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Estado de Humor e Conteúdo emocional na memória de trabalho: A função do Executivo Central e do Detector Hedônico

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Tese apresentada à Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto da USP, como parte das exigências para a obtenção do título de Doutor em Ciências. Área: Psicobiologia.

Orientador: Prof. Dr. César Alexis Galera
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DEDICATÓRIA

Para meus pais, Tida e José. E, especialmente
ao meu pai que sempre acreditou em mim

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Primeiramente, gostaria de agradecer imensamente a minha família por todo o suporte e motivação durante todos esses anos. Á minha mãe, Tida, por todo o carinho, eu sou grata por tê-la sempre ao meu lado nos momentos alegres e difícieis. Ao meu pai, José, que sempre me incentivou a trilhar esse caminho e que acreditou em mim, e mesmo que não esteja mais conosco, eu não poderia ser mais grata por todo o seu incentivo e apoio. Gostaria de agradecer à minha irmã, Angélica, pela fraternidade e amizade que transcende os laços de sangue, e ao meu irmão Lúcio, pelo apoio e carinho.

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“An impression may be so exciting emotionally as almost to leave a *scar* upon the cerebral tissue” (James, 1890)

Lista de Referências:

James, W. (1890). *The principles of psychology* (Vol. 1).

RESUMO

Valenti, L (2020). Efeito do estado de Humor e Conteúdo emocional na memória de trabalho: A função do Executivo central e do Detector Hedônico. Tese de Doutorado, Programa de Pós-Graduação em Psicobiologia da Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto, Universidade de São Paulo.

Diversos estudos mostram que o processamento afetivo depende das conexões entre os aspectos emocionais do estímulo e as funções cognitivas. O objetivo do presente trabalho foi investigar a dinâmica da relação entre os componentes da memória de trabalho e da emoção. Nos dois primeiros estudos, analisou-se a influência de mecanismos cognitivos sobe a memorização de estímulos emocionais e, em um terceiro estudo, avaliou-se o efeito da emoção sobre a realização de tarefas cognitivas. No Estudo 1, a função da atenção (Executivo Central) no reconhecimento de faces foi analisada em um paradigma de tarefa dupla. Os resultados do primeiro estudo foram explorados no Estudo 2 que teve como objetivo investigar a interdependência da carga de memória e da atenção em tarefas de memória de trabalho e de percepção com faces de expressão emocional. Os resultados mostram que a atenção tem um papel relevante ao priorizar os estímulos emocionais, mas que depende de outros mecanismos como a percepção e carga da memória. No Estudo 3, analisamos a influência da emoção (Detector Hedônico) no desempenho de atividades de raciocínio por meio da indução de estados de humor negativos. Os resultados do Estudo 3 mostram que não houve um efeito do humor na realização de tarefas de memória de trabalho. As implicações conceituais e práticas dos resultados dos três estudos foram abordadas e discutidos no presente trabalho.

Palavras-chave: memória de trabalho, atenção, estado de humor, emoção.

ABSTRACT

Valenti, L (2020). Effect of mood and emotional content on working memory: The role of the Central Executive and the Hedonic Detector. Doctoral Thesis, Graduate Program in Psychobiology of the Ribeirão Preto School of Philosophy, Science and Literature, University of São Paulo.

Several studies show that affective processing depends on the connections between the emotional aspects of the stimulus and cognitive functions. The present study aimed to investigate the dynamics of the relationship between working memory components and emotion. In the first two studies, the influence of cognition mechanisms on the memorization of emotional stimuli was analyzed and, in the third study, the effect of emotion in cognitive tasks performance was evaluated. In Study 1, the role of attention (Central Executive) in a face recognition task was analyzed in a dual-task paradigm. The results of the first study were explored in Study 2 that aimed to investigate the interdependence of memory and attention load in tasks of working memory and perception with faces of emotional expression. The results revealed that attention plays an important role in prioritizing emotional stimuli, but it depends on other mechanisms such as perception and memory load. In Study 3, we analyzed the influence of emotion (Hedonic Detector) on the performance of reasoning activities through the induction of negative mood states. The results of Study 3 are exploratory and show that there was no effect of mood on the performance of working memory tasks. The conceptual and practical implications of the results of the three studies were addressed and discussed in the present study.

Keywords: working memory, attention, mood states, emotion.

SUMÁRIO

Introdução Geral

A memória de trabalho é um sistema cognitivo de armazenamento breve e de processamento presente em praticamente todas as atividades cognitivas, desde as mais simples—como a leitura ou a compreensão da fala—até as mais complexas—como a aprendizagem, o raciocínio ou a tomada de decisão em situações de risco (Baddeley, 2010). No modelo de memória de trabalho proposto inicialmente por Baddeley e Hitch (1974) e posteriormente atualizado por Baddeley (1986, 2000, 2007), essas atividades cognitivas eram suportadas por um sistema de controle da atenção—o executivo central—e por três armazenadores—o laço fonológico, o esboço visuoespacial e o armazenador multimodal ou *buffer episódico*. Recentemente, o processamento do conteúdo emocional na memória de trabalho e a interferência do estado de humor em seus subcomponentes (Kensinger & Corkin, 2003; Mikels et al., 2008, para uma revisão, ver Baddeley, 2007) foram incorporadas ao modelo de memória de trabalho através de um novo componente, o detector hedônico (Baddeley et al., 2012).

Componentes da Memória de Trabalho

Um dos componentes mais investigado no modelo de memória de trabalho de Baddeley é o laço fonológico (Baddeley, 2007). Considera-se que o laço fonológico é formado por dois componentes: um armazenador temporário e um sistema de recitação subvocal de natureza articulatória. Diferente do laço fonológico, o esboço visuoespacial foi proposto como um sistema de armazenamento capaz de integrar a informação visual e espacial em uma representação unitária (Baddeley, 1986). O sistema de controle da atenção—o executivo central—é o responsável pelo gerenciamento das operações e processos que ocorrem nos armazenadores—o esboço visuoespacial, o laço fonológico e o *buffer episódico*—considerados como sistemas subsidiários (ou “escravos”) (Baddeley, 2000). Considerado como um sistema supervisor, o executivo central é um componente amodal do modelo de memória de trabalho, que controla as atividades dos sistemas “escravos” (Baddeley, 1986) e atua como um supervisor da atenção ao direcionar e controlar o foco da atenção (Oliveira, 2007; Cattaneo et al., 2006, pp. 101–103).

O executivo central fornece ao *buffer episódico* acesso às informações advindas dos demais componentes da memória de trabalho, da percepção ou da memória de longo-prazo (Baddeley, 2000). O *buffer episódico* é um armazenador de capacidade limitada que integra as informações provenientes de sistemas subsidiários da memória de trabalho e da memória de longo prazo, tais como informações fonológicas, visuais ou espaciais. As informações combinadas formam uma representação multimodal e temporal. As informações semânticas são representações multimodais que podem apresentar características de valência emocional, tornando o *buffer episódico* o armazenador de informações emocionais da memória de trabalho (Baddeley, 2007, Mikels et al, 2008). É através deste componente, controlado pelo executivo central, que as informações presentes nos outros subcomponentes, assim como as informações recuperadas da memória de longo prazo, podem ser inspecionadas e têm acesso à consciência.

Ao considerar que a informação semântica e as representações com conteúdo emocional (valência) são armazenadas no *buffer episódico*, direcionamos o estudo da memória de trabalho para um novo âmbito, o da emoção. Para acomodar esse novo tipo ou dimensão da informação, Baddeley et al. (2012) propõem um sistema chamado de detector hedônico, que depende da memória de trabalho, particularmente do executivo central, e que manipula a informação afetiva (hedônica). Baddeley (2007) propôs o detector hedônico a partir do conceito de marcador somático de Damásio (2009), que é associado ao processo de decisão ao auxiliar no destaque de algumas opções do ambiente, como um sistema de qualificação automática que colabora na filtragem dos aspectos mais relevantes dos estímulos. De acordo Damásio (2015, 2009), a função do marcador somático é direcionar a atenção para a consequência futura de determinada ação e atuar como um sinal de perigo automático ao se escolher a opção que terá resultados negativos. Em outras palavras, o detector hedônico não somente permite identificar estímulos potencialmente perigosos e negativos, como possibilita tomar decisões e agir em função das consequências emocionais. Para Baddeley (2007), o componente hedônico é responsável pela percepção e manutenção de julgamentos de estímulos com valência emocional. Estes julgamentos são baseados em associações dos estados de negatividade e positividade a representações por meio da aprendizagem (utiliza-se da memória de longo-prazo) e em associações dessas representações a consequências futuras (Damásio, 2009). Portanto, o detector hedônico funciona como um sistema perceptual simples, que capta associações positivas ou negativas—a partir de um estímulo ou representações semânticas armazenadas no *buffer episódico*—e mantém tais associações ou julgamentos que serão utilizadas para a tomada de decisões ou avaliação de ações futuras.

Considerado como um marcador somático que auxilia na tomada de decisões futuras ao qualificar automaticamente os cenários diante de nós, o detector pode ser influenciado por diversos fatores, desde os genéticos ou farmacológico, até eventos externos. Indivíduos com depressão, por exemplo, apresentam uma tendência de recordar eventos negativos, o que pode refletir uma disfunção no detector, de modo que o estado de humor depressivo pode resultar na percepção negativa de um evento neutro (Baddeley et al., 2012). Portanto, o estado de humor em indivíduos saudáveis ou clínicos (ex.: depressão, bipolaridade, etc.) afeta diretamente a capacidade de avaliação do detector, que é sensível a mudanças nos níveis dos estados somáticos (de humor) que influenciam a memória de trabalho e a atenção no que se refere ao julgamento de cenários futuros.

Os Componentes da Memória de Trabalho e a Emoção

O conceito de marcador hedônico traz novas implicações para o papel da emoção na tomada de decisões. Baddeley (2007) atribui ao componente hedônico a capacidade de interferir em situações complexas e nas ações subsequentes advindas do julgamento hedônico. Estudos prévios que investigaram a influência do estado de humor na memória de trabalho, como na avaliação e escolha de estratégias, confirmam essa possível associação entre processos cognitivos e emocionais (Jung et al., 2014; Mikels et al., 2008). Por exemplo, o estado de humor negativo pode interferir na recuperação de informações da memória (congruentes com o estado emocional) e com a probabilidade de realizar determinados julgamentos; esse humor então resulta em análises distorcidas e efeitos negativos para a tomada de decisão (Wright & Bower, 1992). O impacto do estado negativo na cognição pode reduzir a capacidade da memória de trabalho, por meio da escolha de estratégias menos elaboradas, e a avaliação de informações do ambiente, isto é, a avaliação da complexidade do contexto que envolve a tomada de decisão (Isen et al., 1982, pp. 257–259). Em contrapartida, o estado de humor positivo pode aumentar a capacidade da memória de trabalho ao aumentar a flexibilidade cognitiva e desencadear a avaliação de diversificadas perspectivas ou metas (Carpenter et al., 2013).

Para além da influência dos estados emocionais na memória, os processos cognitivos também interferem de modo recíproco na manutenção afetiva (Mikels, et al. 2008). Por exemplo, uma alta carga cognitiva pode comprometer o processamento emocional. Em Mikels et al. (2008), os autores mostraram a interferência de uma tarefa de memória de trabalho no julgamento da intensidade afetiva de um estímulo emocional (e.g., ver Experimento 2). Ressalta-se que as tarefas cognitivas ainda tiveram um efeito facilitador na tarefa de avaliação e percepção da carga afetiva. De acordo os autores, tais achados sugerem que os processos cognitivos têm um efeito modulador nas reações afetivas, as quais podem ser amenizadas quando outros processos atencionais (i.e., tarefas da memória de trabalho) estão envolvidos.

Evidências robustas corroboram a hipótese de que a memória de trabalho contribui para a autorregulação da emoção por meio da inibição ou redirecionamento da atenção para estímulos com alta relevância emocional ou motivacional (Lipp & Derakshan, 2005; Phelps et al., 2006; para uma revisão ver Yiend, 2010). Um exemplo desse funcionamento é reportado em pacientes com transtorno depressivo que apresentam maior direcionamento da atenção para estímulos negativos (Leyman et al., 2007). Em vista desse contexto, Baddeley et al. (2012) sugerem uma efetiva participação de processos atencionais no controle e foco do componente hedônico. No entanto, a relação entre processos atencionais e o componente emocional na memória de trabalho ainda não é clara. Nos últimos anos, discussões sobre a relação entre emoção e processos atencionais e a memória de trabalho têm sido beneficiadas por um grande volume de estudos, mas continuam existindo muitas questões a serem respondidas, tais como a dependência de recursos atencionais para o processamento prioritário de estímulos emocionais e a interdependência desse processo com a capacidade da memória de trabalho. Os estudos reportados nesse trabalho tratam dessas lacunas empíricas.

Apresentação dos Estudos

A presente pesquisa foi dividida em três estudos que abrangem a relação entre emoção e memória de trabalho. Nos Estudos 1 e 2 (realizados no Brasil e Reino Unido, respectivamente), investigamos a influência da cognição no processamento das emoções na memória de trabalho. No Estudo 3, avaliamos o efeito da emoção em tarefas de raciocínio.

No primeiro estudo, manipulamos a carga da atenção em um paradigma de tarefas duplas—apresentamos a tarefa de reconhecimento de faces de emoção (i.e., memória de trabalho) como tarefa principal com carga única de memória (dois estímulos), e a tarefa de contagem de tons graves (i.e., tarefa da atenção) como tarefa secundária. Na tarefa de atenção, uma sequência de tons agudos e graves (i.e., carga alta) ou de ruídos brancos (i.e., carga baixa) foi apresentada durante toda a tarefa de memória de trabalho. Na tarefa de memória, duas faces de expressão emocional (i.e., raiva, alegria, tristeza, neutra) foram apresentadas na codificação e uma face de valência emocional (Experimento 1) ou neutra

(Experimento 2) foi apresentada no teste, de maneira a verificar se os resultados podem ser generalizados para essas duas maneiras de testar o reconhecimento de faces emocionais utilizadas pela literatura. O participante deveria responder se a face-teste tinha uma identidade igual ou diferente das faces memorizadas. Os resultados desse Estudo 1 mostraram que o reconhecimento de faces com expressão emocional depende de recursos atencionais, no entanto, a demanda da atenção é reduzida (Experimento 1) ou praticamente nula (Experimento 2) para as faces de alegria. A menor carga da atenção direcionada para o processamento das faces de alegria indica uma cofidicação/manutenção mais automática das faces positivas em comparação às faces negativas. O uso da face-teste com expressão emocional (Experimento 1) ou neutra (Experimento 2) resultou em diferentes padrões de desempenho, indicando que o reconhecimento usando expressões neutras é mais difícil de maneira geral, com maior prejuízo para reconhecer as faces codificadas com expressão de alegria. Dado a maior diferença perceptual entre faces neutras e de alegria do que entre faces neutras e de tristeza e raiva, é preciso considerar que nossos resultados também refletem fatores perceptuais, conforme investigado e demonstrado no Estudo 2.

O Estudo 2 também realizou dois experimentos e estendeu a investigação do processamento de faces com expressão emocional na memória de trabalho. Com base em estudos prévios da literatura, o segundo estudo explorou a influência da carga de memória e da atenção na emoção. O estudo foi desenvolvido na Universidade de Aberdeen durante a bolsa de pesquisa no exterior e foi supervisionado pela professora Dra. Margaret Jackson, que tem pesquisas e publicações na área de emoção com carga de memória de trabalho. O objetivo da pesquisa foi investigar a inter-relação entre as funções cognitivas, de carga da atenção e da memória, no processamento das emoções, a partir do mesmo paradigma metodológico do Estudo 1.

No Estudo 2, manipulamos a carga de memória: uma face (i.e., carga baixa) ou três faces (i.e., carga alta) de expressão emocional (i.e., raiva, alegria, tristeza) foram apresentadas na tarefa de reconhecimento utilizando faces-teste com expressões neutras (Experimento 1). Para maior exploração dos fatores cognitivos e perceptuais, a influência da percepção emocional também foi investigada em uma tarefa de discriminação de faces de emoção (i.e., tarefa de percepção) com as mesmas condições de carga de atenção (Experimento 2).

Os resultados do Experimento 1 mostraram que as faces de tristeza foram menos prejudicadas pela alta carga de atenção e, ao contrário do efeito da atenção, a carga de memória afetou mais as faces de raiva e tristeza do que a de alegria. No Experimento 2, os resultados mostraram que os participantes discriminaram melhor as faces de tristeza da face neutra (i.e., face-teste), e que a discriminação de faces de alegria é mais difícil, indicando que de fato é mais difícil parear faces neutras às de alegria. Esse resultado indica que o processamento perceptual pode ter influenciado a resposta dos participantes na tarefa de memória de trabalho no Experimento 1 e no Estudo 1. Em geral, os resultados dos Estudos 1 e 2 mostram que a carga da atenção e memória interagem e, tem efeitos distintos no reconhecimento das faces de expressão emocional.

No Estudo 3, investigamos o efeito da emoção em tarefas de raciocínio por meio da indução de humor negativo. As tarefas de raciocínio foram baseadas na tarefa de raciocínio gramatical de Baddeley e Hitch (1974) e na tarefa de raciocínio visuo-espacial do estudo de Shah e Miyake (1996). Os resultados mostram que a indução de humor negativo não afetou o desempenho dos participantes.

Considerações Éticas

Todos os participantes, em cada Estudo, foram informados sobre sua participação voluntária por meio do Termo de Consentimento Livre e Esclarecido (TCLE) aprovado pela Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto da Universidade de São Paulo (**Anexo A**) e pelo Departamento de Psicologia da Universidade de Aberdeen (**Anexo B** e **C**).

Attentional Effects on Emotional Content in Working Memory (Study 1)

Abstract

Emotion influences the storage of information in working memory due to attentional focus on emotional stimuli. In this study, we investigated the role of attentional resources in the processing of emotional information on working memory. In Experiment 1 and 2, participants memorized two faces arrays with the same emotion but different identities and were required to judge whether the test face had the same identity as one of the previous faces. Simultaneously to this task, a sequence of high-or-low pitched tones (high attentional load) or white noise bursts (low attentional load) was presented and the participants were required to count how many low-tones were heard. Experiment 1 results showed a significant impairment in recognition of emotional faces in the high load but a marginal impairment on happy faces. Happy faces were better recognized than other emotional faces when attention resources were depleted. In Experiment 2, we investigated whether the emotional face in the test would have affected the retrieval process. Participants performed the same task but with a neutral face test. Results revealed only an impairment on negative faces and the worst performance on happy faces in a low load. This evidence suggests an attentional influence but also shows that an emotion boost on memory depends on another cognitive factor.

