	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟨	🟨	🟨	🟪	🟪	🟪	🟪
	s10	🟦	🟪	🟨	🟨	🟨	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟨	🟨	🟨	🟪	🟪	🟨	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟨	🟨
	s11	🟦	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟪	🟪	🟪	🟨	🟨	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
	s12	🟦	🟪	🟪	🟨	🟪	🟪	🟪	🟨	🟨	🟨	🟨	🟪	🟪	🟪	🟪	🟪	🟨	🟨	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟨	🟪

Table 6

Time series for Position and Relevant Behavior during the Reversal Test (part 02)

Group	**Subjects**	**Epochs (10 seconds)**																											
		31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	5
Insight	s01																													
	s02																													
	s03	🟪	🟪	🟪	🟪	🟪	🟨	▨	🟩	🟥																				
	s04																													
	s05																													
	s06																													



Non-Insight	s07	🟨	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟨	🟨	🟨	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
	s08	🟪	🟪	🟪	🟪	🟪	🟨	🟨	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟨	🟨	🟪	🟪	🟪	🟪	🟪	🟨	🟨	🟨	🟨	🟨	🟪
	s09	🟨	🟨	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟨	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟨	🟪	🟪	🟪	🟪	🟪	🟪
	s10	🟪	🟪	🟪	🟨	🟨	🟪	🟪	🟪	🟪	🟪	🟨	🟪	🟪	🟨	🟨	🟨	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟨	🟨
	s11	🟨	🟨	🟨	🟪	🟪	🟨	🟨	🟪	🟪	🟪	🟪	🟨	🟨	🟨	🟨	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
	s12	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟨	🟨	🟨	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟨	🟨	🟨	🟨

Starting position	🟦
Q1	■
Q2	🟩
Q3	🟨
Q4	🟪
Target reach (finished)	🟥
Crossing	▦
Digging	▥

Figure 4. Identification of the marks for Tables 3, 4, 5 and 6.

ATTACHMENT C – Individual performance in Experiment 03

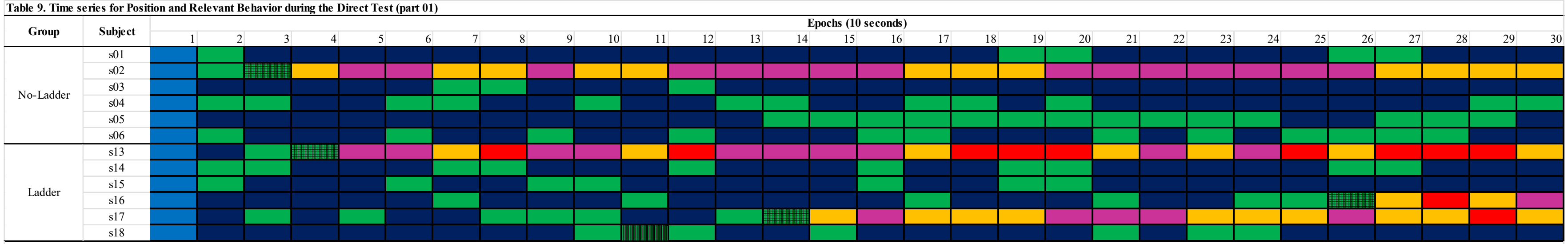


Table 9. Time series for Position and Relevant Behavior during the Direct Test (part 01)

Group	Subject	Epochs (10 seconds)																													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
No-Ladder	s01	🟦	🟩	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟩	🟩	⬛	⬛	⬛	⬛	⬛	🟩	🟩	⬛	⬛	⬛
	s02	🟦	🟩	▦	🟨	🟪	🟪	🟨	🟨	🟪	🟨	🟨	🟪	🟪	🟪	🟪	🟪	🟨	🟨	🟨	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟨	🟨	🟨	🟨
	s03	🟦	⬛	⬛	⬛	⬛	⬛	🟩	🟩	⬛	⬛	⬛	🟩	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛
	s04	🟦	🟩	🟩	⬛	⬛	🟩	🟩	⬛	⬛	🟩	⬛	⬛	🟩	🟩	⬛	⬛	🟩	🟩	⬛	🟩	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟩	🟩
	s05	🟦	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	⬛	⬛	🟩	🟩	🟩	⬛
	s06	🟦	🟩	⬛	⬛	⬛	🟩	⬛	⬛	🟩	⬛	⬛	🟩	⬛	⬛	⬛	🟩	🟩	⬛	⬛	⬛	🟩	⬛	🟩	⬛	🟩	🟩	🟩	🟩	⬛	⬛
Ladder	s13	🟦	⬛	🟩	▦	🟪	🟪	🟨	🟥	🟪	🟪	🟨	🟥	🟪	🟪	🟪	🟪	🟨	🟥	🟥	🟥	🟨	🟪	🟨	🟪	🟥	🟨	🟥	🟥	🟥	🟨
	s14	🟦	🟩	🟩	⬛	⬛	⬛	🟩	🟩	⬛	⬛	⬛	🟩	⬛	⬛	⬛	🟩	⬛	⬛	🟩	🟩	⬛	⬛	⬛	⬛	⬛	🟩	🟩	⬛	⬛	⬛
	s15	🟦	🟩	⬛	⬛	⬛	🟩	⬛	⬛	🟩	🟩	⬛	⬛	⬛	⬛	⬛	🟩	⬛	⬛	🟩	🟩	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛
	s16	🟦	⬛	⬛	⬛	⬛	⬛	🟩	⬛	⬛	⬛	🟩	⬛	⬛	⬛	⬛	⬛	🟩	⬛	⬛	⬛	🟩	⬛	⬛	🟩	🟩	▦	🟨	🟥	🟨	🟪
	s17	🟦	⬛	🟩	⬛	🟩	⬛	⬛	🟩	🟩	🟩	⬛	⬛	🟩	▦	🟨	🟪	🟨	🟨	🟨	🟪	🟪	🟪	🟨	🟨	🟨	🟪	🟨	🟨	🟥	🟨
	s18	🟦	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟩	▥	🟩	⬛	⬛	🟩	⬛	⬛	⬛	⬛	⬛	🟩	⬛	🟩	🟩	⬛	⬛	⬛	⬛	⬛	⬛

