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The Mind's Eye: How Emotional Stimuli Shape Working Memory and Face Recognition in Depression

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Abstract

This study examined the effect of emotional stimuli on working memory and face recognition efficiency. Additionally, it examined the interplay of depressive symptoms with the performance of participants. Participants were randomly assigned to watch a positive, negative or neutral video and complete a digit span task and a face recognition task before and after being exposed to the stimuli. Results from repeated measures MANOVA indicated a significant main effect of stimuli on both tasks, with participants assigned to the positive condition having a drastically higher performance on both tasks in comparison to the negative and neutral conditions. No significant effect of time and time x stimuli was found. However, although depressive symptoms did not significantly affect performance on both tasks, participants who had the highest BDI scores exhibited lower performance that in contrast to participants of the other two conditions. These findings further prove the interplay between emotion and cognitive functions, as well as suggest that individuals with higher depressive symptoms may be more susceptible to negative stimuli which leads to a decrease in their performance. Implications and recommendations for future studies are discussed.

Keywords

Face recognition, Working memory, Emotional stimuli, Depressive symptoms,

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Introduction

Face Recognition and Emotional Stimuli

One of the primary objectives of the human mind is the constant pursuit of acquiring knowledge and information (1). For this to happen, it utilizes various cognitive functions such as memory, learning, face recognition, attention and perceptual motor functions (2). Face perception and recognition specifically, are essential skills for humans and can even be considered aspects of an individual's social intelligence (3). Face recognition is defined as the ability to memorize the identity of several new faces, then accurately pick them out when they are interspersed among other faces (4-6) while face perception is the ability to instantly recognize and retain information from faces (7,8). Face perception and recognition are vital for everyday life as it provides us with a large amount of information regarding our environment (9). While some activation can be seen in the superior temporal sulcus and part of the occipital lobe (10), the most apparent activation is seen in the fusiform face area (FFA) (11,12). Correct recognition of facial expressions is vital for the correct structure of interpersonal and cognitive functions (13,14).

In fact, humans from their nature are experts in assessing faces (15) in the point where it has being suggested that face recognition is far stronger in comparison to object recognition (16,17) which is anticipated as in contrast to different stimuli, faces effortlessly capture visual attention, and are more likely to be stored in the human visual working memory (VWM) in comparison to other more complex stimuli (18). Consequently, many studies have examined the impact of emotional stimulus on face recognition and have determined that individuals exhibit a preference towards emotional faces whether positive or negative. This phenomenon of negative and positive bias has been studied thoroughly utilizing a variety of emotional materials, such as faces (19-20) words (21) and movie excerpts (22-23). Movie excerpts specifically have proven to elicit stronger emotional and physiological changes (24-26). The phenomenon of negative bias is defined as the preference of processing negative stimuli such as an angry, fearful or disgusted face, over a positive stimulus such as a happy face. In contrast, the positive bias refers to the processing advantage of positive stimuli (21,27). Additionally, VWM studies have found a similar phenomenon, in both negative and positive advantages to VWM performance (19, 28-30). Surprisingly, other studies have found contradictory evidence to the ones of the majority of literature. These studies have proven that in some cases emotional stimuli interference doesn't affect face recognition efficiency when certain aspects such as face inversion are examined (31,32).

Working Memory and Emotional Stimuli

On the other end of the spectrum, human memory consists of different systems, each functioning in various ways for the acquisition, maintenance, and retrieval of information (33-34). Memory is typically divided between long-term and short-term memory (35-36). However, in the last few decades studies have constantly debated whether or not working memory (WM) is considered a third type of memory as its functions are relative similar to the ones of short-term memory (37-39). Specifically, WM temporarily retains task-relevant information over the course of complex cognitive tasks that require awareness and attention such as reasoning, planning, manipulation of the information and the control and coordination of perception and action in complex cognitive operations (40,41). In accordance with the structural working memory model (42) the central executive system controls three subsystems which are the phonological loop, the visuospatial sketchpad and the episodic buffer. (43-45).