Keywords: Visual working memory; attention; face recognition; emotion.

Introduction

The evaluation of emotional situations in everyday life is essential to planning and predicting behavioural responses and making decisions as to avoid or escape dangerous or stressful environment. The capacity to perceive and process emotional signs depends on differential processing of information in working memory (Brosch et al., 2013; Dolan, 2002; Yiend, 2010).

Previous studies have investigated the influence of the effects of emotion on attention and working memory capacity, mostly focusing on the response to threatening stimuli (Leyman et al., 2007; Lipp & Derakshan, 2005; Phelps et al., 2006). For instance, evidence has shown a modification of the automatic processing in primary areas of the visual cortex when faces of fear are presented, directing attention to the aversive stimuli and then, increasing the perception and selection of faces or fear. The direction of attention to negative stimuli and its prioritization indicates a negative bias in memory (Phelps et. al, 2006). Lipp and Derakshan (2005) also found attention driven by aversive stimuli, such as images of snakes and spiders, in visual attention tasks (dot probe-task), suggesting a negative bias in healthy individuals. Evidence also shows an attention bias for negative stimuli related to a depressed mood, with depressed patients having greater maintenance and engagement of attention towards angry faces than to neutral faces (Leyman et. al., 2007).

On the other hand, studies have also reported a positive bias in emotional processing in healthy individuals, indicating the prioritization of the positive content (for a review see Yiend, 2010). Furthermore, the direction of attention towards emotional stimuli has been linked to the priority processing of emotional information in working memory. For example, Linden et al. (2011) investigated whether depressed patients have an emotional bias in a working memory task and found that depressed individuals better recognize faces of sadness compared with other negative and positive faces. This negative bias in memory has been found not only in depressed mood individuals (Gotlib et al., 1988; Ridout et al., 2003) but also in healthy individuals (Bradley et al., 1995; Jackson et al., 2014).

The role of attention during the processing of emotional stimuli in memory was also addressed by Talmi et al. (2007), who investigated whether the availability of attentional resources would mediate the processing of emotional stimuli (i.e., positive, negative and neutral pictures) and the emotional bias effect in memory. Using a dual-task procedure to manipulate the availability of attentional resources (i.e. full or divided attention conditions), the results showed distinct effects of attention depending on the valence of the stimuli. In particular, the results showed that high attentional load impaired memory for positive stimuli, but not for negative stimuli, suggesting the automatic processing of negative stimuli and attentional mediation in the memorization of positive stimuli.

The studies reviewed so far suggest that events or objects with emotional valence tend to be selected and processed with higher priority compared to stimuli with neutral valence, but this boost of emotional information in memory may vary according to different task procedures and conditions (Pessoa, 2009; Pessoa, Kastner, et al., 2002), for example, the positive or negative emotional prioritization depends on the perception of this content as relevant to the selection of attention (Yiend, 2010). Another relevant aspect to consider is the emotional nature of the stimuli used during the retrieval of information, as studies varied according to the presentation of a neutral or an emotional test face in the recognition task. For instance, some studies had demonstrated a memory enhancement for angry faces when a neutral test face was presented (Jackson et al., 2009, Jackson et al., 2014) or a better recognition of happy faces when the test face was also a happy face (i.e., emotional face) (Chen et al., 2015). Thus, it may be the case that these conflicting results regarding memory enhancement for either negative (angry) or positive (happy) faces may be attributed to the emotional nature of the test stimuli.

In this current study, we investigated the role of attentional resources in the processing of emotional information in working memory. We intended to clarify whether the attentional load significantly influences the memorization of visuospatial information (faces) with emotional valence (neutral, positive, or negative faces). To explore the influence of attention on working memory, we employed a dual-task paradigm with a main face recognition task and a secondary attentional task (i.e., a tone counting task). In the main task, the participant had to memorize an array of two faces with the same emotion but of different identities, and after a brief interval had to answer whether a test face had the same or different identity of the previous faces. The test faces had the same emotions of the memorized faces (Experiment 1) or a neutral expression (Experiment 2), since studies in the literature varied according to the emotional content of the test faces (e.g. Chen et al., 2015; Jackson et al., 2014, Talmi et al., 2007).

The dual-task paradigm was intended to manipulate the availability and the allocation of attentional resources during the processing and memorization of emotional stimuli. Thus, if the processing of emotional information in working memory depends on attentional resources, it is to be expected that the recognition of the emotional faces would be impaired (as proposed by Talmi et al., 2007). Otherwise, if the processing of emotional stimuli is automatic, it would not be impaired when attentional resources are depleted. The load on attentional resources was manipulated by the tone counting task with a high attentional load (i.e., sequence presentation of high- and low-pitched tones) or with low attentional load (i.e., sequence presentation of burst noises).

Furthermore, to ensure that differences in the test stimuli of the face recognition task is not a relevant factor impacting on the results would not interfere in our findings, we presented an array of two emotional faces at encoding and an emotional face at recognition (Experiment 1) or a neutral face at recognition (Experiment 2). Only in Experiment 1, there was a correspondence of the emotional information between encoding and retrieval, (e.g., angry-angry faces; neutral-neutral faces; happy-happy faces; sad-sad faces). For both experiments, participants were required to answer whether the test face was of the same or different identity of the previously presented face array, regardless of the emotional expression of the face.

Experiment 1

Method

Participants

A total of 40 participants (22 females) aged 18-35 years (*M* = 25.15 years, *SD* = 6.09), with normal or corrected normal vision and normal hearing, voluntarily participated in the experiment. The Research Ethics Committee of our institution approved the project, and all participants signed consent forms. As a measure of control, the participants were evaluated with the Beck Anxiety Inventory and the Beck Depression Inventory. The participants were compensated for their transportation to the laboratory with an amount equivalent to US$ 2.50.

Materials and Stimuli

The stimuli of the face recognition task (the working memory task) were extracted from the Karolinska Directed Emotional Faces database (KDEF) (Goeleven et al., 2008). We conducted a pilot study to ensure the KDEF stimuli could be used in our country with equivalent ratings of facial expressions (see the **Appendix A** for the details), and the results revealed similar valence and arousal ratings to the original study (Goeleven et al., 2008). We selected eight male faces for four types of emotional expression (neutral, happiness, angriness, and sadness). The stimuli were 32 male greyscale faces, without hair and cropped into an oval, and were subtended approximately 19 × 26 degrees of visual angle, or 562 × 762 pixels in a monitor with 1280 × 1024 pixels of resolution. The stimuli were displayed in four randomized locations within a 2 × 2 grid (52° × 52°). Since we used two faces per trial, the other locations within the grid were filled with scrambled faces that were created by segmenting a face into 19 squares and then randomly rearranging them. The composite image was cropped into an oval pattern to maintain a face-like outline. The stimuli of the tone counting task (TC) were a low-pitched tone (200 Hz), a high-pitched tone (1500 Hz) or white noise bursts. The stimuli had 250 ms and were generated using the program Audacity. The participants were required to use headphones attached to the computer's external loudspeaker pin.

Procedure

At the beginning of the session, each participant was evaluated with the Beck Anxiety Inventory, BAI, (Beck et al., 1988) and the Beck Depression Inventory, BDI, (Beck et al., 1961). The participants received instructions about the tasks and performed six practice trials for the face recognition task alone, six practice trials for the tone counting task alone, and then six practice trials for the complete dual task working memory procedure.

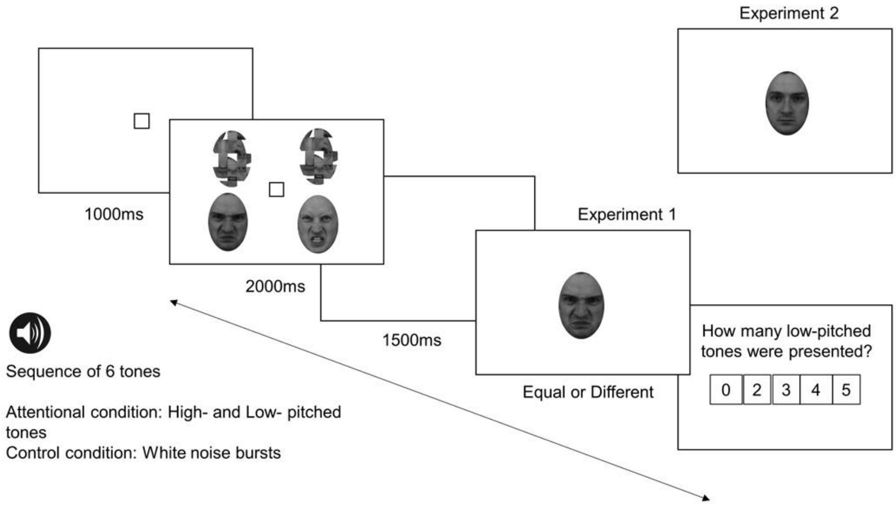
The participants performed the face recognition working memory task adapted from Linden et al. (2011) concurrently with the tone counting task. In each trial, after the presentation of a fixation point for 1000 ms and a white screen for 250 ms, the encoding array of two faces was presented for 2000 ms. The faces in the encoding array had the same emotional expression. After a retention interval of a blank screen for 1500 ms, a test face with neutral expression was presented in the centre of the screen until response. On half of the trials, the test face shared identity with one of the faces presented in the encoding array, and on the other half it did not share identity (i.e., the neutral face was from a different person). The task was to respond "yes" (left mouse button) if the test face identity was present in the encoding array or "no" (right mouse button) if it was not. The participant was instructed to respond as quickly and accurately as possible to the test.

The concurrent tone counting task (TC) comprised a sequence of six low- and high-pitched tones in the high attention condition, or a sequence of six white noise bursts in the low attention condition. The participants were required to count the number of low-pitched tones presented in the trial, which varied from two to five tones in randomized order, or zero in the low attention condition. The tones were presented through headphones during both encoding and maintenance, and started simultaneously to the presentation of the encoding face array, each tone lasting 250 ms with approximately 333 ms interval between tones (i.e. five intervals of 333 ms and one interval of 335 ms). The response to the test face was followed by a scale with five numbers in the centre of the screen (i.e., 0, 2, 3, 4, 5) and the participants were required to indicate the tone counting response option. The main components of the trial sequence for each experiment are shown in Figure 1.

There were 160 trials in total, 80 trials per each attentional condition, each one with 20 trials for each one of the four emotional expressions. All the trials conditions were presented in random order.

Figure 1

Sequences of events in Experiment 1 and 2



Note: Illustration of one trial with the emotional expression of anger.

Data Analyses

Performance in the face recognition task was measured by the discrimination index *d'* and the response bias parameter *c* derived from the signal detection theory and calculated as follows: $d' = Z(H) – Z(F)$ and $c = 0.5 \times [z(H) + z(F)]$, where *H* and *F* are adjusted hit and false alarm rates, respectively (Snodgrass & Corwin, 1988). Regarding the criterion *c*, positive values indicate a conservative criterion (i.e., a bias towards responding 'no') and negative values indicate a liberal criterion (i.e., a bias towards responding 'yes'), with the neutral criterion with values closer to zero. These data were analysed by using repeated-measures 2 × 4 ANOVAs considering attentional condition (low and high attention) and emotional expressions (happy, angry, sad and neutral) as within-subject factors. These analyses were carried out preliminarily inserting BAI and BDI scores as covariates for verifying any significant confounding effects by the participants' levels of anxiety and depression. In addition, we also analysed performance in tone counting task for verifying the participants' engagement in the secondary task. For all the analyses, the significance level was set at .05, partial Eta squared (η^2_p) effect sizes were computed, and post-hoc analyses and *t*-tests using Bonferroni's correction were carried out, as necessary.

Results

Preliminary analyses indicated that the sample's mean scores in the BAI (4.8, *SD* = 5.5) and the BDI (5.6, *SD* = 6.2) were mainly low and within cut-off values of anxiety and depression, respectively. In fact, levels of anxiety and depression had no significant impacts on performance (*d'*) in the working memory task, as revealed by the ANCOVA including BAI scores, $F(1, 37) < 1$, $p = .63$, $\eta^2_p = .006$, and BDI scores as covariates, $F(1, 37) < 1$, $p = .69$, $\eta^2_p = .004$, so these variables were subsequently disregarded. The response bias *c* also was not significantly influence by BAI scores, $F(1, 37) < 1$, $p = .75$, $\eta^2_p = .003$, and BDI scores, $F(1, 37) < 1$, $p = .36$, $\eta^2_p = .023$. Our preliminary analyses also showed the participants' engagement in the secondary task (*M* = .74, *SD* = .13). The ANOVA revealed no significant difference between the four emotion condition, $F(3, 117) = 1.35$, $p = .26$, $\eta^2_p = .03$, with a similar performance level across happy (*M* = .74, *SE* = .02), neutral (*M* = .73, *SE* = .02), angry (*M* = .76, *SE* = .02), and sad faces (*M* = .72, *SE* = .02).

Figure 2 shows the mean performance and response bias for the two attentional conditions and the four emotional faces. The 2 (attentional condition) × 4 (emotion) repeated measures ANOVA on discrimination index *d'* revealed a main effect of attentional condition, $F(1, 39) = 71.16$, $p < .001$, $\eta^2_p = .65$, since participants performed better in the low attention condition ($M = 2.43$, $SE = .07$) than in the high attention condition ($M = 1.78$, $SE = .09$). The results revealed a significant main effect of emotion, $F(3, 117) = 3.12$, $p = .029$, $\eta^2_p = .07$, but post-hoc comparisons showed no significant difference of performance between emotions: happy faces ($M = 2.28$, $SE = .10$) versus neutral faces ($p = .14$; $M = 2.05$, $SE = .10$), happy faces versus sad faces ($p = .08$; $M = 2.05$, $SE = .08$), neutral faces versus angry faces ($p = 1$; $M = 2.03$, $SE = .09$), neutral faces versus sad faces ($p = 1$), and angry faces versus sad faces ($p = 1$). The difference between happy faces versus angry faces ($p = .055$) was marginally significant.

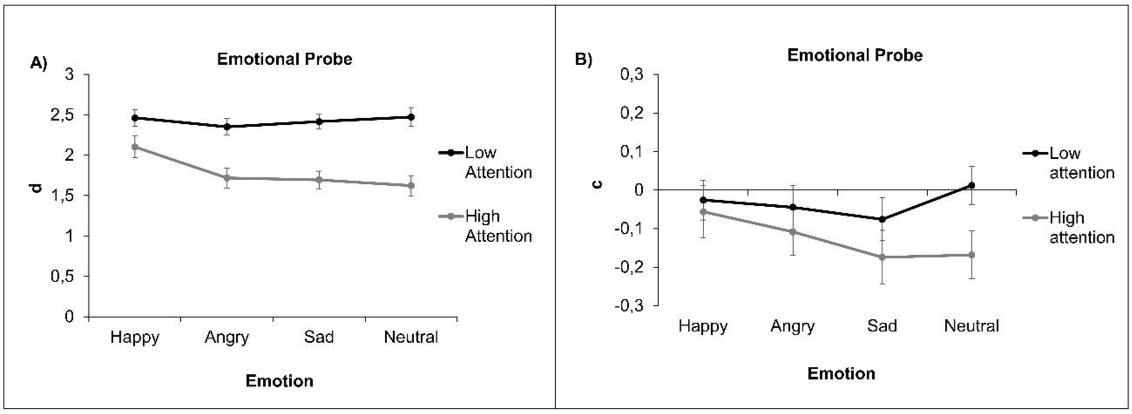
The interaction between attentional condition and emotion was significant, $F(3, 117) = 2.89$, $p = .038$, $\eta^2_p = .07$). To further explore this interaction, Bonferroni corrected *t*-tests with adjusted *p*-values for the number of comparisons (i.e., 4) were carried out for comparing performance between low and high attention condition for each emotion, and revealed significant differences ($p < .001$) for neutral faces ($M = 2.47$, $SE = .12$ vs. $M = 1.62$, $SE = .12$), angry faces ($M = 2.35$, $SE = .10$ vs. $M = 1.72$, $SE = .12$), and sad faces ($M = 2.42$, $SE = .10$ vs. $M = 1.69$, $SE = .11$), but no significant difference ($p > .05$) for happy faces ($M = 2.46$, $SE = .10$ vs. $M = 2.10$, $SE = .13$).

Given the interaction between attentional condition and emotion, we carried out additional ANOVAs for low and high attention conditions separately to better assess the difference between emotional faces. The results revealed a significant difference between emotions only under high attention condition, $F(3, 117) = 5.48$, $p = .001$, $\eta^2_p = .12$, since performance was better for happy faces in comparison with neutral faces ($p = .01$), angry faces ($p = .01$), and sad faces ($p = .01$), as revealed by post-hoc comparisons with Bonferroni's correction. In contrast, there were no significant differences between emotions under the low attention condition, $F(3, 117) = .38$, $p = .76$, $\eta^2_p = .01$.

The 2 (attentional condition) × 4 (emotion) repeated measures ANOVA on the response bias criterion *c* revealed that the effect of attentional condition approached significance, $F(1, 39) = 4.18$, $p = .048$, $\eta^2_p = .097$, since *c* was closer to zero in the low attention condition ($M = -0.034$, $SE = .03$) than in the high attention condition ($M = -0.127$, $SE = .05$). The effect of emotion, $F(1, 39) < 1$, $p = .41$, $\eta^2_p = .024$, and the interaction between attention and emotion, $F(1, 39) < 1$, $p = .41$, $\eta^2_p = .024$, were not significant.

Figure 2

Mean performance and response bias on high and low attention *trials across emotion of Experiment 1*



Note. Error bars indicate standard errors of the mean.

Discussion

The main aim of this experiment was to assess whether the processing of emotional information in WM demands attentional resources. To this purpose, the participants performed a face recognition task with four types of emotional faces under concurrent low and high attentional conditions. Our preliminary analyses indicated that neither mood disorders symptoms (i.e., anxiety and depression scores) nor response bias influenced the performance of the participants in recognition of emotional faces. Response bias was influenced by the attentional load, with more neutral bias in the low attention condition and a more liberal bias in the high attention condition, indicating that participants were more prone to false alarms and less memory discrimination under high attentional load.