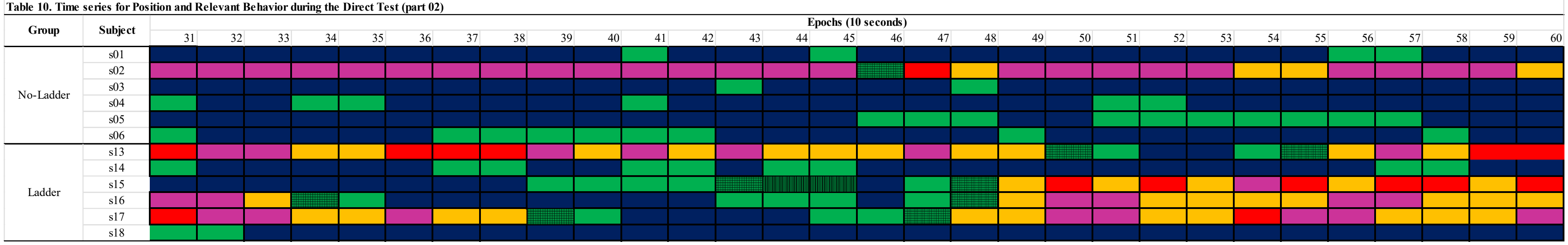
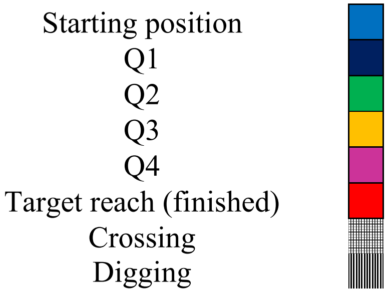


Table 10. Time series for Position and Relevant Behavior during the Direct Test (part 02)

Group	Subject	Epochs (10 seconds)																													
		31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
No-Ladder	s01	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟩	⬛	⬛	⬛	🟩	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟩	🟩	⬛	⬛	⬛
	s02	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	▦	🟥	🟨	🟪	🟪	🟪	🟪	🟪	🟨	🟨	🟪	🟪	🟪	🟪	🟨
	s03	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟩	⬛	⬛	⬛	⬛	🟩	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛
	s04	🟩	⬛	⬛	🟩	🟩	⬛	⬛	⬛	⬛	⬛	🟩	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟩	🟩	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛
	s05	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟩	🟩	🟩	⬛	⬛	🟩	🟩	🟩	🟩	🟩	🟩	🟩	⬛	⬛	⬛
	s06	🟩	⬛	⬛	⬛	⬛	⬛	🟩	🟩	🟩	🟩	🟩	🟩	⬛	⬛	⬛	⬛	⬛	⬛	🟩	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟩	⬛	⬛
Ladder	s13	🟥	🟪	🟪	🟨	🟨	🟥	🟥	🟥	🟪	🟨	🟪	🟨	🟪	🟨	🟨	🟨	🟪	🟨	🟨	▦	🟩	⬛	⬛	🟩	▦	🟨	🟪	🟨	🟥	🟥
	s14	🟩	⬛	⬛	⬛	⬛	⬛	🟩	🟩	⬛	⬛	🟩	🟩	⬛	🟩	🟩	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟩	🟩	⬛	⬛
	s15	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟩	🟩	🟩	🟩	▦	▥	▥	⬛	🟩	▦	🟨	🟥	🟨	🟥	🟨	🟪	🟥	🟨	🟥	🟥	🟨	🟥
	s16	🟪	🟪	🟨	▦	🟩	⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟩	🟩	🟩	⬛	🟩	▦	🟨	🟪	🟪	🟨	🟨	🟨	🟨	🟪	🟪	🟨	🟨	🟨
	s17	🟥	🟪	🟪	🟨	🟨	🟪	🟨	🟨	▦	🟩	⬛	⬛	⬛	⬛	🟩	🟩	▦	🟨	🟨	🟪	🟪	🟨	🟨	🟥	🟪	🟪	🟨	🟨	🟨	🟪
	s18	🟩	🟩	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛



Starting position	🟦
Q1	⬛
Q2	🟩
Q3	🟨
Q4	🟪
Target reach (finished)	🟥
Crossing	▦
Digging	▥

Figure 4. Identification of the marks for Tables 3, 4, 5 and 6.