These three components are of limited capacity and are typically examined through memory tasks such as digit span and word recall tasks (46). These WM span tasks have proven to be of high importance and reliability to examine complex cognitive behaviors such as problem solving and reasoning. In fact, studies have found that many participants in their attempt to increase their efficiency utilize cognitive strategies such as visualizing or chunking the digits or words they see (47-48). Forward and backward digit span tasks are one of the most used tests of working memory (49) as it examines simple attention while also assessing cognitive flexibility and mental alertness (50) when an individual shifts between the two tasks. However, factors such as emotional stimuli might hinder the proper function of working memory influencing proper efficiency in these tasks. Negative or positive emotional stimuli exposure before WM tasks have been found to affect both storage and attentional processing required for the efficiency of WM. Studies using simple span and complex span tasks found that specifically negative mood induction can decrease WM performance regardless of the type of task (51).

Outcomes seem to demonstrate that participants who are negatively mood-induced are less able to suppress intrusive negative thoughts (52-53) which in turn leads to a decrease in the efficiency of their working memory (54-56). In contrast, positive stimuli have proven to increase WM performance and storage capacity (57-59). Nevertheless, the level of valence and arousal of emotional stimuli must also be taken into consideration as different levels may lead to different results (60). Valence is defined as the measurement of the pleasantness linked with the emotion and ranges from negative (unpleasant) to positive (pleasant), whereas arousal is defined as the level of emotional activation induced (61,62). In most studies examining the influence of emotional stimuli, arousal and valence are moderate as intense arousal can impair memory (63,64). Conversely, while the prevailing body of research indicates that emotional stimuli can significantly influence working memory efficiency, other studies have suggested that this is not always the case. For instance, research has proven that participants' efficiency in a n-back task may not always by affected by the emotional type of stimuli (65) while others have found that participants' performance was better in the negative emotional and sexual arousal condition (66). Additionally, other studies have proven that regardless of the valence of the stimuli the performance of working memory remains unaffected (67,68). These findings illustrate that working memory efficiency might also be task dependent as not all tasks target the same cognitive processes (69-72). Lastly the influence of individual differences requires further analysis (73,74).

Depression and Cognitive Functions

Apart from emotional stimuli, other factors such as depressive symptoms can affect an individual's working memory and face recognition skills. Depressed individuals exhibit a large range of impairments in executive functioning (including working memory), that might lead to a significant burden on everyday mental processes (75-77). This impairment might be the result of their difficulty filtering irrelevant information which in many cases leads to cognitive overload (78). Specifically, individuals with depression have been argued to exhibit lower WM capacity (14,79) while simultaneously showing impaired memory for neutral and positive stimuli (80-82). On the other hand, depressed individuals tend to showcase negative cognitive biases which render them incapable of shifting their attention away from negative emotions (83,84) leading to difficulties in controlling and suppressing negative thoughts, which in turn makes it harder to focus on tasks that require working memory activation (85). More specifically, studies have shown that depressed individuals tend to perform worse in digit span tasks, especially in the backward span which requires additional cognitive manipulation (86).

On the other end of the spectrum, other studies have put more emphasis to determine how the neurobiological differences present in depressed individuals can affect their efficiency in the completion of the two tasks previously discussed. Such studies have shown that depression is associated with reduced activation in the dorsolateral prefrontal cortex (DLPFC) which constitutes one of the most fundamental brain areas for the correct functioning of working memory (87-89). Other studies have shown an increased activity in the amygdala which might explain the negative cognitive bias of depressed individuals (90,91). Lastly, reduced hippocampal volume is one of the most common defective structural findings (92-94) which can help justify the cognitive difficulties that depressed individuals exhibit (95-96). Nevertheless, the influence of depressive symptoms can also be seen in face recognition tasks. Studies have shown that depressed individuals struggle to accurately recall, recognize and sort faces (97) which may be the result of their tendency to misinterpret neutral and positive faces as negative (98). In average, an individual suffering from depression usually exhibits slower reaction times when identifying or sorting an emotional face in comparison to a healthy individual (99). A study comparing healthy, depressive and bipolar groups found that the individuals suffering from depression had slower responses and lowest accuracy in a working memory task using emotional faces (100).

The impact of depression can also be seen in the brain's face recognition-related regions. For example, the fusiform face area (FFA) tends to have reduced activity in individuals with depression (101). However, these findings have proven to be inconsistent as studies have shown that in some cases individuals with depression manage to not exhibit difficulties in executive functioning (98, 102,103). Moreover, it has been determined that while severe depression leads to cognitive impairment, early-stage or mild depression may not result in cognitive deficits (104).