Our results revealed significant effects of attentional load and emotional faces since performance was impaired by the high attentional load and varied according across emotions. More importantly, these factors interacted significantly since recognition of happy faces was not significantly impaired by the high attentional load, in contrast with the impairment observed in the recognition of angry, sad, and neutral faces. Under the high attention load condition, performance was significantly better with happy faces than with the other faces. That is, happy faces were better recognized than other emotional faces when attention resources were depleted, suggesting a “preattentive/automaticity” process for happy faces in working memory. However, a limitation must be acknowledged regarding the influence of emotional expression face on memory retrieval. Our results could be due to an emotional correspondence between encoding and retrieval, where a probe face with a happy expression would facilitate the identity recognition process (Chen et al., 2015). Indeed, prior studies reported an angry enhancement on short-term memory when a test face with a neutral expression was employed, but not for happy faces (Jackson et al., 2009; Jackson et al., 2014; Linden et al., 2011). On the other hand, if this were the case, a happy advantage would also be expected in the low attention condition. Contrary to this hypothesis, happy faces were better recognized that the other faces only in the high demand attentional condition.

Thus, it is unknown whether this emotional association would affect the attentional influence on the recognition of emotional faces in working memory. To address this issue, we repeated our face WM task under the high and low attention conditions, but in the test, a face with neutral expression was presented.

Experiment 2

The main purpose of this experiment was to investigate whether the attentional effect on working memory found in Experiment 1 would be replicated without the emotional correspondence between encoding and retrieval phases. Participants performed the face recognition task under low and high attentional conditions, with three types of emotional faces at encoding and a neutral face in the test (i.e., happy-neutral, angry-neutral, sad-neutral).

Method

Participants

A total of 38 participants (24 females) aged 18-35 years (23.55 years, *SD* = 4.58) with normal or corrected normal vision and normal hearing, voluntarily participated in the experiment. All participants signed consent forms.

Materials and Stimuli

The stimuli were the same as Experiment 1.

Procedure

The procedure was the same as Experiment 1, but with slight changes in the stimuli, namely, the encoding array always comprised emotional faces and the test stimulus was always a neutral face (i.e., happy-neutral, angry-neutral, sad-neutral). The main components of the trial sequence for each experiment are shown in Figure 1.

Data Analysis

The Data analysis was the same as Experiment 1.

Results

We considered the data from 37 participants with satisfactory engagement in the secondary task (*M* = .796, *SD* = .09), since our preliminary analyses indicated that one participant had low performances both in the low attention (*M* = .52, *SD* = .13) and high attention (M = .20, SD = .13) conditions. The ANOVA revealed no significant difference between the three emotion condition, $F(2, 72) = 1.07$, $p = .34$, $\eta^2_p = .02$, with a similar performance level across happy (M = .63, SE = .03), angry (M = .61, SE = .03), and sad faces (M = .59, SE = .03).

Preliminary analyses indicated that the sample's mean scores in the BAI (14.2, SD = 10.4) and the BDI (12.2, SD = 8.7) were significantly higher than the scores from the Experiment 1 sample, $t(75) = 4.98$, $p < .001$, and $t(75) = 3.89$, $p < .001$, respectively. The ANCOVA including BAI and BDI scores as covariates indicated that anxiety levels had no significant impact on performance (d') in the working memory task, $F(1, 34) < 1$, p = .42, $\eta^2_p = .018$, but the effect of depression levels approached significance, $F(1, 34)$ = 4.14, $p = .05$, $\eta^2_p = .108$. Thus, we report the analysis of performance (d') including the covariates. The response bias c was not significantly influenced by BAI scores, $F(1, 37)$ < 1, $p = .64$, $\eta^2_p = .006$, and BDI scores, $F(1, 37) = 1.45$, $p = .24$, $\eta^2_p = .041$.

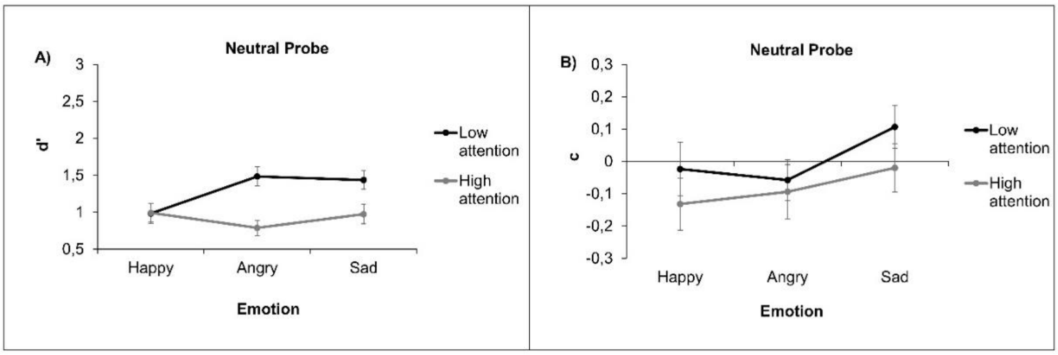
Figure 3 shows the mean performance and response bias for the two attentional conditions and the three emotional faces. The 2 (attentional condition) × 3 (emotion) repeated-measures ANCOVA discrimination index d' revealed a main effect of attentional condition, $F(1, 34) = 30.17$, $p < .001$, $\eta^2_p = .47$, since participants performed better in the low attention condition (M = 1.30, SE = .11) than in the high attention condition (M = 0.92, SE = .10). The main effect of emotion was also significant, $F(2, 68)$ = 3.13, $p = .050$, $\eta^2_p = .084$, since performance was poorer ($p = .05$) with happy faces (M = 0.99, SE = .11) than with sad faces (M = 1.21, SE = .11) and angry faces (M = 1.14, SE = .10), which did not differ from each other, as indicated by Bonferroni post-hoc tests.

There was a significant interaction between attentional condition and emotion, $F(2, 68) = 7.52$, p = = .001, $\eta^2_p = .18$. Post-hoc comparisons between low and high attention condition for each emotion revealed no significant difference (p = 1) for happy faces (M = 0.98, SE = .14 versus M = 0.99, SE = .13), but significant differences (< .01) for angry (M = 1.48, SE = .13 versus M = 0.79, SE = .10) and sad faces (M = 1.44, SE = .13 versus M = 0.97, SE = .13). In addition, the post-hoc comparisons revealed no significant differences (p = 1) between emotions under the high attention condition, but under the low attention condition performance was significantly poorer for happy faces than for angry ($p = .004$) and sad ($p = .014$) faces.

The 2 (attentional condition) × 3 (emotion) repeated measures ANOVA on the response bias criterion c showed that the main effect of attentional condition was not significant, $F(1, 36) = 2.15$, $p = .15$, $\eta^2_p = .056$. The main effect of emotion was significant, $F(2, 72) = 3.32$, $p = .042$, $\eta^2_p = .085$, given the liberal criterion (i.e. negative *c* values) observed for happy (*M* = -0.078, *SE* = .077) and angry faces (*M* = -0.076, *SE* = .059), and more conservative criterion (i.e., positives *c* values) for sad faces (*M* = 0.043, *SE* = .057), although the Bonferroni corrected p-values were not significant regarding happy versus angry ($p = 1$), sad versus happy ($p = .08$) and sad versus angry ($p = .09$) comparisons. Finally, the interaction between attentional condition and emotion was not significant, $F(2, 72) < 1$, $p = .50$, $\eta^2_p = .019$.

Figure 3

Mean performance and response bias on high and low attention trials across emotion of Experiment 2



Note. Error bars indicate standard errors of the mean.

Discussion

In Experiment 2, we investigated whether the results observed in Experiment 1 would be replicated using neutral faces at retrieval. To address this issue, we repeated the face recognition task under the high and low attention conditions, but in the test, a face with neutral expression was presented. The results revealed that memory for happy faces is less dependent on attentional resources, in contrast with negative faces, as in Experiment 1. Such effects were more evident with the presentation of neutral probes at retrieval. Contrary to the results from the first experiment, an opposite pattern was found in the low attention condition, with better performance for negative faces than with happy faces. Taken together, these results suggest an influence of the emotional expression face at the retrieval in the first experiment and, also one possible perception influence on performance when a neutral face test is presented in the second experiment. In other words, the neutral test faces in Experiment 2 require additional face perception processes involved in deciding whether the given face was presented at encoding with different emotional expressions. The interpretation for a perception influence is supported by the conservative response bias towards sad faces (i.e., more "different" responses) and liberal response bias to happy and angry faces (i.e., more "same" responses). Although a liberal bias has been linked to negative images (Miendlarzewska et al., 2013), the same pattern has not been found with schematic faces (Tamm et al., 2016) which showed a more liberal response bias to happy faces. Indeed, the neutral probe employed in the second experiment may have elicited perceptual feature discrimination between the emotional faces and the neutral face test, which would have prompted response biases. However, this change in the discrimination criterion did not influence the competition for attentional resources in the processing of emotional information and, as in Experiment 1, the high attention load impaired more the negative faces than happy faces.

General Discussion of Study 1

The present study examined the influence of attentional resources in the process of emotional faces in working memory. In a dual-task paradigm, we analysed the performance of a face recognition task with emotional faces at retrieval (Experiment 1) and neutral faces at retrieval (Experiment 2) under low and high attentional conditions. The results showed a detrimental effect of attention on sad and angry faces but not on happy faces in both experiments. The better recognition of happy faces under a high attention condition in Experiment 1 suggest a “preattentive” processing of positive stimuli in working memory. In addition, in both experiments we did not observe an attention load effect on the recognition of happy faces, favouring the view that recognition of happy faces does not require attentional resources. In contrast, memory for angry, sad, and neutral faces was significantly impaired by the high attentional load (in Experiment 1), and this was further supported by the results of Experiment 2. Thus, we have evidence that memory for negative and neutral faces require attentional resources.

Regarding the worse performance for happy-neutral trials compared to angry-neutral and sad-neutral trials under the low attention demand imply that the presence or absence of a facial expression at retrieval could activate perception strategies that may influence the face identity decision. The evidence seems to suggest that attentional selection acts in the processing of emotional faces in working memory, but the emotion boost in memory also depends on another cognitive factor, as a perception mechanism.

Previous studies have shown that emotional stimuli capture attentional resources (Pessoa, McKenna, et al., 2002; Pottage & Schaefer, 2012; Talmi et al., 2007; Talmi et al., 2008; for review see Hamann, 2001) demonstrating evidence that attention plays an important role in the consolidation of emotional memories. Our findings suggest that only negative faces require higher demands of attention. Indeed, a large body of evidence has shown a preferential enhancement of visual attention to threatening stimuli (Huang et al., 2011; Feldmann-Wüstefeld et al., 2011), especially in studies using a divided attention paradigm (Pottage & Schaefer, 2012; Talmi et al., 2008).

The lack of attentional effect in the happy face’s recognition imply that fewer attentional resources are allocated to happy faces (Srinivasan & Gupta, 2010; Srinivasan & Srinivasan, 2010). Feasibly, these results concur with findings that happy faces convey positive social cues (Becker & Srinivasan, 2014) which facilitate the encoding of facial expression (Silvia et al., 2006) and consequently, enable more resources to process facial identity (D’Argembeau & Van Der Linden, 2011). However, if happy expressions have a facilitative effect, a “happy superiority” should have been found in the second experiment, in the absence of an emotional expression in the test. In contrast, negative faces were enhancement when the face at retrieval was a neutral expression. Previous works showed a similar pattern with an anger-benefit effect on visual working memory when emotional faces were presented only at encoding (Jackson et al. 2009; Jackson et. al, 2014).

One perceptual interpretation could account for this specific emotion effect in recognition. A neutral probe face in the test might lead one to predict a better performance of angry and sad faces due to physical features similarities with a neutral expression and hence a facilitate recognition of the face identity. In fact, there is evidence that neutral and angry (Juth et al., 2005) or neutral and sad (Valenti, Garcia, et al., 2020) expressions are more similar to each other than happy and neutral expressions. Most recently, Valenti, Garcia, et al. (2020) investigated the role of perception in the process of face identity and found evidence that support this claim. The authors used a perceptual matching identity task with one or three emotional faces at encoding and a neutral probe in the test and reported a better performance of sad and angry faces compared to happy faces.

Though there is some evidence to support the influence of visual similarities between emotional expressions, the visual physical similarity may contribute little for the memory consolidation process. For example, Chen et al. (2011) found contrasting results in an identity matching task between faces displaying the same emotional expression faces (see their Experiment 1) or matching emotional and neutral expression faces (see their Experiment 2). Although they reported a better matching performance for the pair sad-neutral face, the accuracy was not different between matches of angry-neutral and happy-neutral faces. Also, a perceptual interpretation cannot account for the results under the high-attentional condition. The fact that this emotion effect was absent under conditions in which attentional resources were severely limited suggests that an involvement of perceptual process depends on the availability of attentional resources. There has been a considerable debate over the “automaticity/ preattentive” of emotion perception process since some evidences suggest a central (Tomasik et al., 2009) and spatial attention (Pessoa, McKenna, et al., 2002) demand to process emotion and other imply no requirement of attentional resources (Shaw et al., 2011). This hypothesis should be more investigated in future studies.

It is important to note that we do not rule out the role of emotion in our results. The advantage of angry faces with schematic (Juth et al., 2005) and real faces (Jackson et. al., 2009; Jackson et al., 2012; Jackson et al.; 2014) suggests an enhanced maintenance of threatening information and therefore a more allocation of working memory resources to angry faces. Jackson et al., (2014) proposes a motivational approach to explain how angry faces might influence the competition for resources on working memory. For the authors, angry faces have a greater motivational value and therefore demand more resources from working memory rather than attentional processing. However, the present findings indicate a detrimental effect in recognition of angry faces when there is competition for attentional resources. Our findings are consistent with other studies investigating attention modulation of emotional faces on working memory (MacNamara & Hajcak, 2011; Van Dillen & Belle Derks, 2012) which evidence suggest that processing of threat faces depends on availability of attention resources.

Importantly, future research is needed to explain the social relevance of emotional faces in a motivational approach and avoidance system. Indeed, social context may facilitate the evaluation of face processing (Fischer & Van Kleef, 2010) and the priority of emotion on perception (Bublatzky et al., 2014) but further studies should investigate the connection of the attentional function to approach/avoidance behaviour for angry-happy faces.

Attentional and Working Memory Load modulate the recognition of emotional faces (Study 2)

Abstract

Memory for emotional stimuli is enhanced in relation to neutral stimuli. This enhancement has been associated with physiological and cognitive factors. There is evidence that both attention and working memory load modulate the process of emotional information, but their relationship remains uncertain. In the present study, we investigated how these cognitive functions interfere in recognition of emotional faces on working memory. In Experiment 1, participants performed a face working memory task with a set size of one (low WM load) and three (high WM load) emotional faces (happy, angry, sad) under a tone counting task with a presentation of white noises burst (low load) or low and high pitched tones sequence (high load). The results revealed two contrast patterns of interaction with emotion: 1) a lower effect of attentional demands on sad faces and a higher effect on happy and angry faces and, 2) a higher effect of WM load on negative faces compared to happy faces. To investigate if the face WM task instigated a perceptual bias due to better discrimination between sad and neutral probe face, in Experiment 2, participants performed a perceptual matching task with the same attention and load condition of the first experiment. Although the results revealed better discrimination between neutral-sad and neutral-angry faces, the interference pattern of set size and attentional load on emotion perception task was different from the effects on the WM task. Taken together, these results demonstrate an inter-relation between attention and WM load but a different pattern of influence of each function on emotion information.

Keywords: Visual working memory load, attention; face recognition; emotion; perception.

Introduction

There is a rich and growing literature showing a strong interaction between emotion and cognitive processes. Emotional information seems to determine the priority of stimulus to be processed (Bradley et al, 1995; Jackson et al., 2014; Jackson et al., 2009; Linden et al., 2011). The capacity of working memory (WM) to store emotional stimuli seems to be better than the capacity to store neutral ones, and it has been reported that threat-related stimuli can be processed automatically with minimal attention required (Leyman et al., 2007; Phelps et al., 2006).

The identification of emotional expressions seems to be dependent on WM capacity (Herrmann et al., 2016), attentional resources (Gupta & Srinivasan, 2015), and the cognitive load of the task (Pessoa, 2009). Various studies have reported an interaction between emotion and attention related to the priority access of emotional stimuli in WM (Lim et al., 2014; Srinivasan & Gupta, 2010; Srivastava & Srinivasan, 2010; Van Dillen, & Derks, 2012). In particular, emotional information is processed more efficiently when sufficient attentional resources are available (Pessoa, Kastner, et al., 2002; Pessoa, McKenna, et al., 2002). That is, high attentional load seems to impair WM performance for emotional stimuli. Although meaningful stimuli are likely to capture attention, some studies have reported different patterns of interaction between emotion and attention, and some divergences concerning the cognitive and emotional task demands. For instance, Van Dillen & Derks (2012) found a negative bias on WM when the attentional load was manipulated during a gender-naming task. They found that responses were slower to name the gender of angry faces when participants had to retain one-digit number (i.e., low load), but the response latencies for the happy faces were greater when an eight-number digit was retained (i.e., high load) compared to one-digit number trials. These results indicate that angry faces required more processing and attentional resources over happy faces in a low attention load condition, resulting in slower responses to engage attention to a not-emotional attribute of the face, but not in high load trials. Srinivasan and Gupta (2010) found that emotion prioritization is associated with differences in the scope of attentional resources. The authors investigated the recognition of happy and sad faces in a divided-attention task with low and high load conditions. The results showed a better identification of happy faces compared to sad faces under conditions of distributed attention (i.e., less focused attention to the faces) whereas sad faces were linked to more focused attention.

Besides the effect of attentional processes, there is evidence that the WM load also modulates the competition between emotional content and available resources (Simione et al., 2014). An increase in WM load may interfere with emotional face recognition since high WM load decreases memory capacity due to a poor distribution of resources (Bay et al., 2009). In this view, some studies suggest that a salient emotional stimulus enhance a preattentive/automatic process, but the prioritization depends on the task demands because of the limitations in processing capacity (Pessoa, McKenna, et al., 2002; for a review see Pourtois et al., 2013). For instance, Simione et al. (2014) investigated the prioritization of emotional stimuli in a demanding WM task where participants had to decide which emotional face was presented in a prespecified location. In this WM task with set sizes of three and five faces, they found a threat superiority effect (i.e., angry faces) independently of set size, with higher accuracy for angry than happy and neutral faces.

