EMOTIONAL INTERFERENCE: THE IMPACT OF TASK-RELEVANT EMOTIONAL STIMULI ON COGNITIVE PERFORMANCE

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EMOTIONAL INTERFERENCE: THE IMPACT OF TASK-RELEVANT EMOTIONAL STIMULI ON COGNITIVE PERFORMANCE

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Baddeley’s model of working memory suggests that there are four components used to manipulate and maintain information for a task. According to this model, there is a system called the central executive which allocates attention resources to the components of working memory. Since attention resources are limited, working memory capacity is limited (Baddeley, 2007; Baddeley, 2012). The limited resources theory suggests that there are limited attention resources and that the addition of each novel event takes resources away from the task at hand generating performance decline on that task (Lichtenstein-Vidne, Henik, & Safad, 2012). Emotion can be seen as an event which would require attention resources, predicting that the presence of emotion in a task would impair performance (Dolcos & McCarthy, 2006, King & Schaefer, 2011; Black, 2008). The current study used an n-back working memory task to compare participants’ performance on blocks of stimuli that varied in valence and content. There were blocked trials of three different stimulus content types: faces, nature images, and
words, and three different valence types: positive, negative, and neutral. I predicted to find slower reaction times and poorer accuracy for emotionally-charged stimuli, particularly for negative stimuli. Mood was also assessed through the Positive and Negative Affect Scale (Watson, Clark, & Tellegen, 1988) to assess if mood interacted with participants’ performance. Overall, results indicated an effect of content and valence on working memory performance. The general findings support the hypothesis that emotionally-charged stimuli elicit performance decrement for working memory tasks. 

*Keywords:* working memory, emotion, n-back, limited resources theory, central executive.
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CHAPTER I

INTRODUCTION

Working memory, or the ability to hold information in mind and manipulate it “online” or while completing a task, is crucial for many human pursuits, from driving in a new city to performing complex medical procedures. According to the limited resources theory, however, our working memory is not unlimited (MacLean, Arnell, & Busseri, 2010; Wickens, 2002). Specifically, the limited resources theory suggests that new and salient information captures what restricted attention is available to complete a task (Lichtenstein-Vidne, Henik, & Safad, 2012). Emotional information in particular may direct attention away from holding pertinent information in mind while completing a task. From an evolutionary perspective, humans must assess the risk for survival. Negative emotional information in particular may signal a potential threat and draw on limited cognitive resources (Kensinger & Corkin, 2003). Identifying factors that may influence working memory under conditions in which emotionally salient information is present has particularly important implications for those working in professions such as medicine, military, and criminal justice. However, previous research has not addressed the effects of both positive and negative emotional information and human versus non-human stimuli on working memory in the context of a person’s current mood (Sakaki, 2007). The present research examined the effect of emotional information on working memory and the moderating effects of mood.
Working Memory

Baddeley’s prominent model of working memory includes four components, the visuospatial sketchpad, the phonological loop, the episodic buffer, and a component called the central executive (Baddeley, 2012). The phonological loop maintains auditory input. The visuospatial sketchpad organizes visual and spatial inputs and is also somewhat oriented to memory of physical actions. The episodic buffer is a chunking storage unit that may act as a communicator between the phonological loop and the visuospatial sketchpad (Baddeley, 2007). It is suggested that the working memory capacity is four bits of information, but the episodic buffer aids with chunking to maintain additional information in working memory. This model indicates that the phonological loop and visuospatial sketchpad may work independently of each other with little interference. This would suggest that tasks which require both may not actually be an overload and limit working memory. The central executive component acts as a guide for the delegation of resources and attention within the model (Baddeley, 2012). The role of the central executive in the allocation of resources to manage and maintain information in mind during a working memory task is further specified within the limited resources theory.