Working memory and face recognition are two of the most examined cognitive functions of the brain. Countless studies have examined them separately and simultaneously while also investigating possible factors that may hinder their efficiency. For instance, in a recent study (105) examined the influence of negative emotional pictures on working memory efficiency. Their study showed that negative images lead to a decrease in the efficiency of the participants' working memory efficiency in comparison to the neutral images, a finding in accordance with the literature.

In turn based on their research, this study aims to investigate the effects of emotional stimuli on working memory and face recognition while also examining the potential role of depressive symptoms. The study will use three types of emotional charged videos (positive, neutral, negative) instead of pictures and will examine the participants' face recognition and working memory efficiency before and after being exposed to the emotional stimuli. In addition, the influence that depressive symptoms have on participants' efficiency is analysed. This multifaceted approach aims to provide a more holistic understanding of how emotional stimuli influence complex cognitive functions while also examining the role of depressive symptoms.

Hypotheses

Firstly, it is hypothesized that negative emotional stimuli will decrease the efficiency of working memory in comparison to neutral and positive stimuli (51,56). Secondly, it is hypothesized that face recognition efficiency will decrease after exposure to negative stimuli in contrast to the positive and neutral (106). Lastly it is hypothesized that higher depressive symptoms are linked with higher cognitive exhaustion in both working memory and face recognition tasks after exposure to the stimuli.

Analytic Strategy

The first hypothesis was that negative emotional stimuli will decrease the efficiency of working memory in comparison to neutral and positive stimuli. The second hypothesis was that face recognition efficiency will decrease after exposure to negative stimuli in contrast to the positive and neutral conditions. For both hypothesis a repeated measures MANOVA was conducted. The third hypothesis was that higher depressive symptoms are linked with higher cognitive exhaustion in both working memory and face recognition tasks after exposure to the stimuli. A One-way Independent Anova was used to test this hypothesis.

Method

Design

This study employs a Repeated Measures ANOVA 2 (Time: Before/After exposure to stimuli) X 3 (Emotional Video Type: Positive, Neutral, Negative). This experiment aims to examine how different types of emotional video stimuli can affect participants' performance in a working memory task (digit span task) and a face recognition task (UNSW Face Test). The experiment is comprised of two independent variables (IV) and two dependent variables (DV). The first independent variable is the Category of Emotional Video, which consists of three levels. Positive, neutral and negative emotional videos. The second independent variable is Time which consists of two levels. Before and After exposure to the emotional stimuli. The first dependent variable is Working Memory Performance. The second Dependent variable is Face Recognition Performance. After the main analysis, the interaction between depressive symptoms and participants' performance will be analysed.

Participants

To determine the appropriate sample size for this study, G*Power (3.1.9.7) (107) was used to ensure that the study would have sufficient power to detect a significant effect should there be one. The power analysis was set to an alpha level of 0.05 and a power of 0.90. The effect size used for this study was determined to be set at 0.58 (Cohen's f) based on previous studies that have determined it to be sufficient (104,108). The power analysis calculated that a total sample size of at least 15 participants would be needed to achieve adequate statistical power and exclude the possibility of Type II errors. However, to increase the validity of the study and ensure that the results can be implemented in a wider population the sample size of the study was set at 21 participants. The participants will be an opportunity sample recruited from the social and personal circle of the researcher. The participants were all fluent English speakers with a normal or corrected to normal vision and were required to have completed their high school studies. The participants' age ranged from 18-30 and were consisted of 10 men and 11 women. The age mean was calculated to be 23.14 with a standard deviation (SD) of 3.35. Individuals suffering from neurological or psychiatric disorders, cognitive dysfunctions and serious sensory disorders were excluded from the study. All participants stated that they were not under the influence of alcohol or any type of addictive substances 24 hours before the experiment. All participants had read and signed the participant information sheet and consent form according to the BPS (2009) ethical standards (109).