In addition, Jackson et al. (2009) found a better storage of angry face identities in WM compared to storage of happy or neutral face identities. These results permit to suppose that selective storage of angry face information demands fewer resources from WM and, thus, allowing higher storage in this system. Furthermore, Miendlarzewska et al. (2013) investigated the effect of WM load in the incidental memory of emotional images and, also found that better recognition of emotional stimuli depends on WM load, but, in contrast to the previous studies (Jackson et al., 2009; Simione et al., 2014), the accuracy of negative images was not better than positive ones in a high WM load task. These results indicate that negative stimuli do not always require fewer resources from WM to be processed. Tsouli et al. (2017), on the other hand, showed that WM resources do not affect emotion recognition, supporting only a visual attentional process. The authors investigated whether emotion recognition is dependent of WM resources in a dual-paradigm task with a face recognition task (i.e., primary task) and a word length retention task (i.e., secondary task) of short (i.e., low load) or long word (i.e., high load) or no-word (i.e., no-load) presentation. The results showed slower responses to angry and fear faces compared to happy and neutral faces across both loads, indicating that negative faces require, at least, fewer attentional resources but its processing does not depend on WM loads.

It is important to note that the interaction pattern of emotion and WM resources such as attention demands and cognitive load (i.e., WM load) has not been investigated previously in the same paradigm, researches have studied separately, the relation of each function with emotion, or more precisely, with emotional face processing. The question of whether emotional content demands WM resources and its relationship with the attentional function remains uncertain. Our goal, in the present study, was to investigate the effect of attentional demands and visual WM load during the storage of emotional content through a dual-task paradigm. The relevant question was the role of WM resources in the processing of emotional faces, more specifically, whether emotional information competes for attentional resources and how WM load modulate the selection and prioritization of the relevant information. We investigated the effect of concurrent attentional demands (low vs high) and WM loads (one and three emotional faces to remember) in a recognition task with emotional stimuli (angry, happy, sad). We expected that under a high WM load (i.e., three faces) and high attentional load (i.e. tone counting task), only emotional stimulus with an automatic entry would be stored in visual WM. According to our hypothesis, we should obtain better performance with happy and angry faces in low attentional and WM load, if there is automatically processing for emotional faces on WM, supported by previous studies (Becker & Srinivasan, 2014; Linden et al., 2011; Spotorno et al., 2018). Furthermore, we should also observe an impairment in performance for all the emotional faces, except for angry faces (Jackson et al., 2014; Simone et al., 2014) in the high WM attentional and WM load, according to the threat bias effect. In short, we expected that high WM load and high attentional load would attenuate the enhanced processing of emotional content observed under low WM and attentional loads.

Experiment 1

We conducted a face WM task with one and three faces arrays (low and high WM load) under a discrimination/counting tone task (TC) (high attentional load) or with white noises (low attentional load). The participant responded to whether the test face was presented with same identity of one of the preceding faces. Previous work with similar experimental design and presentation control was used as a base to set the conditions (Jackson, et al., 2009; Valenti, Wada, et al., 2020).

Method

Participants

Forty-one students (29 women) from the University of Aberdeen over 18 years old (*M* = 25.05 years; *SD* = 4.49) participated in this study. Only participants with normal or corrected-to-normal vision were selected. All participants provided informed consent approved by the Research Ethics Committee at the School of Psychology in Aberdeen.

Materials and Stimuli

The stimuli of the WM task were 32 male greyscale faces from four individuals (i.e., four identities) with eight faces for each emotional expression: happy, anger, sad and neutral expression. Faces were subtended approximately 19 ° × 26 ° (or 562 × 762 pixels) degrees of visual angle and were displayed in four randomized locations within a 2 × 2 grid of 52° × 52° in a monitor of 1280 x 1024. The faces were extracted from Karolinska Directed Emotional Faces, KDEF (Goeleven et al., 2008), and each face was cropped into an oval without hair. One (load one) or three faces (load three) with the same emotional expression, but different identities were displayed in an array. Other array locations were occupied with scrambled greyscale faces. Each scrambled image was created by segmenting a face into 19 squares and then randomly rearranging them. The composite image was cropped into an oval pattern to maintain a face-like outline. For the tone counting task (TC), the stimulus was a tone that was either low pitched (200 Hz) or high pitched (1500 Hz). The stimuli had 250 ms and were generated using the program Audacity. The participants were required to use headphones attached to the computer's external loudspeaker pin.

Procedure

At the beginning or end of the session (counterbalanced), each participant was evaluated with the Beck Anxiety Inventory, BAI, (Beck et al., 1988) and Beck Depression Inventory, BDI, (Beck et al., 1961). The participants received instructions about the tasks and performed six practice trials for the face recognition task alone, six practice trials for the tone counting task alone, and then six practice trials for the complete dual task working memory procedure.

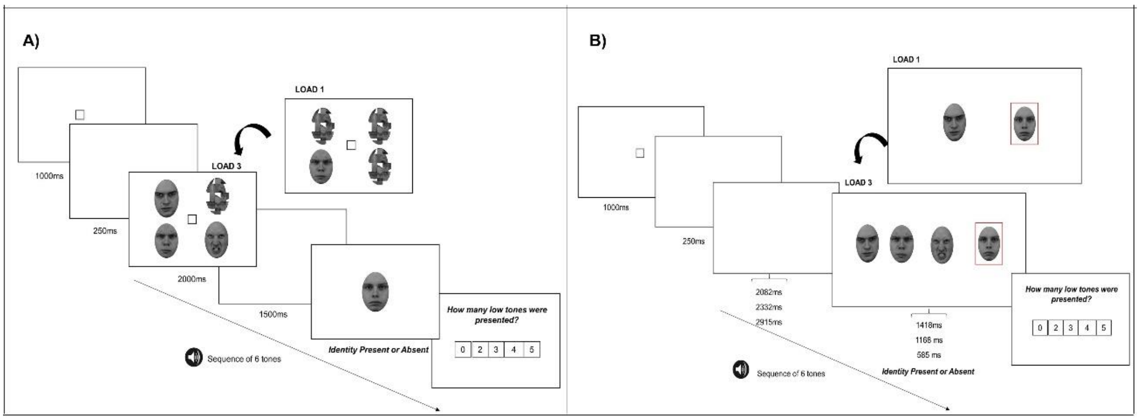
Participants performed the face WM task concurrently with the tone counting task (TC). The face WM task was adapted from Jackson at al. (2009; 2014) and the dual-paradigm task with the face WM task combined to the TC was adapted from Valenti, Wada, et al. (2020). In each trial, after a fixation signal of 1000 ms presentation, a white screen was displayed for 250 ms, followed by an encoding array of one or three faces for 2000 ms. All faces in the encoding array displayed the same emotional expression (i.e., happy, angry or sad). After a blank retention interval of 1500 ms, a test face with neutral expression was presented in the centre of the screen until response. On half of the trials, the test face shared identity with one of the faces presented in the preceding array; and on the other half, the test face was from a different identity than the faces presented in the preceding array. The task was to respond “yes” (left mouse button) if the test face identity was present in the preceding array or “no” (right mouse button) if it was not. The participant was instructed to respond as quickly as possible to the test.

The concurrent tone counting task comprised a sequence of six low- and high-pitched tones in the high attentional load, or a sequence of six white noise bursts in the low attentional load. The participants were required to count the number of low-pitched tones presented in the trial, which varied from two to five tones in randomized order, or zero in the low attention condition. The tones were presented through headphones during both encoding and maintenance, and started simultaneously to the presentation of the encoding face array, each tone lasting 250 ms with approximately 333 ms interval between tones (i.e. five intervals of 333 ms and one interval of 335 ms). The response to the test face was followed by a scale with five numbers in the centre of the screen (i.e., 0, 2, 3, 4, 5) and the participants were required to indicate the tone counting response option. The main components of the trial sequence for each experiment are shown in Figure 4.

There were 144 trials in each per WM load block, and 72 randomized trials for each attentional load in each load block. There were 24 trials for each emotional expression (i.e., happy, angry, sad) presented in random order for each attentional load. The presentation of the load block (1 and 3) was counterbalanced between participants.

Figure 4

Sequences of events of Experiment 1 (A) and 2 (B)



Data Analysis

Performance in the face WM task was measured by the discrimination index *d'* and the response bias parameter *c* derived from the signal detection theory and calculated as follows: $d' = Z(H) – Z(F)$ and $c = 0.5 \times [z(H) + z(F)]$ (Snodgrass & Corwin, 1988), where *H* and *F* are hit and false alarm rates, respectively. Regarding the criterion *c*, positive values indicate a conservative criterion (i.e., a bias towards responding 'no') and negative values indicate a liberal criterion (i.e., a bias towards responding 'yes'), with the neutral criterion with values closer to zero. These data were analysed by using repeated-measures 2 × 2 × 3 ANOVAs considering memory load (1 and 3 items), attentional load (low and high attention), and emotional expressions (happy, angry, and sad) as within-subject factors.

We carried out preliminary analyses for verifying the presentation order of the BAI and BDI questionnaires (prior or after the experiment) and the memory load blocks for ensuring that presentation order effects were not significant. To this purpose, we carried out two separate ANOVAs including the questionnaire presentation order and the memory load block order as between-subjects factors. We also carried out preliminarily analyses inserting BAI and BDI scores as covariates for verifying any significant confounding effects by the participants' levels of anxiety and depression

In addition, we also analysed performance in tone counting task (i.e., control trials were not included) for verifying the participants' engagement in the secondary task. The TC data were analysed using a repeated-measures 2 × 3 ANOVAs considering memory load (1 and 3 items), and emotional expressions (angry, happy, and sad) as within-subject factors. For all the analyses, the significance level was set at .05, partial Eta squared (η^2_p) effect sizes were computed, and post-hoc analyses and *t*-tests using Bonferroni's correction were carried out, as necessary.

Results

We considered the data from 40 participants with satisfactory engagement in the secondary task (*M* = 25.13 years; *SD* = 4.52), since our preliminary analyses indicated that one participant had low performances both in the low attention (*M* = .63, *SD* = .13) and high attention (*M* = .26, *SD* = .03) loads. The ANOVA on tone counting performance revealed a main effect of WM load, $F(1, 39) = 22.67$, $p < .001$, $\eta^2_p = .36$, where participants performed better on load one (*M* = .75, *SE* = .02) than on load three trials (*M* = .65, *SE* = .03). The main effect of emotion, $F(2, 78) = 1.98$, $p = .14$, $\eta^2_p = .05$, and the interaction between emotion and WM load, $F(2,78) < 1$, $p = .38$, $\eta^2_p = .02$, were not significant. The results indicate that increased WM load impaired tone counting ability, but the emotion effect did not.

Preliminary analyses indicated that the sample's mean scores in the BAI (*M* = 9.5, *SD* = 7.9) and the BDI (*M* = 7.9, *SD* = 8.6) were mainly low and within cut-off values of anxiety and depression, respectively. In fact, levels of anxiety and depression had no significant impacts on performance (*d'*) in the working memory task, as revealed by the ANCOVA including BAI scores, $F(1, 37) < 1$, $p = .46$, $\eta^2_p = .01$, and BDI scores as covariates, $F(1, 37) = 1.60$, $p = .21$, $\eta^2_p = .04$, so these variables were subsequently disregarded. The response bias *c* also was not significantly influenced by BAI scores, $F(1, 37) = 1.28$, $p = .26$, $\eta^2_p = .03$, and BDI scores, $F(1, 37) = 1.43$, $p = .23$, $\eta^2_p = .03$.

Preliminary ANOVAs showed no effect of the BAI and BDI presentation order, $F(1,38) = 1.41$, $p = .24$, $\eta^2_p = .03$, and nonsignificant interaction with the other factors (all *ps* > .17; all Fs< 1.8). The analysis with WM load order as a between-subjects variable revealed a nonsignificant main effect on WM accuracy, $F(1,38) < 1$, $p = .57$, $\eta^2_p = .008$, but there was a significant interaction between load order (i.e., order 1-3 or 3-1) and performance in each WM load , $F(1,38) = 8.83$, $p = .005$, $\eta^2_p = .18$. However, post-hoc analyses did not reveal significant differences between load order for each WM load. While performance increased for load one as the second block of trials ($M_{31} = 2.25$, $SE_{31} = .11$) in comparison with as the first block of trials ($M_{13} = 1.97$, $SE_{13} = .14$), this difference was nonsignificant $t(38) = -1.5$, $p = .13$. There was also a nonsignificant increase in performance when load three was presented as the second block ($M_{13} = .84$, $SE_{13} = .11$) and as the first block of trials ($M_{31} = .72$, $SE_{31} = .04$), $t(38) = .95$, $p = .34$. Thus, performance was collapsed across block orders for other analyses.

Face WM Task

The 2 (WM load) × 2 (attentional load) × 3 (emotion) repeated measures ANOVA on discrimination index *d'* (results reported in Table 1) revealed a main effect of attentional load, $F(1, 39) = 39.29$, $p < .001$, $\eta^2_p = .50$, since participants performed better in the low attention load (*M* = 1.66, *SE* = .08) than in the high attention load (*M* = 1.23, *SE* = .07). The main effect of WM load was significant, $F(1, 39) = 329.78$, $p < .001$, $\eta^2_p = .89$, with a better performance in load one ($M = 2.11$, $SE = .09$) than in load three ($M = .78$, $SE = .06$). The main effect of emotion was also significant, $F(2,78) = 5.85$, $p = .004$, $\eta^2_p = .13$, and Bonferroni post-hoc tests revealed better WM accuracy for sad faces ($M = 1.55$, $SE = .07$) than for angry faces ($M = 1.34$, $SE = .08$), $p = .004$. The difference for sad faces versus happy faces ($M = 1.45$, $SE = .07$), $p = .28$, and angry faces versus happy faces were not significant, $p = .30$. The three-way interaction was not significant, $F(2,78) = .16$, $p = .85$, $\eta^2_p = .004$. Next, we describe and further analyse the significant interactions between attentional load and emotional faces, between WM load and emotional faces, and between WM load and attentional load.

Figure 5A and 5B shows, respectively, the mean performance and response bias for the two attentional loads and the three emotional faces. There was a significant interaction between attentional load and emotion, $F(2,78) = 3.30$, $p = .04$, $\eta^2_p = .07$. To further explore this interaction, we computed the mean difference between low and high attentional load for each emotion, followed by pairwise comparisons using *t*-tests with Bonferroni's corrected *p*-values for the number of comparisons (i.e., three). The results revealed that the attentional load effect for sad faces (mean difference = .25, *SE* = .09) was lower, $p = .03$, in comparison with happy faces (mean difference = .55, *SE* = .09), but not in comparison with angry faces (mean difference = .48, *SE* = .10), $p = .19$. The comparison between angry and happy faces was also nonsignificant, $p = 1$.

We also carried out additional ANOVAs for low and high attention loads separately to better assess the difference between emotional faces. The results revealed a significant difference between emotions only under high attention load, $F(2,78) = 6.75\ 1$, $p = .002$, $\eta^2_p = .14$, where WM accuracy was better for sad faces ($M = 1.42$, $SE = .09$) in comparison with angry faces ($M = 1.10$, $SE = .09$), $p = .006$ and sad faces in comparison with happy faces ($M = 1.17$, $SE = .08$), $p = .01$, as revealed by post-hoc comparisons with Bonferroni's correction. In contrast, there was no significant differences between emotions under the low attention load, $F(2,78) = 1.68$, $p = .19$, $\eta^2_p = .04$.

Figure 5C shows the mean performance for the two WM load and the three emotional faces. Also, there was an interaction between emotion and load, $F(2,78) = 9.21$, $p < .001$ $\eta^2_p = .19$. We computed the mean differences between low and high WM load for each emotion, followed by pairwise comparisons using *t*-tests with Bonferroni's corrected *p*-values for the number of comparisons (i.e., three). The results revealed a higher WM load effect, $p < .001$, for sad faces (mean difference = 1.51, *SE* = .08) in comparison with happy faces (mean difference = 1.07, *SE* = .09), but not for sad faces in comparison with angry faces (mean difference = 1.39, *SE* = .10), p = .94. The effect of WM load was higher for angry faces in comparison with happy faces, p =.015.

In addition, we carried out separate ANOVAs for low and high WM load to assess the difference between emotional faces. An effect of emotion was observed at load one, $F(2,78) = 9.45$, $p < .001$, $\eta^2_p = .19$, where performance was better for sad faces (*M* = 2.31, *SE* = .10) in comparison with angry faces (*M* = 2.04, *SE* = .11), p =.008, and sad faces in comparison with happy faces (*M* = 1.98, *SE* = .10), $p < .001$, and there was no significant difference between happy and angry, p = 1 . In contrast, at load three, the significant main effect of emotion, $F(2,78) = 5.30$, $p = .007$, $\eta^2_p = .12$, revealed a better performance for happy faces (*M* = .91, *SE* = .08) in comparison with angry faces (*M* = .64, *SE* = .08), p = .01, but a nonsignificant difference between sad faces (*M* = .79, *SE* = .07) and happy faces, p = .42, or sad faces in comparison with angry faces, p = .22.

Figure 5D shows the mean performance for the two WM load and the two attentional loads. The interaction between attentional load and WM load was also observed, $F(1,39) = 6.42$, $p = .01$ $\eta^2_p = .14$. To explore the interaction, we conducted separated ANOVAs for the attentional loads and the WM load. The results revealed the effect of attention on load one trials, $F(1,39) = 45.10$., $p < .001$, $\eta^2_p = .53$, and load three trials, $F(1,39) =11.27$, $p = .002$, $\eta^2_p = .22$. The mean differences between low and high attentional load for each WM set size (i.e., load one and load three) revealed a higher attentional effect, p = .015, for load one trials (mean difference = .56, *SE* = .08) in comparison with load three trials (mean difference = .29, *SE* = .08).

The effect of WM load was also observed in the low, $F(1,39) = 293.02$, $p < .001$, $\eta^2_p = .88$, and high attentional loads, $F(1,39) = 160.75$, $p < .001$, $\eta^2_p = .80$. The mean differences between load one and load three trials for each attentional load revealed a higher WM load effect, p = .015, for low attentional load (mean difference = 1.46, *SE* = .08) in comparison with high attentional load (mean difference = 1.19, *SE* = .09).