Limited Resources Theory and Emotion

The limited resources theory represents the idea that humans do not have an unlimited ability to attend, but rather attention is commonly pulled in multiple directions (Lichtenstein-Vidne et al., 2012). Prior work indicates that emotionally salient information may limit humans’ ability to attend during complex tasks (Black, 2008; Mi-Hyun Choi, 2010). For example, the attention network task (Fan, McCandliss, Sommer,
Raz, & Posner, 2002) has been used to study the influence of emotional information on attentional resources (Cohen & Henik, 2012). The goal of this task is to determine the direction of the middle arrow in a line of preceding and succeeding arrows while ignoring the direction of the surrounding arrows (Fan et al., 2002; Cohen & Henik, 2012). It draws on attentional resources because it requires participants to judge the direction of an arrow in the presence of distracting and irrelevant information. Researchers have found that the presence of task-irrelevant negative emotional stimuli during completion of this task altered task performance. The introduction of task-irrelevant negative emotional stimuli generated delay in decision making for directionality (Cohen & Henik, 2012). The addition of fearful faces also generated performance decrement in reaction time (Dennis, Chen, & McCandliss, 2008). These studies used task-irrelevant emotional stimuli, but in many real-world situations, emotional stimuli are relevant for the task at hand.

Another task commonly used to assess attention skills is the attentional blink task (Shapiro, 1994). The task involves the presentation of two stimuli within 500 milliseconds of each other. The participant is asked to respond upon noticing the second stimulus. The second stimulus, usually a dot, is not well encoded due to a “blink” effect and reaction times are typically skewed (Shapiro, 1994). Using emotional words as the first stimulus induced greater interference with encoding of the second stimulus, indicating that reaction times suffered from the dispersed attention with the addition of emotion (MacLean et al., 2010). Salient negative emotion had the greatest detrimental effect on response times and was seen as an attention narrower, implying that it draws the majority of attention resources to the negative stimuli. These studies such as the attentional blink studies and the attention network task suggest that negative emotional
stimuli attract limited attentional resources and prohibit individuals from optimal task performance. However, the extent to which this effect can be extended to more complex working memory tasks, particularly using task-relevant emotional stimuli, and to positive emotional stimuli is not well understood.

Studying the effects of task-relevant emotional interference on working memory may be beneficial to understanding applications like medical environments or military scenarios when emotion is present, but optimum memory performance is a must. When emotional information is presented as task-relevant, meaning attention to the emotional information is required in order to complete the task, working memory performance may decline (Dolcos & McCarthy, 2006, King & Schaefer, 2011). Emotional information could be a distracter even when observing emotional information is part of the main objective of a task (Black, 2008). For example, emotional words have been shown to affect recall of information during a working memory task such that positive and negative emotional word lists resulted in opposite effects (Allen et al., 2009). Specifically, the positive word lists resulted in a recency effect—the later words were recalled best, and the negative word lists resulted in a primacy effect—the first words presented were recalled better. These results suggest that the encoding of future information may have been inhibited in the negative words condition by a preference towards the salient information presented first (Allen et al., 2009). Positive emotion may not have been quite as attention detaining, thus the new information could have been properly encoded to be recalled in the later task (Black, 2008).

Negative effects of emotional information have also been observed in designs using an n-back task. The 2-back task requires working memory in that participants must
respond to events that match those from two times ago. Essentially, a participant would respond upon recognizing that the stimulus in front of them matches the stimulus two times before, a “sandwich” where the outer stimuli match, but the one presented directly prior is different (Jaeggi, Buschkuehl, Perrig, & Meier, 2010). In an n-back task that used task-relevant emotional images obtained from the International Affective Picture System, the best reaction times and accuracy were observed for neutral pictures, followed by positive images, and then negative images. Performance suffered the most for negative conditions (Mi-Hyun Choi, 2010).

A study by Kensigner and Corkin (2003) assessed the effect of neutral or negative emotional information on working memory by varying if the stimuli were human faces or words. They expected face stimuli to draw attention as relating more toward the self, which would intensify the negative effects for negative emotional information. The experiment was completed using a 2-back working memory task. Participants were faster with neutral faces as opposed to fearful or negative emotional faces. Word stimuli were also presented, but the same effect on reaction time was not observed. There are two possible interpretations of these results. The difference could have been due to differences in verbal and non-verbal stimuli, such that the non-verbal or faces stimuli were more attention grabbing than verbal stimuli, but it is possible that these results may have represented differences between human and non-human stimuli more generally. In other words, the specific effects for faces may have reflected human preference for and attention to human faces over other stimuli, beginning early in life (Rosa Salva, Farroni, Regolin, Vallortigara, & Johnson, 2011). In the current study, I used two non-verbal stimuli types (humans and nature) to better distinguish between these two competing
interpretations. To summarize, previous research suggests an effect for both positive and negative emotional information and for faces compared to word stimuli. Systematically varying positive and negative stimuli using both faces and non-faces stimuli (one verbal and one non-verbal stimuli set) in a single study is an important next step in understanding exactly how emotional stimuli and working memory skills are related.