Materials

The first material that this study will use is a digit span task which aimed to measure the participants' working memory efficiency before and after being exposed to the emotional stimuli. Their efficiency is measured through the usage of a computerized delivery of randomized digit sequences that can be increased and decreased. The participants had to go through all trials and the task ended when the participant scored 0 two times consecutive in the same digit task (forward or backward). The second material that was used was the University of New South Wales (UNSW) Face Test (110). This Face Test recorded the face recognition efficiency of the participants and in the end provided two scores, one for the Face Memory Test and one for the Face Sorting Test. In the end, the sum of the two tasks is the final score. The third material that was used were three videos from FilmStim's database (111). This database provided emotional excerpts from movies. Each video had a specific duration and was intended to elicit a specific feeling to the viewer (anger, disgust, amusement, tenderness etc.). To measure depressive symptoms Beck's Depression Inventory (BDI) was used (112). The inventory involves 21 items, and each item is evaluated on a 4-point Likert scale that ranges from 0 to 3. The final score is determined by summing the score that the participant had on every question. A Dell G15_Ryzen Edition, 15,6 Full HD, 120 Hz, WVA Display, NVIDIA Discrete Graphic computer was used to conduct the experiment. The use of an external private space was necessary to conduct the experiment. Finally, participant information sheets, consent forms, and debriefing sheets were used and distributed.

Procedure

The experiment was conducted in a private outdoor space. The participants were asked to attend the space one by one in which they would be privately tested individually. Each participant was first handed out the participant information sheet in which they were informed about the aim of the study, what they were asked to do and finally about their right to withdraw from the study at whatever point they desired. Additionally, anonymity and confidentiality of their data was ensured. After reading the participant information sheet, they were requested to sign the consent form which confirmed and guaranteed their voluntary participation in the study. After reading and completing the two forms the participants were ready to take part. The participants were randomly assigned to one of the three conditions. Firstly, the participants were asked to complete the Beck's Depression Inventory (BDI) questionnaire. After completing the inventory their answers were recorded from the researcher. Next, the participants were asked to sit across the laptop in which the digit span task would be completed. Prior to commencing the task, participants were seated approximately 60 cm away from the computer screen (113) and the researcher verbally explained the instructions of the digit span task to each participant.

The participants were required to complete the task as far as they can. In the first trial the participants were presented with one number which needs to be remembered. The task then asks to input the number that was presented. In the second trial the task shows two numbers which the participant is required to remember and input once again. In each trial the number sequence increases by one digit. The maximum forward trials that the participant can complete are eight. After completing all forward tasks or failing twice in the same sequence, the participants moved on to the backward span where in each trial the numbers increased by one digit and should be input backwards from the order that they were presented. The maximum backwards trials that the participants could go through were eight. The task ends when the participant scores 0 two times consecutive in the same number span or completes all 8 sequences. The maximum score that the participant can achieve in the forward span is 13 whereas in the backward span the maximum score is 14. In order to measure each participant's efficiency their score and span were multiplied with each other to determine the subject of each condition (forward and backward). After completing the digit task, the participant is asked to complete the UNSW Face Test. In the first phase of the task, the participant is presented with 20 faces that they are required to remember as accurately as possible. These faces are presented one at a time and the participants are given 5 seconds at a time to remember each face. After viewing the faces, the participants are presented once again with 20 additional faces. The participants are asked to press the key "y" when they have previously seen the face and "n" when they have not. In the second phase of the task the participants in each trial are presented with a target face. They are then asked to sort four pictures and place the ones on which the target face is shown on the right, and the ones on which they are not on the left. In the end of the two phases two scores are shown and recorded. One for the Face Memory Test and one for the Face Sorting Test.

The final score of the Face Recognition Task is the sum of the scores. After completing the digit span task and the Face recognition task, the participants, depending on the group that they were randomly assigned, are asked to view a short video which acts as an emotional stimulus. The video can be either positive, neutral or negative and was selected to induce the according emotional response to the participant. On average the emotional videos had a duration of one and a half minutes. After watching the video, the participants are asked to complete the digit span task and the Face recognition task once again. After completing both tasks, the participants' scores are all registered and compared before and after the exposure to the emotional stimuli. Once the experiment was completed, the participants were given the debriefing sheet, where they were thanked for their participation in the research and informed that they had the option to withdraw their data within a reasonable timeframe. All ethical guidelines were followed in accordance with the latest edition of the BPS (2009).

Results

After the statistical analysis of the data, it was calculated that the skewness and kurtosis of all variables were between the required range of -1.96 to +1.96. Due to the small sample size, some minor outliers were found (see appendix 13) while the histograms showcased a normal distribution. Lastly, Z-Scores were calculated and were found to be between the -3 to +3 range. In general, normality is more easily affected due to the small sample size. After the usage of multiple indicators of normality, the data were confirmed to be normally distributed and parametric. For this reason, it was decided that a REPEATED MEASURES MANOVA would be conducted to examine the effect of emotional stimuli on working memory and face recognition efficiency. Secondly, a ONE-WAY INDEPENDENT MEASURES ANOVA analysis was conducted to examine whether depressive symptoms have affected the efficiency of the participants in the two tasks.