ATTACHMENT C – Individual performance in Experiment 03

Table 13. Time series for Position and Relevant Behavior during the Direct Test (part 01)

Group	Subject	Epochs (10 seconds)																													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Rwd Crossing	s01	🟦	🟩	⬛	⬛	🟩	⬛	🟩	⬛	🟩	⬛	⬛	🟩	⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟩	⬛	🟩	⬛	🟩	⬛	⬛	⬛	🟩	🟩	⬛
	s02	🟦	▦	🟪	🟪	🟪	🟨	🟪	🟪	🟥	🟥	🟪	🟪	🟨	🟨	🟥	🟨	▦	⬛	🟩	⬛	⬛	⬛	▦	🟨	🟪	🟪	🟪	🟪	🟪	🟪
	s03	🟦	⬛	▦	🟪	🟪	🟨	🟪	🟪	🟪	🟨	🟥	🟪	🟥	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟨	🟨	🟪	🟪	🟨	🟪	🟪
	s04	🟦	⬛	⬛	🟩	🟩	🟩	⬛	▦	🟨	🟪	🟪	🟪	🟪	🟪	🟪	🟨	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟨	🟨	🟨	🟨	🟨	🟪
Non-Rwd Crossing	s05	🟦	▦	🟨	🟪	🟪	🟪	🟪	🟪	🟨	🟨	🟥	🟪	▦	🟩	⬛	⬛	⬛	▦	🟨	🟨	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
	s06	🟦	🟩	⬛	⬛	🟩	⬛	▦	🟥	🟥	🟪	🟨	🟨	▦	⬛	⬛	⬛	🟩	▦	🟨	🟨	🟥	🟥	🟥	🟥	🟥	🟥	🟨	🟪	🟪	▦
	s07	🟦	⬛	⬛	⬛	🟩	▦	🟨	🟪	🟨	🟥	🟥	🟥	🟨	🟨	▦	🟩	⬛	▦	🟨	🟪	🟪	🟥	🟥	🟥	🟨	🟥	🟥	🟨	🟨	🟨
	s08	🟦	⬛	🟩	⬛	🟩	⬛	⬛	🟩	▦	▦	🟨	🟪	🟨	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟪	🟨	🟨	🟨	🟨	🟥	🟨	🟨	🟪	🟨

Table 14. Time series for Position and Relevant Behavior during the Direct Test (part 02)

Group	Subject	Epochs (10 seconds)																													
		31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Rwd Crossing	s01	🟩	🟩	⬛	⬛	⬛	⬛	🟩	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟩	⬛	⬛	🟩	⬛	⬛	⬛	⬛	⬛	⬛
	s02	🟪	🟪	🟨	🟨	🟨	🟨	🟥	🟪	🟪	🟪	🟪	🟨	▦	🟩	▦	🟪	🟪	🟪	🟨	🟨	🟨	🟨	🟪	🟥	🟪	🟪	🟪	🟪	🟪	🟪
	s03	🟨	🟨	🟥	🟨	🟪	🟪	🟨	🟨	🟨	🟪	🟪	🟪	🟪	🟪	🟪	🟨	🟪	🟪	🟨	🟨	🟨	🟪	🟪	🟪	🟪	🟨	🟨	🟪	🟪	🟪
	s04	🟪	🟪	🟪	🟪	🟨	🟨	🟨	🟨	🟨	🟪	🟪	🟨	🟨	🟪	🟪	🟪	🟪	🟪	🟨	🟨	🟨	🟨	🟨	🟪	🟨	🟨	🟨	🟪	🟨	🟨
Non-Rwd Crossing	s05	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟨	🟨	🟥	🟪	▦	🟩	⬛	⬛	▦	🟨	🟨	🟥	🟪	▦	⬛	⬛	▦	🟨	🟥	🟥	🟥	🟥
	s06	⬛	⬛	⬛	▦	🟨	🟪	🟨	🟨	🟥	🟥	🟥	🟥	🟥	🟪	🟪	🟨	🟥	🟪	🟪	🟨	▦	⬛	⬛	🟩	🟩	⬛	⬛	⬛	⬛	⬛
	s07	🟨	🟨	🟨	🟪	🟨	🟨	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟨	🟨	🟥	🟨	🟨	🟥	🟨	🟨	🟥	🟥	🟥	🟥
	s08	🟨	🟪	🟪	🟪	🟪	🟨	🟨	🟨	🟨	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟨	🟪	🟨	🟨	🟨	🟪	🟨	🟪	🟪	🟨

Starting position	🟦
Q1	⬛
Q2	🟩
Q3	🟨
Q4	🟪
Target reach (finished)	🟥
Crossing	▦
Digging	▥

Figure 4. Identification of the marks for Tables 3, 4, 5 and 6.