Response Bias

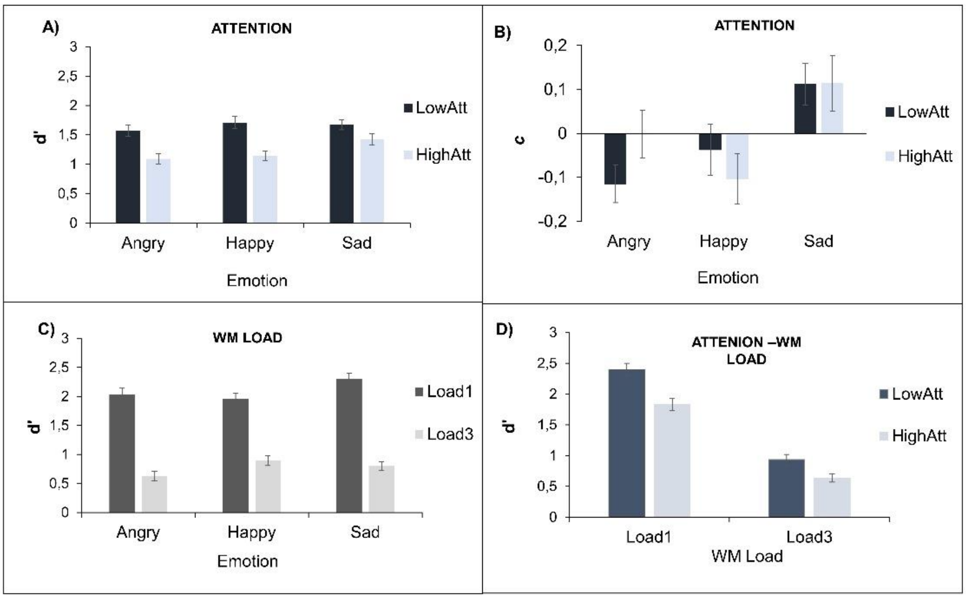
The 2 (WM load) × 2 (attentional load) × 3 (emotion) repeated measures ANOVA on the response bias criterion *c* revealed nonsignificant effect of the attentional load, $F(1,39) < 1$, p =.72, $\eta^2_p = .003$, and WM load, $F(1,39) < 1$, p =.33, $\eta^2_p = .02$. The emotion effect was significant, $F(2,78) = 18.75$, $p < .001$, $\eta^2_p = .32$, indicating a more conservative (i.e., mostly like to response "no") to sad faces ($M = .11$, $SE = .04$) than happy ($M = - .07$, $SE = .05$) and angry ($M = - .05$, $SE = .03$).

The interaction between emotion and attention, $F(2,78) = 3.93$, $p = .02$, $\eta^2_p = .09$, was also significant. To explore the interaction, we carried out separate ANOVAs for the low and high attentional loads to assess the difference between emotional faces. In the low attentional trials, the effect of emotion was significant, $F(2,78) = 10.94$, $p <.001$, $\eta^2_p = .21$, and Bonferroni post-hoc comparisons revealed a more conservative response for sad ($M = .11$, $SE = .04$) than angry ($M = -.11$, $SE = .04$), $p < .001$, and happy faces ($M = -.03$, $SE = .05$), $p =.02$, but not for happy in comparison with angry, $p = .39$. It was also observed an emotion effect at the high attentional trials, $F(2,78) > 1$, $p <.001$, $\eta^2_p = .24$, since participants were more conservative in their responses to sad faces ($M = .11$, $SE = .06$) compared to angry ($M = -.001$, $SE = .05$), $p = .047$, and happy faces ($M = -.10$, $SE = .05$), $p < .001$, but there was no significant difference between happy and angry faces, $p=.07$.

The three-way interaction between attentional load, WM load and emotion was also significant, $F(2,78) = 3.90$, $p = .02$, $\eta^2_p = .09$ (results reported in Table 2). To explore the interaction, we conducted separate ANOVAs for each attentional load across emotions in the load one (i.e., low attentional load × emotion, and high attentional load × emotion) and load three trials (i.e., low attentional load × emotion, and high attentional load × emotion). At the low attentional load, on both load one, $F(2,78) = 5.45$, $p = .006$, $\eta^2_p = .12$, and load three trials, $F(2,78) = 11.74$, $p <.001$, $\eta^2_p = .23$, pairwise comparisons revealed more conservative response to sad faces than angry faces and happy faces, all *ps* $<.05$, but not for angry in comparison with happy faces, $p = 1$. At the high attentional load, on both load one, $F(2,78) = 8.46$, $p <.001$, $\eta^2_p = .17$, and load three trials, , $F(2,78) = 4.40$, $p = .01$, $\eta^2_p = .10$, participants responses were more conservative only to sad faces compared to happy faces, all *ps* $< .01$.

Figure 5

Mean performance and response bias in the Experiment 1



Note: A) two-way interactions between attentional load trials and emotion, B) response bias between attentional load and emotion, C) two-way interactions between WM load trials and emotion, D) two-way interactions between attentional load trials and WM load. Bars represent the standard errors of the mean.

Table 1

Measures of d' for the two attentional load, two WM load and emotion in the Experiment 1.

	Discrimination Index (*d'*)					
	Low WM load			High WM load		
	Angry	Happy	Sad	Angry	Happy	Sad
Low attention	2.33 (.14)	2.35 (.12)	2.51 (.10)	0.84 (.10)	1.11 (.12)	0.85 (.09)
High attention	1.75 (.12)	1.63 (.12)	2.11 (.13)	0.45 (.10)	0.72 (.08)	0.74 (.10)

Note: Values in brackets indicate SE of the Mean

Table 2

Measures of Response Bias for the two attentional load, two WM load and emotion in Experiment 1.

	Criterion *c*					
	Low WM load			High WM load		
	Angry	Happy	Sad	Angry	Happy	Sad
Low attention	-.15(.05)	.01(.06)	.03(.06)	-.08(.07)	-.09(.08)	.19(.06)
High attention	-.03(.07)	-.16(.06)	.08(.06)	.03(.06)	-.05(.08)	.14(.09)

Note: Values in brackets indicate SE of the Mean

Discussion

In Experiment 1, we investigated whether there is an inter-dependent relation between attentional and WM load during the emotional face processing. In a dual-paradigm task, participants performed a face WM task with one and three faces in each trial, under a high and low attentional load. The WM load was measured by the face array size of one or three faces. The results showed that attentional demands on emotional faces have a lower effect on sad faces and a higher impairment effect on happy faces. In contrast, WM load affects more negative faces (i.e., sad, and angry faces) than happy faces. It is interesting to note a coherent pattern of dependence between attention and WM load resources in recognition of visual information. The two-way interaction between attentional load and WM load revealed that depletion of attention resources (i.e., high attention load trials) affects more lower WM load (i.e., one face) and an increased WM load (i.e., three faces) impairs more lower attention demand condition (i.e., low attention load trials). The results suggest an inter-relation between the two functions, but a different pattern of influence on emotion processing.

Perception Influence on Face WM Task

Although the results revealed a different pattern of interaction between the two functions and emotion processing, we would have to consider the influence of a perceptual mechanism on the WM task. A facilitated perceptual strategy might have been created by the use of a neutral probe in the face WM task. Many studies demonstrated that neutral faces share similar psychical features with sad faces compared to happy faces (Chen et al., 2011; Juth et al., 2005). It is plausible that higher physical similarity between sad and neutral faces would have facilitated the response regarding the identity of faces and reduced the cost of resources from attention.

This hypothesis is supported by the response bias towards conservative responses to sad faces, and liberal responses to happy and angry faces. These results showed that the effects of emotion come from shifts of internal discrimination criterion accompanied by memory sensitivity or effectiveness (Miendlarzewska et al., 2013). In accordance with our results, Tamm et al. (2016) found more liberal responses to happy faces on schematic happy faces. The authors suggest a perceptual strategy involved in the face processing that would elicit this response bias. However, in contrast to Tamm et al. study (2016), we found emotion effects in working memory performance which would indicate that facial emotion recognition would not depend only on the sensory process. Thus, we proposed a second experiment to explore these hypotheses in which participants performed a perception matching task with the same attention and load conditions of Experiment 1.

Experiment 2

In Experiment 2, we addressed the question of whether the influence of perception could explain the findings of Experiment 1. To investigate this hypothesis, participants performed a matching faces task (perception task) with the same attentional load (i.e., tone counting task) and load condition (1 and 3) of Experiment 1. We hypothesized that if the sad benefit arises due to the engagement of a perceptual mechanism, sad faces would be perceived as more similar to neutral faces and results would reveal a better and faster matching between sad and neutral faces. In this way, it would be expected fewer attentional resources to match faces with neutral expression compared to the pair happy-neutral and angry-neutral face. In addition, accuracy and RT would be less affected by the tone counting task (i.e., high attentional load) in the matching pair of sad-neutral faces.

Method

Participants

Thirty-four students (27 women) from the University of Aberdeen over 18 years old (*M* = 22.91 years; *SD* = 3.97) participated in this study. Only participants with normal or corrected-to-normal vision were selected. All participants provided informed consent approved by the Research Ethics Committee at the School of Psychology in Aberdeen.

Materials and Stimuli

The stimuli were the same as Experiment 1.

Procedure

In Experiment 2, participants performed a perceptual matching task combined with a tone counting task. In the perception task, there were two load condition trials: A) one emotional face next to one neutral face (1-item load) where the participant responded whether or not they had the same identity and, B) three emotional faces in a row next to one neutral face (3-items load) where the participant stated if or not the neutral face had the same identity from one of the three faces. In all the trials, the neutral face was framed by a red outline to highlight the face test. Also, there were two attentional loads, like Experiment 1, with A) a presentation of low-high tones sequence (high attentional load) and white noise burst sequence (low attentional load).

In the Experiment, to replicate the 3500 ms of the duration of the tone sequence in the Experiment, each trial was divided into two screens: 1) a white-screen with no face presentation (i.e., no-face) followed by an 2) emotional and neutral faces (i.e., yes-face). There were three-time sequence for each screen pair (“no-face – yes-face” screen): 2082 – 1418 ms, 2332 – 1168 ms, 2915 – 585 ms. The tone sequence was presented in the entire trial. Participants were instructed to respond if the identity of the neutral face was the same as the emotional face as quickly as possible, even if the tone sequence was still playing.

The WM load trials were blocked, and the presentation was counterbalanced between participants and, the attentional load trials were randomized in each WM block. The BAI and BDI questionnaires were presented at the end of the experiment session. The main components of the trial sequence for each experiment are shown in Figure 4B.

Data Analysis

Performance in the perceptual task was measured by accuracy (proportion correct) and RT with a 2 (perceptual load) × 2 (attentional load) × 3 (emotion) ANOVA. The analysis of RT considered only correct responses. Preliminary analyses were the same as Experiment 1.

Results

We considered the data from 33 participants with satisfactory engagement in the secondary task (M = 22.94 years; SD = 4.02), since our preliminary analyses indicated that one participant had low performances both in the low attention (M = .51, SD = .34) and high attention (*M* = .29, *SD* = .11) conditions. The ANOVA revealed a main effect of WM load, $F(1, 32) = 4.53$, $p = .04$, $\eta^2_p = .12$, where participants performed better on load one (*M* = .80, *SE* = .03) than on load three trials (*M* = .75, *SE* = .03). The main effect of emotion, $F(2,64) < 1$, $p = .81$, $\eta^2_p = .006$, and the interaction between emotion and load, $F(2,64) < 1$, $p = .91$, $\eta^2_p = .003$, were nonsignificant.

Preliminary analyses indicated that the sample's mean scores in the BAI (*M* = 13.00, *SD* = 12.00) and the BDI (*M* = 12.40, *SD* = 11.51) were mainly low. In fact, levels of anxiety and depression had no significant impacts on accuracy in the perception task, as revealed by the ANCOVA including BAI scores, $F(1, 30) < 1$, $p = .52$, $\eta^2_p = .01$, and BDI scores as covariates, $F(1, 30) < 1$, $p = .72$, $\eta^2_p = .004$, so these variables were subsequently disregarded.

Additional ANOVAs with perceptual load order as a between-subjects variable revealed a nonsignificant main effect on accuracy, $F(1,31) < 1$, $p = .92$, $\eta^2_p < .001$. The other factors interactions were nonsignificant (all *p*s > .06; all Fs<3).

Perceptual Accuracy

The 2 (perceptual load) × 2 (attentional load) x 3 (emotion) trials repeated measures ANOVA (results reported in Table 3) revealed a main effect of load, $F(1, 32) = 21.62$, $p < .001$, $\eta^2_p = .40$, where performance was better with load one (*M* = .91, *SE* = .01) than with load three (*M* = .86, *SE* = .01). The main effect of emotion was also significant, $F(2,64) = 14.05$, $p < .001$, $\eta^2_p = .30$, and Bonferroni post-hoc tests revealed a better accuracy of the sad faces (*M* = .90, *SE* = .01) than the happy faces (*M* = .86, *SE* = .01) , $p < .001$ but not for sad faces versus angry faces (*M* = .89, *SE* = .01) $p = .54$. Accuracy also was better for angry faces (*M* = .89, *SE* = .01) than happy faces, $p = .002$. The main effect of attentional load was nonsignificant, $F(1, 32) = 1.20$, $p = .28$, $\eta^2_p = .03$.

Figure 6A shows the mean performance for the two perceptual load conditions and the three emotional faces. There was a significant interaction between load and emotion, $F(2,64) = 3.50$, $p = .03$, $\eta^2_p = .09$. To explore the interaction, we carried out separate ANOVAs for the low and high load to examine the difference between emotional faces. The results revealed a significant effect of emotion on load one trials, $F(2,64) = 16.04$, $p < .001$, $\eta^2_p = .33$, where perceptual accuracy was better for sad (*M* = .93, *SE* = .01) in comparison with happy faces (*M* = .88, *SE* = .01), $p < .001$ but not for sad faces in comparison with angry faces (*M* = .93, *SE* = .01), *p* = 1. Also, accuracy was better for angry faces than happy faces, *p* <.001. At load three trials, the effect of emotion was also significant, *F*(2,64) = 4.31, *p* =.01, η^2_p = .11, where perceptual accuracy was only better for sad faces (*M* = .88, *SE* = .02) in comparison with happy faces (*M* = .84, *SE* = .02), *p* =.04. The accuracy for sad faces in comparison with angry faces (*M* = .85, *SE* = .02), *p* = .10, and angry compared to versus happy faces, *p* =1, were nonsignificant.

Regarding the interaction between load and emotion, we also compared the mean difference between low and high perceptual load for each emotion, followed by pairwise comparisons using *t*-tests with Bonferroni's corrected *p*-values for the number of comparisons (i.e., three). The results revealed a marginally effect for angry faces (mean difference = .81, *SE* = .01) in comparison with happy faces (mean difference = .39, *SE* = .01) with a higher effect of perceptual load for angry faces, *p* = .051, but not, *p* =.08, for angry faces in comparison with sad faces (mean difference = .49, *SE* = .01) and happy faces in comparison with sad faces, *p* = 1.

The interaction between emotion and attentional load, *F*(2,64) = 1.00, *p* =.37, η^2_p = .03, and the three-way interaction of emotion, attentional load and load, *F*(2,64) < 1, *p* =.46, η^2_p = .02, was nonsignificant.

Perceptual RTs

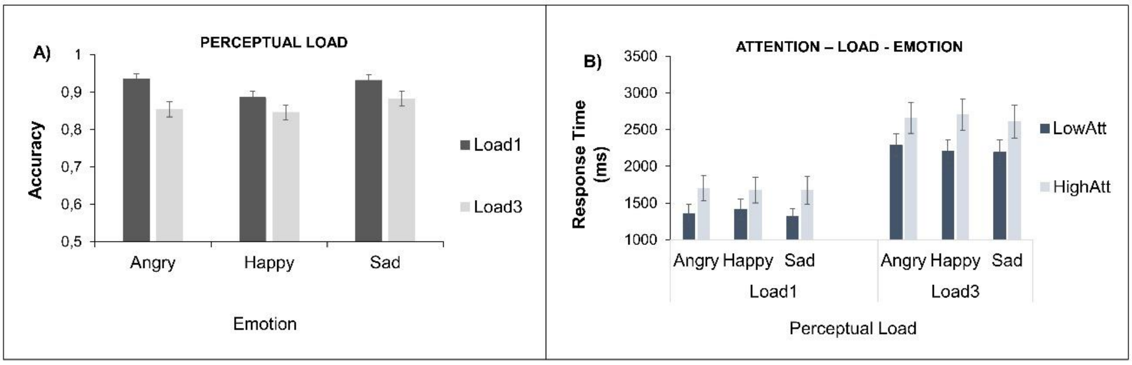
The response time analysis using a 2 (perceptual load) × 2 (attentional load) x 3 (emotion) repeated measures ANOVA revealed a significant main effect of attentional load, *F*(1, 32) = 26.84, *p* < .001, η^2_p = .45, where participants on low attentional trials (*M* = 1794 ms, *SE* = 131 ms) were faster than on high attentional trials (*M* = 2171 ms, *SE* = 183 ms). There was a significant effect of perceptual load, *F*(1, 32) = 56.79, *p* < .001, η^2_p = .64, where responses were faster at load one (*M* = 1522 ms, *SE* = 148 ms) than at load three (*M* = 2442 ms, *SE* = 183 ms). The main effect of emotion was nonsignificant, *F*(2,64) = 2.56, *p* = .08, η^2_p = .07.

Figure 6B shows the RTs for the three-way interaction. A significant three-way interaction with attention, perceptual load and emotion factors was observed, *F*(2,64) = 4.71, *p* = .01, η^2_p = .12. To explore this interaction, we carried out separate ANOVAs for each condition to assess the effect of the emotion on the RT. There was a tendency for an emotion effect in the low attentional load with load one, *p* =.051, and load three trials, *p*

= .07, but there was no effect of emotion in the high attentional load for load one, p = .76. and three, p = .25.

Figure 6

Mean performance and response time in the Experiment 2.



Note: A) two-way interactions between perceptual load trials and emotion, B) three-way interaction between perceptual load trials, attention and emotion. Bars represent the standard errors of the mean.

Table 3

Measures of proportion correct for the two attentional load, two WM load and emotion in the Experiment 2.

	Proportion Correct					
	Low perceptual load			High perceptual load		
	Angry	Happy	Sad	Angry	Happy	Sad
Low attention	0.93 (.01)	0.89 (.02)	0.93 (.01)	0.85 (.02)	0,.85 (.02)	0.87 (.02)
High attention	0.95 (.01)	0.88 (.02)	0.93 (.02)	0.86 (.02)	0.84 (.02)	0.89 (.02)

Note: Values in brackets indicate SE of the Mean

Discussion

In Experiment 2, we addressed the question of whether perception might have influenced the recognition of emotional faces. We predicted that a higher similarity of physical features between the pair neutral-sad faces would improve the accuracy of the sad face trials. To investigate this hypothesis, participants performed a perceptual matching task with the same attention and load conditions of Experiment 1. According to the results, discrimination of sad faces is better when compared to happy faces but is not different from angry faces. Indeed, accuracy is better for angry and sad faces when a neutral face probe is presented. Also, the perceptual load affected the discrimination of negative faces, but not of happy faces. However, contrary to attentional effects on WM, the attention-demanding condition affected only the response time, but not the accuracy on emotional perception, suggesting that attention resources partly modulated responses on emotional perception.