**Mood Congruent Emotion Effects**

In addition to research investigating the influence of emotional information on working memory, recent research has also investigated whether or not the current mood of participants themselves influences their performance on working memory tasks. Bower's network theory of affect (Bower, Giligan, & Monteiro, 1981) suggests that when emotional information agrees with a participants’ current mood (regardless of valence – positive or negative), working memory performance will increase. Recent studies have supported this idea (e.g., Becker & Leinenger, 2011; Parrott & Sabini, 1990; Singer & Salovey, 1988), suggesting that a congruence between participant mood and emotional information demands less attention than an incongruence in which a participant’s mood does not match the emotional information presented. Yet, there could potentially be some instances where incongruent mood increases memory performance. In a study of autobiographical memory recall, Sakaki (2007) determined that mood congruent improvements were seen when the recall was related to the self. Mood incongruence recall increased memory performance when the task was not related to the self. However, more research is needed to investigate mood congruence effects and their application to working memory tasks and to both human and non-human emotional stimuli.
**Current Study**

Prior research has yielded important findings about the nature of emotional information and how it influences people’s ability to attend and remember. However, prior work is limited in at least three ways. First, prior work has focused primarily on negative emotional information, but we do not know enough about how positive emotional information influences working memory. Specifically, could it actually boost working memory and increase performance on challenging tasks or distract further attention just to a lesser degree than negative emotion? Second, prior work has focused primarily on emotional information having to do with faces, but the extent to which these findings generalize to emotional information in non-human stimuli is limited. Finally, the extent to which participant mood during these tasks is related to both positive and non-human information has yet to be explored. In the current study, I compared participants’ performance on a working memory task across varying valence conditions (neutral, positive, negative) and content conditions (pictures of faces, nature, words) and assessed if these factors interacted with participant mood.

**Hypotheses**

Consistent with prior research, I hypothesized that working memory performance will be inhibited the most by the presence of emotionally-charged stimuli compared to neutral stimuli in the faces condition. Within the emotionally-charged stimuli, I also hypothesized that working memory performance will be inhibited more by negative versus positive faces stimuli. To extend the Kensinger and Corkin (2003) finding that negative faces yielded worse working memory performance compared to neutral faces, I
hypothesized that I would not find the same effect of valence on performance within the words stimuli. I tested competing predictions for the nature condition. Kensinger and Corkin proposed that differences in performance across valence for faces and words stimuli could be due to verbal vs. non-verbal stimuli, or they could be due to differences between faces and non-faces stimuli. If the former interpretation holds, then I would expect for nature images to show similar effects to face images. However, if the difference is actually between faces and non-face stimuli, then performance on nature images should not show differences across valence. Finally, I expected interactions between valence and content to be moderated by the current mood of the participants. Specifically, I predicted that participants in a negative mood will perform better on negative face stimuli compared to positive stimuli and neutral stimuli while participants in a negative mood will perform better on positive non-faces stimuli versus negative non-faces stimuli and neutral stimuli. This is based on work suggesting that stimuli that are reminiscent of the self have better success for congruent mood (when a participants’ mood matches the valence of the stimuli) while stimuli unrelated to the self such as nature images and words, yield better performance for incongruent mood situations (Sakaki, 2007).
CHAPTER II

METHOD

Participants

Participants consisted of 79 University of Dayton Undergraduate students recruited through an online sign-up system. There were 57 females and 22 males. The mean age of the participants was 19.08 (SD = 1.48). Participants received credit for lower-level Psychology courses upon completion of the task.