Data were analyzed using a 2 (time: before and after exposure) x 3 (stimuli: positive, negative, neutral) Repeated Measures MANOVA to examine the participants' digit span and face recognition efficiency before and after being exposed to the emotional stimuli. Mauchly's test indicated that the assumption of sphericity was met for the main effect of stimuli (W = .919, p = .489), but violated for the time × stimuli interaction (W = .330, p < 0.001). Thus, the Greenhouse-Geisser correction was applied instead.

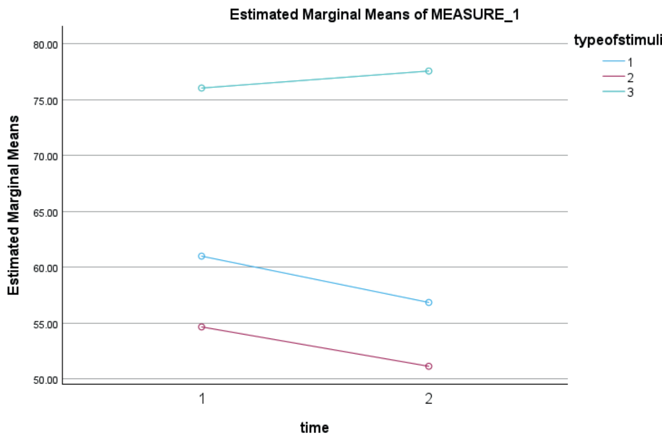
Table 1. Mean numbers of digit span and face recognition efficiency on positive negative and neutral conditions (with standard deviations)

	POSITIVE	NEGATIVE	NEUTRAL	TOTAL
PREFORWSUBJ	65.57 (25.04)	62.28 (25.16)	55.14 (17.17)	61.00 (22.18)
PREBACKSUBJ	52.00 (16.97)	52.00 (33.22)	60.00 (24.00)	54.66 (24.60)
PREFACERECO	75.71 (8.97)	72.71 (3.35)	79.71 (11.78)	76.04 (8.82)
TOTAL	64.42 (20.08)	62.33 (24.48)	64.95 (20.53)	

	POSITIVE	NEGATIVE	NEUTRAL	TOTAL
PREFORWSUBJ	75.42 (24.94)	36.14 (13.92)	59.00 (20.68)	56.85 (25.41)
PREBACKSUBJ	68.28 (39.80)	25.14 (11.48)	60.00 (29.93)	51.14 (33.91)
PREFACERECO	78.57 (8.50)	72.57 (8.73)	81.57 (8.30)	77.57 (8.94)
TOTAL	74.09 (26.51)	48.28 (21.18)	66.85 (23.05)	

There was no significant main effect of time with a small effect size, $F(1, 18) = 0.652$, $p = .430$ $\eta^2=0.002$ but there was a significant main effect of stimuli, with a large effect size $F(2, 36) = 15.19$, $p < .001$, $\eta^2= 0.249$ indicating that digit span and face recognition efficiency differed across emotional conditions. The interaction between time and stimuli was not significant after correction with a small effect size, $F(1.19, 21.56) = 0.318$, $p = .729$ $\eta^2= 0$. This suggests that the emotional video type had a similar effect on participants' performance in both the pre-test and post-test conditions.

Table 2. Estimated Marginal Means



The estimated marginal means show that participants in the positive emotional video condition had the highest performance scores, increasing slightly from approximately 76.5 at pre-exposure to approximately 78.0 at post-exposure. In the neutral condition, performance declined from about 61.0 at pre-exposure to approximately 57.5 at post-exposure. Lastly, the negative condition showed the lowest performance throughout, decreasing from around 54.5 at pre-exposure to 51.5 at post-exposure. These means show that positive emotional stimuli improved performance in both tasks, while neutral and especially negative stimuli were associated with a decline in task performance. This graph further showcases the significant main effect of emotional stimuli despite the interaction with time not being statistically significant.