Effect of Emotional Perception on the Face WM Task

Differences on Emotion Effects

Contrary to the previous hypothesis that attention load would disrupt the emotional perception accuracy, the tone counting task did not impair the accuracy performance, and there was no effect of attentional load across emotions. Although there was an attention interference on response time, the effect was the same for all the emotional expressions. It should be noted, however, that there was a better accuracy of sad and angry faces due to a facilitated perception of sad-neutral and angry-neutral pair faces. Thus, it is plausible that visual discrimination, and not the relevance of emotional expression, influenced the face WM task in the first experiment. On the other hand, if participants had based only their responses on visual perception in Experiment 1, not only sad but also angry faces should have been better recognised, which would suggest that perception influence on the first experiment cannot solely explain the first experiment data. These results suggest that the neutral probe face can enhance better discrimination of sad and angry faces, but this bottom-up process does not determinate the response of WM on the processing of emotional information.

Differences in Load Effects

In accordance with WM load effects, increased perceptual load (i.e., effect of load) impaired negative faces, but a different effect was found on happy faces. Contrary to the first experiment, results revealed no effect of perceptual load on happy faces compared to negative faces. Likewise, there was a better accuracy of angry faces compared to happy faces on perceptual load one. If participants had used a perceptual strategy to decision making in the face WM task, there should have also been an accuracy benefit for angry faces with low WM load (i.e., load one). Taken together, these results show a bottom-up process on emotion perception that is unlikely to explain the cognitive load effects of the first experiment.

Differences in Attentional Effects

The significant emotion effect reveals better discrimination of sad faces, but this accuracy benefit is not affected by the attention condition. However, slower responses in the tone counting condition reflects an impairment of emotion perception task due to the high attentional load, as in Experiment 1. Although the attentional demand did not affect accuracy in the perceptual task, the interference of the perceptual load in the tone counting task suggest that there is competition for attentional resources. In addition, the response time is affected by attentional load, suggesting that at least part of the process is driven by attention. The lack of effect on accuracy can reflect different perceptual process measured by accuracy and response time (Santee & Egeth, 1982). Some authors argue that these two measures are affected by attention via distinct cognitive and neutral processes (van Ede et al., 2012). Thus, it does not appear that emotion perception is immune to attention-demanding interference.

In concern to the automaticity versus competition of attentional resources debate on perception, contrary results report that emotion perception requires attention demands (Tomasik et al., 2009; Pessoa, McKenna, et al., 2002) meanwhile others imply that emotion perception is automatic (Shaw et al., 2011). For instance, Pessoa et al. (2002) measured the activation of brain regions by attention load when participants had to judge the orientation of bars or to determine the gender of emotional faces. They found different responses to emotional faces only when sufficient spatial attention resources were available. However, Shaw et al. (2011) found that attentional shifts to an emotional face occurred even without central attentional resources. They had participants decide the gender or location of a prespecified emotional expression in a screen with an angry or happy face presented adjacent to each other while perform a discrimination tone-versus-noise task. It should be emphasized that in Shaw et al. study, there is a competition between different emotion expressions with high arousals (i.e., happy vs angry face) what would have altered the demand of the task compared to the current study (i.e., emotional expression vs neutral expression).

General Discussion

In the present study, we examined whether emotion information competes for attentional resources and how WM load modulate the selection and prioritization of these relevant content. Experiment 1 confirmed a different pattern of influence on emotion processing with a greater load effect but a less attentional impairment on sad faces compared to other emotional expressions. Furthermore, in Experiment 2, we addressed the question of whether perception might have influenced the recognition of emotional faces on WM. The results revealed a visual similarity between sad-neutral and angry-neutral pair of faces but showed that the effects of attention and load on the emotional perception task were different from the WM effects in the first experiment.

The Effect of Emotion on WM is Modulated by Load

In concern to the WM resources, the poor performance on the three-load condition reflects a higher competition from WM resources which involves a greater cost for angry faces. Although our results showed that angry faces also required attention processing, its demands were not different from other emotional faces. This finding is consistent with the perspective that greater resources are allocated to angry faces because of its motivational value (Jackson et al., 2014). According to previous studies, a motivated process contributes to the competitiveness of available resources from WM (Anderson et al., 2009). Indeed, a large body of research has postulated an association between anger and an approach motivation system (Adams et al., 2006, Harmon-Jones & Segilman, 2001, Harmon-Jones, 2003). For example, Adams et al. (2006) found that participants in a reaction-time task were faster to perceive apparent approach movement in faces expressing anger than in faces of fear.

The relevance of angry faces is likely to be associated with an evolutionary capacity to respond and detect faster threat-signal in the environment. This advantage has not been found in other negative stimuli, as sad faces (Ohman et al., 2001), suggesting a distinguishable attribute of angry faces compared to other negative expressions (Darwin, 1872). Thus, it seems unlike that a motivated processing could account for the effects of WM load on sad faces. However, our results demonstrated an advantage for sad faces on memory that have not been found in previous studies.

Why, then, sad faces require greater resources from WM in our study? One possible explanation is related to the relevance of the emotional stimulus in each context. Although emotional expression has been considered as a universal sign (Ekman, 1972), subtle differences, as social norms, would affect the perception of emotional facial expressions (Bublatzky et al., 2014; Fischer & Van Kleef, 2010; see Wieser & Broshc, 2012, for a review) and the effective communication across cultures (Elfenbein & Ambady, 2003a). Recent research has found an influence of culture in relation to how individuals recognize emotions, suggesting subtle differences in the way each perceiver decode emotional expression in their social context (Jack et al., 2012; Viggiano & Marzi, 2010). For example, Westerners (i.e., North Americans) individuals are more sensitivity to detect subtle expressions of anger or sadness than East Asians (i.e., Chinese) (Zhang et al., 2015). Consist with these findings, the relevance of the sad face would change according to its social context, and it could reflect on different cognitive demands for facial processing. It is important to note that previous studies in the field were carried out in different cultures (Jackson et al., 2009; Simione et al., 2014; Valenti, Wada, et al., 2020) which might lead to contrasting findings. In sum, the cultural contact is likely to influence social learning and enhance the decode of emotions from individuals of foreign cultures (Elfenbein & Ambady, 2003b).

The Effect of Emotion on WM depends of Attentional Resources

Contrary to WM demands on emotion recognition, sad faces required less attentional resources than happy faces. Previous findings demonstrate an opposite finding with better recognition of happy faces than sad faces under a high perceptual load in a divided attention task (Gupta & Srivastava, 2015) or under a high attentional load in a dual-paradigm task (Valenti, Wada, et al., 2020). However, similar to our results, Eastwood et al. (2001) found a faster response to sad faces than to happy faces in a visual search task in which participants identified a unique target face with emotional expression (e.g., happy or sad faces) among faces with a neutral expression (e.g., distractors).

Most of these studies have investigated the relation of attention and emotion but not directly its influence on memory. Nevertheless, in a recent study (Valenti, Wada, et al., 2020), we employed a dual-paradigm task to investigate the influence of the availability of attentional resources on the process of emotional faces on WM. We found that negative faces capture more attention than happy faces. The main methodological difference between our studies is the WM load of two faces (Valenti, Wada, et al., 2020) versus one-three faces (i.e., current study). It is interesting to note that the nature of the task can facilitate or interfere in the interaction between representations (Curby et al., 2019). According to Curby et al. (2019), there are competitive/interference effects such as larger set sizes or longer retention interval, and facilitatory effects that can compensate and reduce the costs for the interference effects, for example, via short retention intervals. Consist with this possibility, a larger set size combined with a high attention (i.e., tone counting) task may have rendered more interactions/interferences between the cognitive demands (i.e., attention and WM load) in our study.

Additionally, some authors suggest a shared resource between WM demands and selective attention (Engle, 2002; Lavie, 2005), that is, the WM load would impair the memory performance because of competition over a limited attentional resource. This shared attentional resource hypothesis is supported by our results that show an interference of WM load on attentional task. In sum, the WM load in the current study may have rendered a different selective attentional mechanism from previous studies.

In this case, the way in which attention is guided might influence the response benefit toward the emotional face (Srivastava & Gupta, 2010; Srivastava & Hanif, 2010; Srivastava & Srivastava, 2010, for a review see Srivastava et al., 2010). For example, Srivastava & Hanif (2010) investigated whether attention directed to a global or local level processing would affect the identification of a followed emotional face (i.e., happy and sad faces) in a priming paradigm, and found faster responses to happy faces was linked to global processing while sad faces were related to local processing. In concern to the current study, selective attention more guided to a focus processing would have provided a sad faces benefit, but further studies would have to be conducted to answer this question. Furthermore, we should point out that in our study, the sad accuracy benefit has not been compromised by speed/accuracy tradeoffs because participants did not take more time in recognition of sad faces to become more accurate on performance.

Conclusion

In sum, our results demonstrated that the process of emotional information on WM depends on the inter-relation between attentional and WM load resources, but each function have a distinct pattern in the selection of emotional information. Some relevant factors can modulate the different pattern of influence of attention and WM load on emotional process. An important factor is the inter-relation between cognitive load and attention that might have led to a different selective attentional mechanism, as a selective attention more guided to a focus processing which would have provided a sad faces benefit (Srivastava & Gupta, 2010; Srivastava & Hanif, 2010; Srivastava & Srivastava, 2010).

Neutral and negative mood induction in verbal and visuospatial working memory (Study 3)

Abstract

Previous studies have investigated the role of emotion on working memory through mood effects on decision-making and judgment capacity. The decision-making seems to depend on the judgment of emotional information and mood states effects. In the present study, we examined the effect of the negative mood on working memory in healthy individuals. In Experiment 1 and 2, participants performed a verbal and visual-spatial reasoning task after a negative (negative group) or a neutral (control group) induction. The results revealed a better performance of both groups after the induction than in the pre-induction baseline, suggesting a learning effect. In Experiment 2, we controlled the cognitive load in the visual task and the participants performed the visual task according to their memory span capacity. The results showed no significant improvement in performance in the visuospatial reasoning task for the negative mood induction group, but there was an improvement for the neutral group performance since this group had a lower performance in the baseline trials.

Keywords: Emotion, negative mood, working memory, reasoning, healthy population

Introduction

Emotion research in the past decade has produced many interesting findings regarding the influences of emotion on our actions and beliefs, such as how we think and how we solve cognitive tasks and dilemmas (Kensinger & Kark, 2018; Tyng et al., 2017). Prior studies have focused on the crucial role of emotion on cognition by investigating the influence of mood and emotional states on memory, decision-making and emotional perception (Baddeley et al., 2012; Gunn & Finn, 2015; Pupillo et al., 2020; Storbeck & Clore, 2005; Storbeck & Maswood, 2015). For instance, Baddeley and colleagues (2012) investigated the effect of mood induction (i.e., negative, positive, neutral) in perception and evaluation of emotional valence in stimuli like words, pictures and faces. Participants were induced through the presentation of pieces of classical music and negative, positive or neutral images from the International Affective Pictures System (IAPS) database (Lang et al., 1999), and were required afterwards to evaluate and rate the valence of different types of emotional stimuli. The findings showed that only the induction of the negative mood compared to the positive and neutral mood resulted in substantial changes in valence ratings by the participants, who perceived negative stimuli as being more negative.

Furthermore, it is interesting to note that negative mood (e.g., depression and anxiety) is often associated with impaired working memory performance (Miller et al., 2018; Storbeck et al., 2015), probably due to a reduction in the processing efficiency of task information (Eysenck & Calvo, 1992). Evidence from neuroimaging studies supports this association by showing changes in the activation of neuronal areas or circuits related to working memory during different mood states. For example, the activation of the orbitofrontal cortex, which is one of the areas responsible for emotional processing, decreases the activity of the dorsolateral region (i.e., the dorsolateral prefrontal cortex), influencing cognitive processes such as working memory (Perlstein et al., 2002).

In an attempt to account for the role of emotion on working memory, recent studies have investigated the effect of negative mood on decision-making and judgment capacity (Gunn & Finn, 2015; Szasz et al, 2016). For instance, Szasz et al. (2016) investigated how regulation strategies that attenuate negative states (e.g., anger and sadness emotions), affects decision-making performance. The authors found that adaptative strategies that modulated negative moods promoted a better capacity to make decisions. In this perspective, decision-making seems to depend on the judgment of emotional information and is subject to mood states effects. The individual’s current feelings may not only favor the recall of information that is emotionally congruent but may also serve as a basis for judging current situations, influencing decision making (Schwarz, 2000). For example, positive or negative mood can lead the individual to make more optimistic or pessimistic judgments (Wright & Bower, 1992). In this view, negative emotions tend to trigger more systematic information processing than positive emotions (Loewenstein & Lerner, 2003).

Present Study

In the present study, we investigated the effects of neutral and negative mood induction on working memory in a sample of individuals without mood disorders like anxiety and depression. Based on previous studies that have shown significant impacts of negative mood states (i.e. anxiety and depression) on working memory, particularly on memory and decision-making tasks involving executive functions (Gunn & Finn, 2015; Storbeck & Clore, 2005, Szasz et al, 2016), our objective was to replicate the negative mood effect on working memory in a sample of healthy individuals. Such findings would not only be relevant for the basic cognition research and to the understanding of the cognitive impacts of mood disorders like anxiety and depression, but may also have implications in the understanding of memory and reasoning problems in healthy individuals who work on environments that stimulate negative moods as sadness or anger.

Experiment 1 and 2

We investigated the effect of negative induced mood on a verbal reasoning task, based on Baddeley’s grammatical reasoning task (Baddeley & Hitch, 1974), and on a visuospatial working memory task based on Shah and Miyake (1996). In Experiment 1 and 2, two groups of participants (i.e., neutral and negative mood induction groups) performed each task (i.e., visual and verbal) after mood induction. In Experiment 2, we controlled the capacity of each participant to perform the visuospatial reasoning task with a span task presented before the experiment session.

Method

Participants

In Experiment 1, twenty-seven from the University of São Paulo (15 females, *M* = 24 years, *SD* = 3.37) voluntarily participated in the study. We randomly assigned the students to either a neutral mood induction (n = 13) or a negative mood induction group (n = 14). In Experiment 2, thirty-six university students (19 females, *M* = 24 years, *SD* = 4.48) participated of the neutral (n = 19) or negative group (n = 17).

We ensured that participants entering the study met specific criteria regarding depression and anxiety symptoms. The participants were evaluated with the Beck Anxiety Inventory (Beck et al., 1988) and Beck Depression Inventory-II (BDI -II, Beck, et al., 1996). All of the participants had scores below cut-off values, that is, 17 points in the BDI and 10 points in the BAI (Cunha, 2011). None of the participants was referred to as having a mood disorder. The participants signed informed consent forms and the study was approved by the local Research Ethics Committee. During the recruitment of participants, a total of 20 individuals did not meet the inclusion criteria.

Materials and Stimuli

Mood Induction

Negative mood induction comprised 49 images with negative valence (valence: *M* = 1.73, *SD* = 1.27; *arousal*: *M* = 7.56, *SD* = 1.67) from the International Affective Picture System (IAPS) (Lang et al., 1999) and were displayed in two blocks of 27 images during 2.4 minutes (5.3 seconds per image) (Baddeley et al., 2012), simultaneously with 2.4 minutes of the music Symphony 5: Adagietto by Mahler (Storbeck & Clore, 2005). Neutral mood induction comprised 49 images with neutral valence from IAPS (valence: *M* = 5.09, *SD* = 1.64; *arousal*: *M* = 4.52, *SD* = 1.89) and were displayed in two blocks of 27 images during 2.4 minutes with 2.4 minutes of the music "Pure Arctic Wind" from the Nature Sounds-Artic Wind" compilation. The IAPS images selection was based in national norms for the IAPS (Ribeiro et al., 2004).

Mood Evaluation

Participants completed two instruments at the beginning and the end of the experiment: (1) a list of mood expressions adapted from the Present Mood States List or LEAP ("Lista de Estados de Ânimo Presentes – LEAP", Engelmann, 1986) and (2) a list of words with neutral, positive and negative valence (Oliveira et al., 2013). The LEAP comprised 40 expressions classified in 12 factors of mood states. Each expression was displayed in the center of the monitor for 1,500 ms, followed by a 5-point Likert scale which represented the intensity of the participant emotional state: 1 - very weak, 2 - weak, 3 - average, 4 - present, 5 - very present. The participants were required to judge each expression according to the intensity of their mood state in the current moment sentence was being read. The **Annex D** shows the LEAP list of 40 expressions.

The list of words was based on previous studies that measured mood by the evaluation of words' valence (Baddeley et al., 2012; Fachinello, 2018). The words were selected from a database of 908 Portuguese words classified according to the arousal and valence (Oliveira et al., 2013). Two different lists were used (Fachinello, 2018), each with 15 words and five words for each valence (i.e. neutral, positive and negative), and were presented at the begging and the end of the experiment. In total, 10 words with neutral (valence: M = 5.26, SD = 1.87; arousal: M = 4.38, SD = 1.85), 10 words with positive valence (valence: M = 8.17, SD = 1.63; arousal: M = 3.10, SD = 2.46), and 10 words with negative valence (valence: M = 1.85, SD = 1.86; arousal: M = 7.40, SD = 1.87) were presented in entire experiment. Each word was displayed in the center of the monitor screen for 1,000 ms and followed by an 8-point Likert scale with the 1-point value referred to as "Extremally Negative" and 8-point value as "Extremally Positive". The **Annex E** shows the two lists of words.

Verbal Reasoning Task

In this task the participants were required to memorize a pair of letters (i.e., "AB") and afterwards were required to answer whether a given statement about the letters was 'true' or 'false', for example, given the pair "AB" followed by the statement "A follows B", the correct answer would be 'false'. The task comprised 32 statements about combinations between the letters 'A' and 'B' (either 'AB' or 'BA'), based on the following elements: (1) Precedes or Follows, (2) Active or Passive voice and (3) Positive or Negative sentence. For example, given the pair "AB", the statements "A is followed by B" and "B is not followed by A" are both true. For the practice trials, we used 16 statements about 'CD' or 'DC'.

Visual Reasoning Task

In this task, the participants were required to judge the direction of letters (i.e., normal or mirrored direction) and memorize the orientation angle of letters (a sequence of two letters in Experiment 1 or a sequence of letters defined according to each participant's memory capacity for this task in Experiment 2). That is, the participants were required to perform a direction judgment task while memorizing the orientation angle. The letters were selected from a set of five letters (F, P, R, L and J) of 1° degree of visual angle in Arial Black, and the same letter was used throughout the same trial. Each letter was presented in a normal or mirror-imaged direction in one of seven possible orientations, in 45° increments except by the standard upright position, with a total of 70 possible combinations (5 letters × 7 orientations × 2 directions). The letters orientations were always directed to one of the seven possible sides but never to the upright position and, to ensure that the same orientation could appear only once in the same letter sequence, opposing orientations of the letters were not presented successively within the same sequence.