Design

The study design was a 2 (current mood: positive or negative) x 3 (stimulus content: face stimuli, nature images, or words) x 3 (stimulus valence: negative, positive, or neutral) between and within subjects design. The between subjects factor was current mood.

Materials and Procedure

Participants first completed the Positive and Negative Affect Schedule (PANAS) Questionnaire to assess their current mood from levels of negative and positive affect (Watson, Clark, & Tellegen, 1988). This scale assessed mood using a 5 point Likert scale 1—very slightly or not at all, 5—extremely. Participants indicated their mood right now by rating adjectives such as exciting, guilty, scared, proud, inspired, nervous, active, etc.
The reliability of this scale is approximately .88 for positive affect and .85 for negative affect (Watson et al., 1988). To score the PANAS on a continuous scale, there were ten questions for negative affect and ten for positive affect. The negative affect scores were reversed and totals were calculated. The median score for each person was obtained. Participants were divided into a positive and negative mood based on if they scored above or below the median value. However, it is important to note that the negative mood condition was quite high, suggesting that participants were overall in positive moods.

After completing the PANAS Questionnaire, participants completed nine blocks of trials on a 2-back working memory task. Participants were randomly assigned to complete all nine trial blocks using either positive, negative, or neutrally valenced face stimuli, nature images, or words. The order of stimulus presentation was counterbalanced across trial blocks such that the participant completed three blocks of face images, each a different valence, three blocks of nature images, and three blocks of word stimuli in a random order.

The 2-back working memory task is a modified n-back design from Jaeggi, Buschkuehl, Perrig, and Meier (2010). The task was programmed using E-Prime. Each stimulus was presented for 500 milliseconds and then followed by a 2500 millisecond interstimulus interval (see Appendix A). In a 2-back design, participants were expected to respond to critical stimuli, or stimuli that were a match from two times ago. Essentially, the face stimuli, nature image, or word presented on the screen matches the stimulus seen two prior, where the stimulus directly before is different, but the one prior to that is a match to the current. Responses were made by selecting the “m” key indicating a match.
For the task, participants would enter the lab and sit in front of a laptop. The order of the nine tasks was randomized and participants received the same written instructions for each task minus a one word change (word for word conditions and image for non-word conditions). The instructions for the word tasks were as follows, “Welcome to the experiment. You will see a word followed by a fixation cross. Determine if the word on the screen matches the word from two times ago. Example: ‘car, truck, car.’ Press ‘m’ for a match. PRESS THE SPACEBAR TO BEGIN!” Upon hitting the spacebar, participants were met with the first stimulus which appeared for 500 ms and disappeared leaving a fixation cross for the remaining 2500 ms before the next stimulus. After this interval, the cross disappeared and another stimulus was presented. Thirty trials were presented, and the participant was expected to respond by pressing “m” whenever they thought the stimulus was a match to the one presented two trials previously. They were given the 2999 ms between stimuli presentation to respond. By not pressing, participants indicated that the stimulus they just saw was not a match. Reaction times, false alarms—incorrectly responding to a stimulus, and hits—correctly identifying a critical stimulus were recorded during all nine tasks. Reaction time data for correct hits was used as the primary outcome variable for this task.

Each two-minute trial block included the presentation of 30 face images, nature images, or words, including eight critical stimuli which required a response. There were eight different stimuli pseudo-randomized per trial block to ensure that eight critical stimuli were displayed. The positive, negative, and neutral face images were obtained from the Nimstim database. The reliability of the Nimstim faces is approximately .80 (Tottenham et al., 2009). The nature images of different valence were obtained from the
International Affective Picture System (IAPS) (Lang, Bradley, & Cuthbert, 2008). The images were selected based on valence ratings predetermined by the IAPS rating of pleasantness scale: 1 (unpleasant) to 10 (pleasant) scale. The word stimuli were gathered from the Affective Norms for English words (ANEW) (Bradley & Lang, 1999). It is a well-established database to determine word valence. The words database was categorized on the same pleasantness scale as the IAPS: 1 (unpleasant) to 10 (pleasant).