Participants who were exposed to the positive video showed higher performance across both tasks compared to those in the neutral and negative groups. In the digit span forward task, their scores increased from M = 65.57 to M = 75.43, while those in negative condition dropped from M = 62.29 to M = 36.14, and those in the neutral condition slightly improved from M = 55.14 to M = 59.00. Similar results were observed in the digit span backward task, where scores in the positive condition rose from M = 52.00 to M = 68.29, while those in the negative condition declined from M = 52.00 to M = 25.14. In the face recognition task, all groups performed relatively well, but the positive group had the highest performance (M = 75.71 pre-exposure, M = 78.57 post-exposure), and the neutral group improved slightly (M = 79.71 to M = 81.57). Overall, the negative video condition showed a consistent drop in performance in both tasks, particularly in the digit span tasks, whereas the positive condition was associated with improved performance.

The mean number of BDI scores in each emotional condition is shown in Table 2.

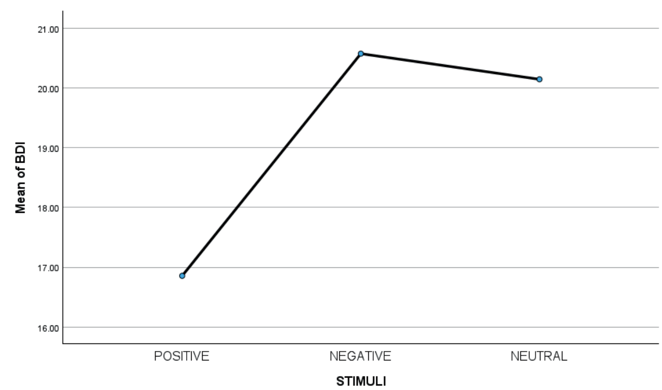
Mean number of BDI scores (with standard deviations) in each emotional condition

POSITIVE	NEGATIVE	NEUTRAL
16.85 (3.43)	20.57 (5.09)	20.14 (4.70)

Data was analysed using a One-way independent measures ANOVA and it was found that although the main effect of BDI symptoms was not statistically significant, the effect size was large ($F(2, 18) = 1.448$, $p = .261$, $\eta^2 = .139$).

However, an interesting finding is that Table 3 shows the differences in BDI symptoms between the three stimulus conditions.

Table 3. Line graph of BDI Mean Scores in each stimulus condition



The line graph illustrates the mean BDI scores across the three stimulus conditions. According to the graph, participants reported the lowest BDI scores during the positive condition ($M \approx 17$) while in contrast, scores peaked in the Negative condition ($M \approx 21$), suggesting the presence of higher depressive symptoms or negative affect in response to negative stimuli. Lastly the neutral condition showed slightly lower BDI scores than the negative condition ($M \approx 20$), but were still higher compared to the positive condition. This graph indicates that while no significant effect of BDI score was found, noticeable changes were present.

Discussion

This study attempted to determine how different emotional stimuli can influence two key cognitive functions: working memory and face recognition, while also examining how depressive symptoms may hinder their performance. Based on previous studies signifying their effect (22,23) emotional movie excerpts (positive, neutral, and negative) were used as mood inducers. Participants were requested to complete a digit span and a face recognition task before and after exposure to the stimuli.

The findings revealed a significant main effect of emotional stimuli, suggesting that the type of emotional video that participants were exposed to had a noticeable impact on their performance in both tasks. Specifically, those exposed to the positive condition outperformed those in the negative and neutral groups. Nevertheless, no significant main effect of time or time × condition interaction was found, suggesting that while emotional valence influenced performance levels, this did not significantly change from pre- to post-exposure. The first hypothesis that negative emotional stimuli will decrease the efficiency of working memory in comparison to neutral and positive stimuli was supported. Participants assigned in the negative condition showed a decline of their efficiency in both forward and backward conditions after being exposed to the stimuli. This finding comes in accordance with the majority of the existing literature in which it has been repeatedly shown that negative stimuli can largely affect the attentional control and storage processes related with working memory (51, 54-56). On the other hand, participants assigned to the positive condition showed an increase in both forward and backward conditions, suggesting that positive stimuli may enhance their performance, a finding which has already continuously been proven (57-59).