In the beginning of the trial, the participant was informed about the particular letter that would be used that trial and was required to press the space bar to start the trial. Then a letter sequence (i.e., with normal or mirror-direction) was presented in the center of the screen. After the sequence, a diamond-shape grid with squares (i.e., buttons for mouse clicks) comprising eight squares of 1.14° × 1.14° degrees of visual angle was displayed in eight-points of the screen, every 45° for representing the possible locations of the top of the letters. The participants were instructed to select the orientation of the top of each presented letter following the same order.

In Experiment 1, the sequence length was fixed in two items, however, given the individual differences in working memory, sequence length in Experiment 2 was defined for each participant based on a visual reasoning span task was used to assess the participant’s capacity for the task, in order to ensure an appropriate cognitive load for each participant. In this task, the number of letters increased until participants failed to correctly answer two successive trials, at a maximum of a five letters sequence. A participant’s span was then defined as the maximum sequence length for which all items were answered correctly.

Procedure

Previously to the experiment, each participant was evaluated by the BDI-II and BAI. The experimental session begun with the assessment of the participants’ mood (LEAP and List of Words) prior to emotional induction, followed by instructions and practice trials of the visual and verbal tasks.

First, participants were instructed about the visual reasoning task and performed 16 trials answering whether the letter was in a normal or mirror-direction, followed by 16 trials answering whether the letter was in a normal or mirror-direction and then indicating the positions of the top of the letters in the grid. For the verbal reasoning task, participants performed a block of 16 practice trials. After the practice trials, participants performed ten trials of each task (i.e., baseline trials) without feedback prior to mood induction, in order to have a measure of baseline performance, which were followed by two blocks of trials (visual and verbal task) after mood induction. At the end of the experiment (i.e., post-induction), participants completed the two-mood evaluation instruments again. Figure 7 describes the trial sequence and Figure 8 describes the tasks and mood evaluation instruments.

Verbal Reasoning Task

In each trial, a pair of letters was presented during 500 ms (i.e., the pair CD/DC was presented in the practice trials, and the pair AB/BA was presented in the baseline and sessions trials), followed by a mask (i.e., pair of letter XX) during 250 ms. After the mask, a sentence describing the order of the pair was presented in the screen (i.e., A precedes B) for a limited time of 8000 ms. Below the sentence, two boxes with the word "True" and "False" were presented respectively in the left and right side of the screen. The participant was instructed to press the left button of the mouse if the sentence was "True" or press the right button of the mouse if the sentence was "False". If the participant's response was delayed and exceeded the time, a null response was punctuated, and the feedback "No Response" in red would appear in the screen in the all the experiment trials (i.e., practice, baseline and session trials). The participant performed 16 practice trials, 10 baseline trials and two practice trials before the 32 session trials. In the practice trials, the participant response was followed by feedback: A blue cross indicated a correct response and a red cross indicated an incorrect response.

Visual Reasoning Task

In each trial, during the presentation of the letters, the participants were required to answer whether the given letter was normal or mirrored by pressing the left mouse button or the right button, respectively. Each letter was presented during a limited time of 2500 ms. In case of no response or a delayed response, a null response was registered. After the letter sequence, the participants were required to mouse to click on each location of the top of presented letters to indicate their orientation in the diamond-shape grid, according the letter sequence order. After the participant clicked on the appropriate number of squares "buttons", the grid disappeared from the monitor screen. A response was punctuated as correct if the participant selected the correct normal/mirror direction and the orientation of the sequence of letters in the order of appearance. The participant performed 10 baseline trials, two practice trials before the 30 session trials (trials after the mood induction) with six sequences for each letter.

Figure 7

Sequence of events in a trial of the negative mood group.

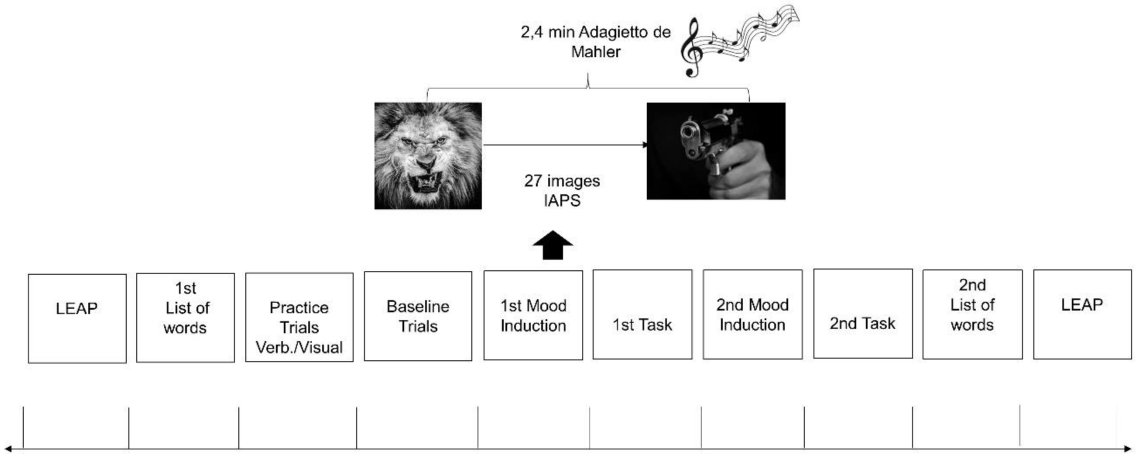
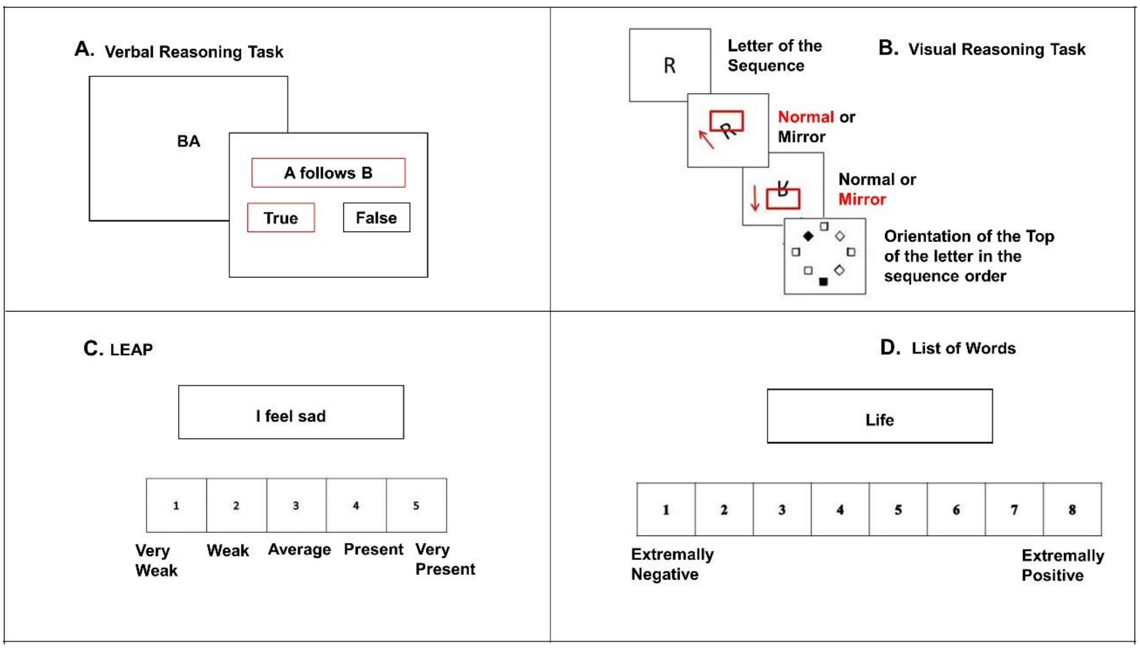


Figure 8

Example of the reasoning tasks and mood evaluation instruments.



Note: A. Verbal and B. Visual (e.g. sequence of two letters). C. LEAP and D. List of Words.

Data Analysis

The proportion of correct answers was computed for each trial. In the visual reasoning task, a correct trial was computed when the participant answered both the direction (i.e., mirror or normal) and orientation (i.e., top of each letter) correctly. The data were submitted to repeated-measures ANOVAs with induction group (negative and neutral) as between-subjects factor, and type of trials (i.e., baseline and post-induction trials) and task (i.e., verbal and visual reasoning task) as within-subjects' factors. The significance level was set at .05, partial Eta squared (η^2_p) effect sizes were computed. In the analyses of mood ratings, we compared the means scores of the list of words and the list of expressions (i.e., LEAP) in the pre-induction and post-induction moment with *t*-tests with Bonferroni's corrected *p*-values for the number of comparisons.

To better explore the differences due to the negative mood induction, we analyzed only expressions from the LEAP list related to extremely negative and positive feelings. We examined four expressions related to negative feelings (e.g., I feel sad) and one positive expression (i.e., "I am happy"); the other expressions were not included due to an expression of a more complex state of emotion or feeling (e.g., "I feel surprised", "I feel sexual attraction"). Thus, our criteria provided an examination of a negative mood instead of broader emotional states.

Results of Experiment 1

Reasoning Task Accuracy

The 2 induction group × 2 trial type × 2 task repeated measures ANOVA revealed a main effect of trial type, $F(1, 25) = 4.89$, $p = .03$, $\eta^2_p = .16$, given that participants performed better in the post-induction trials ($M = .67$, $SE = .03$) than in the baseline trials ($M = .62$, $SE = .04$). The main effect of group $F(1, 25) = .01$, $p = .89$, $\eta^2_p = .001$, and task, $F(1, 25) = .68$, $p = .41$, $\eta^2_p = .027$, were not significant. The means scores of baseline and post-induction trials for the verbal and visual tasks in each group are shown in Table 4.

The interaction between trial type and task was significant, $F(1, 25) = 5.38$, $p = .03$, $\eta^2_p = .17$, but the other interactions were not significant (*Fs* < 1, *ps* > .33). To explore the significant interaction, we examined the participants performance in baseline and post-induction trials separately for each task. The results revealed a significant difference between baseline trials and post-induction trials for the visual task, $F(1, 25) = 8.72$, $p = .007$, $\eta^2_p = .25$, with a higher performance in the post-induction trials than for baseline trials. In contrast, there was no significant difference between trial types for the verbal task. The other interactions were not significant, ($Fs < 1$, $ps > .33$).

Mood Ratings

The means scores of participants for the evaluation of expressions and words in each group are shown, respectively, in Tables 5 and 6.

List of Expressions

In the negative group, Bonferroni corrected *t*-tests with adjusted *p*-values for the number of comparisons (i.e., 5) revealed a significant difference between the pre- and post-induction in the expression, “I am disgusted”, $p < .001$, “I am happy”, $p = .005$. The differences between scores for the other expressions were not significant, all $ps > .03$. In the neutral group, the scores differences were not significant, all $ps > .80$.

List of Words

In the negative group, Bonferroni corrected *t*-tests with adjusted *p*-values for the number of comparisons (i.e., 3) revealed a not significant difference for each valence’s word before and after the induction, all $ps > .18$. In the neutral group, the differences were also not significant, all $ps > .12$.

Table 4

The means scores of baseline-session trials for verbal-visual task in each group of Experiment 1.

	Verbal reasoning task		Visual reasoning task	
	Baseline trials	Session trials	Baseline trials	Session trials
	Mean (*SD)*	Mean (*SD)*	Mean (*SD)*	Mean (*SD)*
Negative Group	.68 (.05)	.70 (.04)	.57 (.09)	.66 (.08)
Neutral Group	.67 (.05)	.63 (.04)	.57 (.09)	.70 (.08)

Note: Values in brackets indicate SE of the Mean

Table 5

The means scores of participants for the evaluation of expressions in each group of Experiment 1

	Negative group		Neutral group	
	Pre-induction	Post-induction	Pre-induction	Post-induction
Expressions	Mean (*SD)*	Mean (*SD)*	Mean (*SD)*	Mean (*SD)*
I am happy	3.71 (.16)	2.78 (.21)	3.00 (.25)	2.84 (.29)
I am scared	2.00 (.23)	2.57 (.34)	2.30 (.32)	2.23 (.25)
I am disgusted	1.07 (.07)	2.71 (.26)	1.30 (.23)	1.38 (.26)
I feel sad	1.92 (.28)	3.00 (.25)	2.46 (.29)	2.61 (.31)
I am angry	1.78 (.28)	2.07 (.26)	2.92 (.38)	2.76 (.42)

Note: Values in brackets indicate SE of the Mean

Table 6

The means scores of participants for the evaluation of words in each group of Experiment 1

	Negative group		Neutral group	
	Pre-induction	Post-induction	Pre-induction	Post-induction
Words	Mean (*SD)*	Mean (*SD)*	Mean (*SD)*	Mean (*SD)*
Negative words	2.02 (.22)	1.92 (.22)	1.75 (.12)	1.60 (.15)
Neutral words	5.08(.23)	4.58 (.11)	4.75 (.19)	4.50 (.19)
Positive words	7.68 (.10)	7.47 (.14)	7.12 (.11)	7.04 (.21)

Note: Values in brackets indicate SE of the Mean

Results of Experiment 2

Visual Reasoning Span Task

The memory span of the participants in each group was of one letter ($n_{negative} = 8$; $n_{neutral} = 9$), two letters ($n_{negative} = 4$; $n_{neutral} = 2$) and three letters ($n_{negative} = 7$; $n_{neutral} = 6$), so that the sequence length of letters in the visual reasoning task was adjusted for each participant.

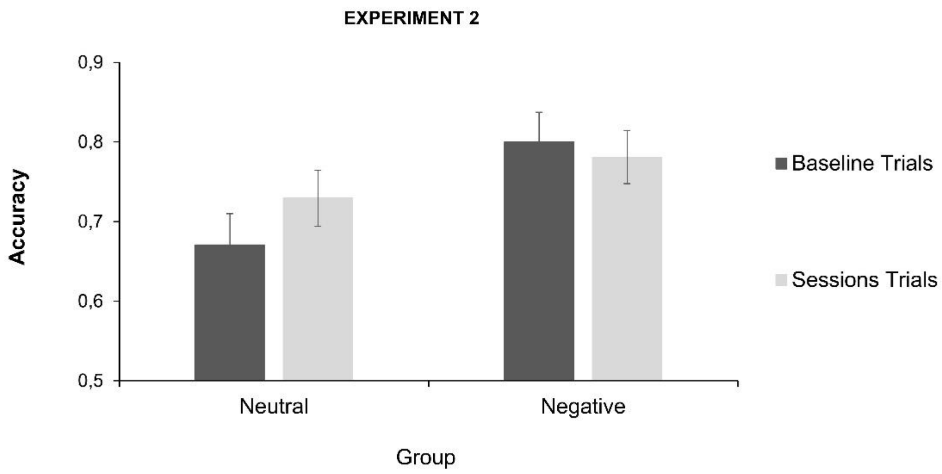
Reasoning Task Accuracy

The 2 induction group × 2 trial type ×2 task repeated measures ANOVA revealed a marginally significant effect of group, $F(1, 34) = 3.41$, $p = .07$, $\eta^2_p = .09$, given that participants performed better in the negative group ($M = .79$, $SE = .03$) than in the neutral group ($M = .70$, $SE = .03$). Also, the main effect of task was significant, $F(1, 34) = 5.40$, $p = .02$, $\eta^2_p = .13$, with better performance in the visual task ($M = .79$, $SE = .03$) than in the verbal task ($M = .69$, $SE = .03$). The difference in performance between baseline and post-induction trials was not significant, $F(1, 34) = 1.42$, $p = .24$, $\eta^2_p = .04$. The mean proportion of correct responses of baseline and post-induction trials for the verbal and visual tasks in each group are shown in Table 7.

The interaction between group and trial type was significant, $F(1, 34) = 5.71$, $p = .02$, $\eta^2_p = .14$ (cf. Figure 9). Bonferroni corrected *t*-tests with adjusted *p*-values for the number of comparisons (i.e., 4) revealed nonsignificant difference between groups in the baseline trials, $p = .08$, and post-induction trials, $p =1$. In addition, for the neutral group we observed a better performance ($p =.04$) in post-induction trials in comparison with baseline trials, but not for the negative group ($p =1$).

Figure 9

Two-away interaction between group (neutral and negative) trials (baseline and session) in Experiment 2.



The interaction between trial type and task was significant, $F(1, 34) = 5.98$, $p = .02$, $\eta^2_p = .15$. To explore this interaction, we examined the participants performance in the baseline trials and post-induction trials at each task with specific ANOVAs. In accordance with results from Experiment 1, there was a significant difference between baseline and post-induction trials for the visual task, $F(1, 34) = 9.17$, $p = .005$, $\eta^2_p = .21$, with higher accuracy in the post-induction trials ($M = .83$, $SE = .04$) than in the baseline trials ($M = .76$, $SE = .04$). For the verbal task, performance did not differ significantly between baseline trials ($M = .70$, $SE = .03$) and post-induction trials ($M = .67$, $SE = .03$), $F(1, 34) = 1.02$, $p = .31$, $\eta^2_p = .03$. The two-way interaction between group and task, $F(1,34) = .22$, $p = .64$ $\eta^2_p = .006$, and the three-way interaction between group, trial, and task were not significant, $F(1,34) = .81$, $p = .37$, $\eta^2_p = .02$.

Mood Ratings

The means scores of participants for the evaluation of expressions and words in each group are shown, respectively, in Table 8 and 9.

List of Expressions

In the negative group, Bonferroni corrected *t*-tests with adjusted *p*-values for the number of comparisons (i.e., 5) revealed only a significant difference in the scores of the pre-induction and post-induction moment in the expression “I am disgusted”, $p = .05$. The mean score across moment of the other expressions were not different, all $ps > .22$. In contrast, there was a not significant difference in the mean score in the neutral group, $ps > .24$.

List of Words

In the negative group, the Bonferroni corrected *t*-tests with adjusted *p*-values for the number of comparisons (i.e., 3) revealed that the evaluation of words across moment was not significantly different, all $ps > .13$. Also, in the neutral group, there was no difference in the evaluation of words in the pre- and post-induction, all $ps > .17$.