In between trial blocks and following the last trial block, a two minute rest period was observed. Participants were debriefed at the end of the study and awarded credit for participation.
Participants completed nine n-back tasks using images that varied in valence and content. Reaction time, false alarms, and hits were recorded for each block. Median response times were calculated for correct hits\(^1\). False alarms occurred when a participant pressed a key after a non-critical stimulus. The results are organized by dependent variable—reaction time, false alarms, and hits (See Table 1 for a full list of descriptive statistics). For each significant omnibus effect found, I conducted follow-up tests based on my hypotheses to determine the specific effects that were present. For valence by content interactions, the follow-up tests included simple effects tests of valence differences within each content type and a complex comparison of the difference between neutral and the average of the emotionally-charged stimuli for each content type.

\(^1\) It is important to note that the \(N\) for reaction time is less than the total \(N\) for false alarms and hits. Some participants did not make any correct responses or otherwise for one or more blocks of trials. These participants were not included for reaction time analysis because their time could not be compared at all levels of the manipulation.
**Reaction Time**

A 2 (mood) x 3 (content) x 3 (valence) mixed ANOVA yielded a significant content by valence interaction, $F(4,65) = 2.58, p = .045$ (see Table 2 for full model results). Follow-up contrasts based on hypotheses were conducted, yielding an unexpected significant difference in reaction times for word stimuli across emotion valence ($F(1,68) = 12.71, p = .001$) where participants were significantly faster in responding to neutral words compared to the average of the emotionally-charged words. Participants were also significantly faster on neutral words compared to negative words ($F(1,68) = 9.28, p = .003$) and positive words ($F(1,68) = 7.35, p = .008$). Based on hypotheses, simple effects tests and a complex comparison were also conducted to compare valence conditions within the faces and nature images conditions. None of these contrasts were significant ($p > .05$).

The mixed ANOVA did not yield any significant interactions for mood. However, the median score for mood was 3.75, which was significantly above the mean score possible. This means that the mood data were skewed and most participants were in a positive mood. The overall three-way interaction with mood, content, and valence was not significant ($p = .789$), as well as the interactions between mood and valence ($p = .671$) and mood and content ($p = .473$). As reaction time was the hypothesized dependent variable of interest and no significant interactions were observed with mood, the results including mood were omitted from further analyses.

**False Alarms**

A 3 (content) x 3 (valence) mixed ANOVA once again yielded the same significant content by valence interaction, $F(4, 74) = 3.24, p = .017$ (see Table 3 for full
model results). Follow-up contrasts based on hypotheses were again conducted. The contrasts yielded a significant difference in the number of false alarms between positive and negative face stimuli, $F(1,77) = 4.75, p = .032$. There were more false alarms committed for negative faces than for positive faces. Also, there were more false alarms for negative faces than for neutral faces, $F(1, 77) = 4.22, p = .042$. These effects were consistent with my hypothesis that faces would draw on attentional resources in the negative valence condition more so than in the positive condition and neutral condition. A simple effects contrast also yielded a significant difference between the number of false alarms for negative nature images and neutral nature images, $F(1, 77) = 5.76, p = .018$, where participants made more false alarms on neutral images. The complex comparisons of neutral valenced stimuli versus the average of positive and negative valenced stimuli were non-significant for face images, nature images, and words (all $p > .05$).