The second hypothesis suggested that face recognition efficiency will decrease after exposure to negative stimuli in contrast to the positive and neutral conditions, which was eventually partially supported as although the difference over time was not significant, overall face recognition scores were higher in the positive condition in contrast to the negative. This suggests that while emotional stimuli can affect their performance, there was not a significant drop in their efficiency over time. This result can be justified as face recognition is regarded as one of the most fundamental cognitive functions (9) due to the large quantity of information it provides. Taking this into consideration, studies have already shown that face recognition is resilient to emotional interference and external factors in general (31,32).

The third and final hypothesis suggested that higher depressive symptoms would be linked with higher cognitive exhaustion in both working memory and face recognition tasks after exposure to the stimuli. The hypothesis was rejected as the one-way ANOVA showed no significant differences among the three groups. However, participants with the highest BDI scores were all found in the negative condition who had the lowest performance in both tasks. This suggests that while the effect was not significant, depressive symptoms might have affected participants' performance. This comes in line with the existing literature where it is reported that high depressive symptoms often lead to lower executive function processes (75-77) and slower reaction times when identifying or sorting an emotional face (99). Additionally, participants with higher depressive symptoms seem to have exhibited poorer performance in the digit span task (in both conditions) in comparison to the face recognition task. This is another result that aligns with previous research as studies have shown that individuals with high depressive symptoms exhibit lower WM capacity (78, 114) negative cognitive biases (83-84) while simultaneously showing impaired memory for neutral and positive stimuli (80-82).

Limitations and Future research

Nevertheless, despite the valuable findings of this study, certain limitations will be analyzed which may have influenced the outcomes of this study. Firstly, due to the extended duration of the study, as well as the high cognitive demand that a working memory and face recognition task require, it is possible that participants may have experienced fatigue over the course of the study, which in turn might have influenced engagement levels and overall performance in the working memory task, as well as the face recognition task. Prior research has proven that prolonged engagement in cognitive challenging tasks can lead to cognitive overload (115,116). For this reason, counterbalancing could be used in order to prevent this. Additionally, in the digit span task participants might have deliberately or subconsciously employed cognitive strategies such as chunking to enhance their performance. This means that the participants might have scored higher in both conditions (forward and backward) than they would have if they were to remember each number individually. This aligns with existing literature where it is explained that individuals use cognitive strategies as a way to improve their recalling efficiency (46, 117). Furthermore, in the UNSW Face test, the majority of the faces presented were either of East or South Asian descent. This might have further challenged the participants as according to the other face effect individuals recognise and remember faces of their own race more accurately than faces of other races (118,119). As a result, participants might have struggled to remember the faces in the first phase of the test and sort the faces in the second phase. Consequently, participants might have exhibited higher face recognition efficiency should the majority of faces be of their own race. Lastly, further EEG studies can shed light on how the brain reacts and what brain regions are activated when completing complex cognitive tasks. More specifically, research focusing on depressed individuals can help further understand how depression working memory and face recognition are interlinked. However, this study leaves room for further analysis and examination of several aspects which require further examination. As previously mentioned, the role of individual differences is still under investigation. Future research could further focus on examining how filtering, encoding and maintaining information in WM tasks differ among individuals (73,74). A way to examine the effect of individual differences is by taking into consideration personality traits as different traits lead to different biases which in turn affect efficiency in cognitive tasks (120,121). Secondly, the participants' efficiency after viewing the emotional stimuli might have improved due to the practice effect which suggests that prior exposure to the tests and study procedures enhances cognitive performance (122,123). This means that participants, having already completed both the working memory and face recognition tasks once, were already aware of what they were required to do after viewing the stimuli. As a result, participants had already completed the face recognition test once so they were already acquainted with the faces that they would be presented which might have given them an advantage in both the Face Memory and Face Sort task. Lastly, future research could focus on expanding the sample size as certain results might differ in a larger number of participants.

Conclusion

This study aimed to examine the effect of emotional stimuli on working memory and face recognition performance while simultaneously considering the role of depressive symptoms. Findings indicated that emotional stimuli indeed affected the participants' performance on both tasks and especially the digit span task as participants in the positive condition performed drastically better than the ones who were assigned to the negative condition. Although time-based changes and BDI symptoms effect were found to be non-significant, observable findings suggested that individuals with higher BDI symptoms performed worse than the ones who achieved lower scores. This study results contributed in the vast body of literature examining the interplay of emotion and cognitive functions. The study's findings and limitations offer the foundation for future research to examine this relationship in greater depth.

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