Table 7

The means scores of baseline-session trials for verbal-visual task in each group of Experiment 2

	Verbal reasoning task		Visual reasoning task	
	Baseline trials	Session trials	Baseline trials	Session trials
	Mean (*SD)*	Mean (*SD)*	Mean (*SD)*	Mean (*SD)*
Negative Group	77. (.04)	.72 (.04)	.82 (.05)	.83 (.05)
Neutral Group	.64 (.05)	.63 (.04)	.70 (.05)	.82 (.05)

Note: Values in brackets indicate SE of the Mean

Table 8

The means scores of participants for the evaluation of expressions in each group of Experiment 2

	Negative group		Neutral group	
	Pre-induction	Post-induction	Pre-induction	Post-induction
Expressions	Mean (*SD)*	Mean (*SD)*	Mean (*SD)*	Mean (*SD)*
I am happy	3.63 (.20)	3.15 (.28)	4.05 (.18)	3.94 (.20)
I am scared	1.78 (.19)	1.89 (.22)	1.82 (.29)	1.88 (.28)
I am disgusted	1.26 (.10)	2.00 (.27)	1.47 (.21)	1.35 (.14)
I feel sad	2.00 (.26)	2.57 (.28)	1.64 (.19)	1.76 (.18)
I am angry	2.15 (.30)	1.89 (.27)	2.00 (.28)	2.41 (.27)

Note: Values in brackets indicate SE of the Mean

Table 9

The means scores of participants for the evaluation of words in each group of Experiment 2

	Negative group		Neutral group	
	Pre-induction	Post-induction	Pre-induction	Post-induction
Words	Mean (*SD)*	Mean (*SD)*	Mean (*SD)*	Mean (*SD)*
Negative words	2.26 (.21)	1.82 (.22)	1.50 (.11)	1.69 (.20)
Neutral words	4.58 (.22)	4.45 (.20)	4.71 (.16)	4.36 (.10)
Positive words	7.33 (.15)	7.33 (.24)	7.40 (.15)	7.37 (.16)

Note: Values in brackets indicate SE of the Mean

Discussion

The current study investigated the negative mood effect on working memory tasks involving visuospatial and verbal domains in healthy individuals. In the first experiment, participants performed working memory tasks based on the grammatical reasoning task (Baddeley and Hitch, 1974) and the visuospatial reasoning task of Shah and Miyake study (1996) after a neutral and a negative mood induction. In Experiment 1, a learning effect in the visual reasoning task was observed, that is, a better performance of both groups after the induction, but no other effect was significant. Critically, the cognitive load of the visual task could have masked an eventual negative mood induction effect on the visual reasoning task in the first experiment, and thus, in Experiment 2, participants performed the visuospatial task according to their memory capacity. It is interesting to note that in the second experiment, there were no greater mood differences before and after the negative mood induction. There was only a significant difference between groups, suggesting a learning performance of the neutral group when compared to the negative group. The results showed that this learning performance was not an effect of the mood induction.

In contrast to previous studies, participants in the negative mood showed no impairment in performance in the working memory tasks (Miller et al., 2018; Storbeck et al., 2015). However, it should be emphasized that our methodological paradigm was based in two components of the working memory: the executive function (i.e., reasoning component) necessary to maintenance and judgment of information, and the mnemonic factor required to retrieval previous information, such as the orientation of letters or the two-letters order. Other studies that have investigated the influence of negative mood in the mnemonic and executive function also failed to find behavioral differences between neutral and negative mood (Storbeck, 2012; Storbeck & Maswood, 2015). For example, Storbeck and Maswood (2015) found no interference of the negative mood in the recall of the correct sequence of words (i.e., verbal working memory span task) or squares locations (i.e. visual working memory span task) after the interference of a processing task, such as a math problem-solving (i.e., executive function). According to the authors, the compensatory or regulatory process could account for the lack of performance differences in the negative mood group. In support of this perspective, many studies have shown subtle effects in behavioral performance but robust brain activation differences on cognition (Aoki et al., 2011, Perlstein et al., 2002, Renner et al., 2017).

Some limitations of the current study might have interfered in the mood effect. First, the mood induction procedure employed in the current study demonstrated an effective change in the disgusting dimension of mood but not in the sad or angry factor. Distinct mood procedures can activate different emotion states (Kucera & Haviger, 2012). They might have different impacts on decision-making (Nuñez et al., 2015) and result in contrasting findings. In this perspective, this mood procedure divergences could explain the different results between the present research and previous studies with depressed patients (for a review, see LeMoult & Gotlib, 2019) and healthy individuals induced into a sad mood (Pupillo, et al., 2020; Szasz et al., 2016). Second, the present study did not access or control the participants ‘intelligence. Previous studies have shown a correlation between intelligence quotient (IQ) or fluid intelligence (gF) and mood states during working memory tasks (Chuderski, 2015; Fairfield et al., 2015), suggesting that cognition capacity can mediate the relationship between mood and working memory. However, we did control the cognitive load of participants on the visual task, which supports the reliability of the results and understate the interference from individual differences in our findings.

Conclusão Geral dos Estudos

Os resultados dos três estudos realizados mostram que a memória de trabalho e a emoção têm conexões entre si. Primeiramente, a carga da atenção prejudica o reconhecimento de faces de expressão emocional, porém, faces de alegria e tristeza requerem menos recursos atencionais. O padrão de influência da atenção modifica-se de acordo com os parâmetros da carga da memória e, possivelmente, das normas culturais. Estudos futuros deverão estabelecer quais fatores culturais e motivacionais podem estar envolvidos no processamento de estímulos emocionais na memória de trabalho.

Limitações no procedimento de indução de estados de humor no Estudo 3 ocasionaram resultados incertos acerca do papel do estado de humor na memória de trabalho. Apesar dos entraves metodológicos, o terceiro estudo mostrou que a indução do estado de humor negativo não prejudica o desempenho em tarefas de memória de trabalho quando os indivíduos são expostos e impactados por imagens de teor escatológico (e.g., mudança predominante no fator de nojo entre os participantes). Com base nos resultados dos estudos, pode-se concluir que a disponibilidade ou limitação dos recursos da memória de trabalho são determinantes no processamento de estímulos emocionais.

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APÊNDICE A – Estudo Piloto: Classificações do *arousal* e da valência das faces

Method

Participants

A total of 20 participants (11 females) aged 18-40 years (M = 36.9 years, SD = 10.58), with normal or corrected normal vision, voluntarily participated in the experiment. The Institution's Ethics Committee approved the project and all participants signed the Term of Consent.

Materials and stimuli

The stimuli were 32 male greyscale faces, without hair and cropped into an oval, each displaying a happy, neutral, angry, and sad expression. Faces subtended approximately 1.2 ° × 1.7 ° (562 × 762 pixels) degrees of visual angle and were selected from KDEF database. The faces were displayed in a projector screen of 203 × 152 cm size. The SAM was a two nine-point scale raking between 1 (low arousal and extremally negative) and 9 (high aroused and extremally positive) scores. The first and second scale was, respectively, associated with the valence and arousal ratings.

Procedure

The experiment occurred in two sessions, each with 10 participants accommodated in a silence classroom. Each participant received a list with the number of the faces and the SAM scale for valence and arousal. The faces were displayed with numbers of the sequence order on a projector screen. The experimenter presented each face during 10s, and each participant had 15s to classify the valence (i.e., first scale) and arousal (i.e., second scale).

Data Analyses

The data analysis was performed through a repeated-measures ANOVA with within-subject factor emotion (angry, happy, neutral, and sad), valence and arousal ratings. The significance level was set at .05, partial Eta squared (η^2_p) effect sizes were computed, and post-hoc analyses using Bonferroni's correction.

Results and Discussion

The ANOVA showed a main effect of emotion for the valence rating, $F(3,57) = 311.60$, $p <.0001$, $\eta^2_p = .94$, and Bonferroni post-hoc tests showed that happy faces were classified with a positive valence, with a higher rating for happy faces than all other emotions (all *ps* < .0001). Angry and sad faces were rated as more negative than neutral faces with a higher rating for neutral faces versus angry, and neutral versus sad faces, but the difference was not significant between angry faces and sad faces ($p =.28$). The arousal rating differed across emotions, $F(3,57) = 47.85$, $p <.0001$, $\eta^2_p = .71$, and Bonferroni post-hoc tests revealed that angry faces were classified with high arousal than all other emotion (all *p*s <.02) with a higher rating for angry compared to happy, neutral and sad faces. Also, arousal rating was higher for happy faces versus neutral and sad faces (all *p*s <.004), and sad faces versus neutral faces ($p < .001$). Table 1 present the valence and arousal SAM ratings. According to these results, participants classified each face with the expected valence (i.e., negative, neutral, positive), and arousal (i.e., low and high). Angry and happy faces were classified with high arousal ratings, contrary to sad and neutral faces, classified as low arousal scores.

Table 1

SAM ratings between different emotional expression faces

	Valence	Arousal
Angry	2.47 (.16)	6.66 (.29)
Happy	7.58 (.15)	5.89 (.33)
Neutral	4.80 (.07)	3.70 (.32)
Sad	2.85 (.13)	4.96 (.31)

Note: Values in brackets indicate SE of the Mean

ANEXO A - TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

Título da pesquisa:
"Efeito do estado de Humor e Conteúdo emocional na memória de trabalho: A função do Executivo Central e do Detector Hedônico."

Orientador: César Aléxis Galera (cesar_galera@ffclrp.usp.br – 36024393)
Aluna: Lívia Valenti (livia_valenti@usp.br)
Instituição: Universidade de São Paulo (USP) – Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto (FFCLRP). Avenida Bandeirantes, 3900 – CEP 14040-901 – Bairro Monte Alegre – Ribeirão Preto – SP.

O sr. (sra.) está sendo convidado(a) a participar dessa pesquisa que tem como objetivo estudar a manipulação da informação emocional memorizada e a influência do estado de humor na memória, com o uso de tarefas de memória visual e de raciocínio. Os dados obtidos pelos responsáveis auxiliarão no maior conhecimento a respeito da função da emoção na memória.

As tarefas serão desempenhadas em um computador no laboratório de Psicologia Cognitiva da FFCLRP e a sessão experimental terá duração média de 15 minutos. Sua tarefa será basicamente memorizar e reconhecer os estímulos (faces) ou de realizar tarefas de raciocínio. A resposta para cada prova será dada através do mouse.

Na primeira etapa dos experimentos será realizada uma avaliação de indicadores de ansiedade e depressão, que não estão necessariamente associados a transtornos psicológicos e, portanto, não se caracteriza como diagnóstico de transtorno depressivo ou de ansiedade. Independentemente de a avaliação mostrar a existência de indicadores de depressão e ansiedade, o experimentador poderá esclarecê-lo (a) sobre os Serviços do Centro de Psicologia Aplicada (CPA).

Salientamos que no presente estudo não há riscos previsíveis e que o sr. (sra.) tem total liberdade para interromper a sua participação a qualquer momento, sem qualquer prejuízo ou penalização e sem necessidade de justificar a interrupção da participação. Será garantido sigilo absoluto sobre a identidade dos participantes; somente o aluno e o orientador terão conhecimento dessa informação. Em qualquer momento o sr. (sra.) poderá solicitar os esclarecimentos que julgar necessários sobre a pesquisa (para esclarecimentos posteriores, por favor, contate os pesquisadores pelo telefone ou e-mails informados acima). Não há benefícios diretos, mas haverá ressarcimento referente ao deslocamento do participante até o local de realização da pesquisa. O valor do ressarcimento será referente ao custo de duas passagens de ônibus, totalizando o valor de R$7,60 (R$ 3,80 cada). A participação na pesquisa irá beneficiar e colaborar com importantes dados para a área de memória de trabalho, na psicologia cognitiva. Esclarece-se, no entanto, que não haverá benefícios diretos para o participante. Os dados obtidos com a realização desse estudo serão utilizados para fins de pesquisa e divulgados em revistas e eventos científicos, sempre garantindo o sigilo dos participantes.

Para somente eventuais dúvidas sobre questões éticas do projeto, contatar o Comitê de Ética em Pesquisa da Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto – USP, no endereço Avenida Bandeirantes, 3900 - Bloco 23 - Casa 37 - 14040-901 - Ribeirão Preto - SP – Brasil. Fone: (16) 3315-4811 / Fax: (16) 3633-2660. E-mail: coetp@ffclrp.usp.br

Tomado o conhecimento dos fatos acima e aceitando participar da pesquisa, você assume não ter sofrido nenhuma pressão para tanto:

Você aceita participar desta pesquisa, ciente de que sua participação é voluntária e está livre para, em qualquer momento, desistir de colaborar com a pesquisa, sem nenhuma espécie de prejuízo. Declara, ainda, que recebeu uma via deste termo de consentimento.

Assinatura: ____Data:____/____/____

Identificação (RG ou CPF):____

Assinatura do pesquisador:____

ANEXO B - TERMO DIGITAL DO ESTUDO 1

Please press the letter "C" on the keyboard to indicate your consent for each of the following statements.

If you do not wish to consent, press the number 0 and inform your experimenter immediately.

Statement 1:

By pressing "C to each statement I understand that I have read each statement and I am giving my consent to participate in this project.

Statement 2:

I understand that my participation in this project will involve a 1) recognition task in which I have to state whether the identity of the face was the same or different from a previous array of emotional faces and, 2) a tone counting task which I have to state how many low pitched sounds were presented in each trial . There are also anxiety and depression questionnaires at the beginning or at the end of the session. The experiment is computer based, and will take approximately 60 minutes of my time.

Statement 3:

I understand that participation in this study is entirely voluntary and that I can withdraw from the study at any time without giving a reason and without loss of course credit, or reimbursement for travel (where relevant).

Statement 4:

I understand that I am free to ask any questions at any time. I am free to withdraw without providing a reason, or to discuss my concerns with Dr Madge Jackson (supervisor) or Livia Valenti (experimenter) (contact details are provided on the Debrief sheet).

Statement 5:

I understand that the information provided by me will be held anonymously so that it is impossible to trace this information back to me individually. Information will be on a password protected computer in a locked room, and may be retained indefinitely.

To ensure access to the data for the wider research community, the anonymous dataset may be archived in an online repository (e.g., the Open Science Framework, https://osf.io/) or sent to other researchers upon request for inspection.

Statement 6:

I understand that at the end of the experiment I will be provided with additional information about the purpose of the study. I can request that the written debrief is also emailed to me.

Statement 7:
I have had an opportunity to discuss with the experimenter any questions or concerns I have about the study at this stage.

Final Statement:

This consent will be stored electronically as part of the Eprime datafile on a password protected computer in a locked room for a minimum of 3 years, but each participant cannot be identified. I consent to participate in this study conducted by visiting PhD student Livia Valenti in the School of Psychology, University of Aberdeen under the supervision of Dr Margaret Jackson.

If you don’t want to answer the question, Press Space.
You won’t

ANEXO C – TERMO DIGITAL DO ESTUDO 2

Please press the letter "C" on the keyboard to indicate your consent for each of the following statements.

If you do not wish to consent, press the number 0 and inform your experimenter immediately.

Statement 1:

By pressing "C to each statement I understand that I have read each statement and I am giving my consent to participate in this project.

Statement 2:

I understand that my participation in this project will involve a 1) perceptual task which I have to match a neutral face to the identity of an emotional face (angry, happy, sad) as quickly and accurately as possible and, 2) a tone counting task which I have to state how many low pitched sounds were presented in each trial. There are also anxiety and depression questionnaires at the beginning or at the end of the session and I understand that single questions can be omitted if I prefer not to answer them. The experiment is computer based and will take approximately 50 minutes of my time.

Statement 3:

I understand that participation in this study is entirely voluntary and that I can withdraw from the study at any time without giving a reason and without loss of course credit, or reimbursement for travel (where relevant).

Statement 4:

I understand that I am free to ask any questions at any time. I am free to withdraw without providing a reason, or to discuss my concerns with Dr Margaret Jackson (supervisor) or Livia Valenti (experimenter) (contact details are provided on the Debrief sheet).

Statement 5:

I understand that the information provided by me will be held anonymously so that it is impossible to trace this information back to me individually. Information will be on a password protected computer in a locked room, and may be retained indefinitely.

To ensure access to the data for the wider research community, the anonymous dataset may be archived in an online repository (e.g., the Open Science Framework, https://osf.io/) or sent to other researchers upon request for inspection.

Statement 6:

I understand that at the end of the experiment I will be provided with additional information about the purpose of the study. I can request that the written debrief is also emailed to me.

Statement 7:
I have had an opportunity to discuss with the experimenter any questions or concerns I have about the study at this stage.

Final Statement:

This consent will be stored electronically as part of the Eprime datafile on a password protected computer in a locked room for 3 years, but each participant cannot be identified. I consent to participate in this study conducted by visiting PhD student Livia Valenti in the School of Psychology, University of Aberdeen under the supervision of Dr Margaret Jackson.

If you don't want to answer the question, Press Space.
You won't

ANEXO D – Expressões da LEAP

LEAP
1. Sinto-me humilhado(a) 2. Sinto-me culpado(a) 3. Sinto-me triste 4. Estou com medo 5. Estou sem graça 6. Sinto raiva 7. Estou com vergonha 8. Estou com inveja de alguém 9. Estou com nojo 10. Sinto ciúme de alguém 11. Sinto uma necessidade 12. Estou tomando cuidado 13. Tenho pena de alguém 14. Estou alegre 15. Estou cansado(a) 16. Estou com sono 17. Estou cheio 18. Sinto uma obrigação 19. Estou com fome 20. Sinto um desejo 21. Estou com esperança 22. Estou gostando de alguém 23. Sinto-me interessado(a) 24. Tenho pena de alguém 25. Sinto uma admiração por alguém 26. Sinto-me orgulhoso(a) 27. Sinto-me surpreso(a) 28. Acabo de levar um susto 29. Acho algo estranho 30. Estou refletindo 31. Estou com frio 32. Faço pouco caso de alguém 33. Acho algo gozado 34. Estou aceitando alguma coisa 35. Estou com calor 36. Sinto atração sexual por alguém 37. Sinto-me calmo(a) 38. Estou conformado(a) 39. Estou com sede 40. Sinto saudade de alguém

ANEXO E – Lista de Palavras

LISTA 1			LISTA 2		
Positiva	**Neutra**	**Negativa**	**Positiva**	**Neutra**	**Negativa**
Alegria	Básico	Doença	Abraço	Asfalto	Dor
Cura	Cesto	Ladrão	Conquista	Caneta	Fracasso
Harmonia	Farelo	Tristeza	Vida	Estado	Pesadelo
Bondade	Lápis	Agressão	Aconchego	Habitante	Corrupção
Paraíso	Bandeira	Sofrimento	Férias	Bolso	Mal-estar