**Hits**

A significant content by valence interaction was again observed as a result of a 3 x 3 mixed ANOVA, $F(4,74) = 2.70, p = .037$ (see Table 4 for full model results). As hypothesized, follow-up contrasts based on hypotheses revealed that participants had significantly less hits for emotionally-charged faces compared to neutral faces, $F(1,77) = 6.60, p = .012$. A simple contrast also revealed a difference between negative and neutral faces, $F(1, 76) = 8.73, p = .004$. There were fewer hits for negative faces than neutral faces. Significant differences between hits for emotionally-charged stimuli and neutral stimuli were also observed for nature images, $F(1,77) = 7.16, p = .009$, and words, $F(1,77) = 6.16, p = .017$. Congruent with the face stimuli, there were less hits for
emotionally-charged words and nature images than neutral words and nature images. A simple effects significant difference was also found in the number of hits when comparing positive and negative nature images, $F(1,77) = 8.52, p = .005$, such that participants had less hits on positive nature images compared to negative nature images. A simple effects contrast also revealed a significant difference between the number of hits for positive nature images and neutral nature images, $F(1,77) = 12.560, p = .001$. There were less hits for positive images than neutral images. A simple effects contrast determined that there was a significant difference in the number of hits between negative words and neutral words ($F(1,77) = 4.80, p = .032$), as well as between positive words and neutral words ($F(1,77) = 5.49, p = .024$). The neutral words condition had the most hits. All other contrasts were not significant ($p > .05$).
I investigated the role of participant mood, stimulus content, and emotional valence on working memory performance using an n-back task. Participants completed nine blocks of n-back trials, crossing negative, positive, and neutral stimuli with face images, nature images, and words. I tested for variations in performance based on which stimuli were used for the n-back task, and I also investigated the interaction between participant mood and stimuli type.

I hypothesized that there would be an interaction between content and valence on performance across the three outcomes. I predicted that emotional stimuli would have aversive effects on performance—slower reaction times, more false alarms, and less hits. Mi-Hyun Choi (2010) suggests that negative stimuli should result in the weakest performance, followed by positive stimuli, and that neutral stimuli should exhibit the least amount of performance decrement. Extending prior work by Kensinger and colleagues (2003), I specifically predicted that these differences would be qualified by an interaction between content type and valence such that this effect would hold for faces but not for words. I also tested competing hypotheses about nature images as a follow-up to Kensinger and colleagues, with one hypothesis predicting effects for nature images to be similar to faces (the verbal versus non-verbal account), and a competing hypothesis predicting effects only for faces and not nature images or words (face versus
non-faces account). The results were consistent with my hypotheses concerning faces
stimuli for the false alarms outcome such that emotionally-charged face stimuli elicited
poorer performance compared to neutral stimuli, and the same effect was not found for
words. For hits, the results were partially consistent with my hypotheses in that faces
yielded poorer performance in the emotionally-charged conditions, but emotionally-
charged words also showed similar poorer performance compared to neutral words.
Inconsistent with my hypothesis, only words stimuli showed significant variation based
on valence for the reaction time outcome. The findings on nature images were mixed,
such that for false alarms, the results actually suggested more false alarms for neutral
images compared to emotionally-charged images. For hits, although participants overall
had less hits in the emotionally-charged nature images conditions, they made more hits
on negative nature images compared to positive nature images.

Beyond emotional stimuli hypotheses, I hypothesized that mood should moderate
performance (Sakaki, 2007). Specifically, I hypothesized that when mood is congruent
with the valence of the face stimuli, participants should perform better. In contrast, when
mood is incongruent with the valence of the emotional images and words, I hypothesized
that performance would be better. The mood results were not consistent with the
hypotheses as a three-way interaction among mood, content, and valence was not found.
There were no mood interactions within reaction time and the variation within mood was
limited to only positive and less positive mood. A negative mood condition was not
observed and thus, the mood interactions could not be properly obtained. I will present
the results of each outcome separately, followed by general limitations and conclusions.
Reaction Time

I found an interaction between the effect of content and valence on participants’ response times on the n-back task. To test my specific hypothesis that participants would have faster response times on neutral stimuli compared to positive and negative, I performed planned comparisons. I first tested the simple effects of valence on reaction times within the faces, images, and words conditions. I also performed a complex comparison of positive and negative images versus neutral images for each content type. The only significant effect was with words. Participants were faster at recognizing neutral words against emotionally-charged words. Discovering a significant difference in word reaction times across valence that did not also hold for faces and nature images is incongruent with Kensinger and Corkin (2003). Specifically, Kensinger and Corkin found no significant difference for words across valence differences. Perhaps the difference between the Kensinger and Corkin insignificance lies in the word type. Kensinger and Corkin used taboo words, whereas the words I used were fear words designed to inflict a threat response. The taboo words consisted mainly of curse words, which may be offensive, but may not have generated a significant effect because the curse words may not elicit fear. Taboo words may generate anger or sadness which is suggested to perhaps affect long term memory more than working memory (Baddeley, Banse, Huang, & Page, 2012). Therefore, I may have found differences in the word condition because the use of threat-related words elicited slower processing of the words, which would be consistent with the limited resources theory. With respect to face images, the pattern of response time differences was consistent with Kensinger and Corkin such that participants were slower to respond to negative versus neutral faces, but in my study this difference did not
reach significance. Using blocked trials of repeated negative stimuli may have lessened the effect somewhat compared to using interleaved trials as Kensinger and Corkin used. This could explain why there was no significant difference for face stimuli across valence.

**False Alarms**

The same interaction between the effect of content and valence discovered for participants’ response times was duplicated for false alarms. To test my specific hypotheses, the same contrasts were tested. There were more false alarms committed for negative faces over positive faces. An increase in false alarms for negative stimuli, particularly faces, is consistent with the results of Kensinger and Corkin (2003) and also Mi-Hyun Choi (2010). This suggests that threat-related face stimuli elicit poorer working memory performance as additional resources are allocated to process the negative stimuli. Contrary to the faces stimuli, I found that neutral nature images yielded the highest accuracy challenges compared to the emotionally-charged stimuli. Although I used stimuli from the same stimulus set as Mi-Hyun Choi (2010), who found that negative images yielded poorer performance compared to positive and neutral images. I restricted my images to those representing nature and not humans or animals. This unexpected effect will have to be explored more in future research as we know less about the ways in which negative and positive nature stimuli specifically might affect working memory performance.

**Hits**

A significant content by valence interaction was observed for hits. Specifically, there were more hits for all neutral stimuli compared to the average of negative and
positive valenced faces, images, and words. Emotionally-charged stimuli resulted in less hits for the faces and words conditions indicating that attention was divided and recognition of critical stimuli was impaired. Yet, there was an opposite effect within the emotionally-charged nature images that was not hypothesized. Positive nature images, instead of negative, generated the least number of hits. Greater accuracy in negative nature images is generally incongruent with both Kensinger and Corkin (2003) and Mi-Hyun Choi (2010).

The fewer number of hits for positive nature images could be explained two different ways. One, the positive nature images could have been appraised as a challenge response to working memory and perhaps the challenge response had greater interference than the threat response increasing the divided attention (Lichtenstein-Vidne et al., 2012), or two, the fewer hits in positive nature images is a repercussion of a lure that coincidentally occurred in this condition. A lure in a 2-back task would be considered a stimulus that matches the stimulus from one or three times before. In a 2-back task, a critical stimulus matches the stimulus presented two trials previous to the critical stimulus, meaning that there is a stimulus, another stimulus, and the third stimulus matches the first. When the stimulus matches the one from one or three times before, it is considered a lure because this stimulus is still maintained in working memory. In this situation, there would be an image, followed by two more images that do not match, followed by a matching stimulus. On this type of trial sequence, participants are more likely to respond when the stimulus should not elicit a response. I found that this lure existed in the nature images randomization that did not also occur in the faces or words conditions. With four stimuli typically maintained in working memory, the lures are held
in working memory capacity and can generate confusion (Szmalec, Verbruggen, Vandierendonck, & Kemps, 2011). If participants were focused on the lure, less critical hits would be observed. Also, the number of false alarms for positive nature images was trending on being significantly higher than negative nature images, further evidence of an unexpected lure.

**Limitations**

Potential limitations could include an unforeseen lure (mentioned above) and inconsistent rating of valence across different stimuli sets. The face stimuli, while obtained from the NimStim database, did not have the same rating scale for levels of emotions compared to the ratings for the nature and words images. The face stimuli were rated on a reliability scale up to 1.00. Most of the pleasant/happy faces were above .90, easily recognizable, the neutral faces, while above .70 were typically not rated above .85. Thus, the percentages by which the neutral and negative faces were labeled were less than that of the positive faces. Although, the data should not be discounted since the reliability of the database is high (.80) (Tottenham et al., 2009). A further limitation is that there was technically not a negative mood group as mood ratings were skewed.

**Implications**

It is important to understand the interaction of mood, emotion, and working memory because emotion is an unavoidable aspect of human existence and if its effects are negative, it might impair an important task. Many occupations are expected to operate under high emotion salience—medical positions, the military, etc. When facing fearful situations, a threat response may be activated driving attention allocation. The limited resources theory addresses the idea that working memory has limited attention resources
to allocate to a task. If emotion is capturing most of the attention resources, the working memory capacity remaining to complete the task is low and performance decrement is observed. Understanding if emotion generates performance decline may allow for ways to counteract it. Personnel in fields such as the medical field or the military would greatly benefit from understanding how to counteract the detrimental effects of emotion on working memory.

Conclusion

The performance decrement I observed for emotionally-charged stimuli across multiple content categories provides general evidence for the limited resources theory (Lichtenstein-Vidne et al., 2012) with a few exceptions. The emotional stimuli generally produced slower reaction times for matches, more false alarms, and fewer correct hits. I extended previous research by showing that these effects generalized beyond faces to words as well when the words are threat-related words. More research could be done with other working memory tasks to test whether this effect generalizes to nature images as I found mixed results with respect to if nature images yield similar performance across valence conditions. There was no evidence for a role for mood in interactions with valence and content. Future research is needed to explore mood using a different method for assessment. For example, a manipulation task in which a negative or positive mood is induced in a laboratory setting may shed more light on the possible mood congruency effect that could not be assessed given the restriction in the scale (most participants scored in the neutral to positive mood range). Overall, this research suggests that under emotionally-charged situations, individuals are not able to perform at a comparable level.
to performance in emotionally neutral situations, indicating working memory can be affected by emotion.


King, R. & Schaefer, A. (2011). The emotional startle effect is disrupted by a concurrent


Table 1

Descriptives for Participant Dependent Variables across Content and Valence.

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Content</th>
<th>Valence</th>
<th>Mean</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction Time</td>
<td>Face</td>
<td>Negative</td>
<td>601.871</td>
<td>26.295</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Positive</td>
<td>560.307</td>
<td>20.303</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neutral</td>
<td>590.100</td>
<td>20.218</td>
</tr>
<tr>
<td></td>
<td>Nature Image</td>
<td>Negative</td>
<td>585.086</td>
<td>23.542</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Positive</td>
<td>628.764</td>
<td>33.385</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neutral</td>
<td>591.464</td>
<td>22.830</td>
</tr>
<tr>
<td></td>
<td>Word</td>
<td>Negative</td>
<td>627.221</td>
<td>32.459</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Positive</td>
<td>605.643</td>
<td>29.946</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neutral</td>
<td>535.957</td>
<td>19.140</td>
</tr>
<tr>
<td>False Alarms</td>
<td>Face</td>
<td>Negative</td>
<td>1.231</td>
<td>.227</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Positive</td>
<td>.744</td>
<td>.122</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neutral</td>
<td>.795</td>
<td>.116</td>
</tr>
<tr>
<td></td>
<td>Nature Image</td>
<td>Negative</td>
<td>.897</td>
<td>.152</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Positive</td>
<td>1.321</td>
<td>.203</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neutral</td>
<td>1.538</td>
<td>.257</td>
</tr>
<tr>
<td></td>
<td>Word</td>
<td>Negative</td>
<td>1.077</td>
<td>.188</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Positive</td>
<td>.897</td>
<td>.177</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neutral</td>
<td>.808</td>
<td>.190</td>
</tr>
<tr>
<td>Hits</td>
<td>Face</td>
<td>Negative</td>
<td>6.256</td>
<td>.244</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Positive</td>
<td>6.577</td>
<td>.242</td>
</tr>
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<td>Neutral</td>
<td>6.808</td>
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<tr>
<td></td>
<td>Nature Image</td>
<td>Negative</td>
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<tr>
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<td>Positive</td>
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<td></td>
<td></td>
<td>Neutral</td>
<td>6.821</td>
<td>.174</td>
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<tr>
<td></td>
<td>Word</td>
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<td></td>
<td></td>
<td>Positive</td>
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<td>.225</td>
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<tr>
<td></td>
<td></td>
<td>Neutral</td>
<td>7.167</td>
<td>.179</td>
</tr>
</tbody>
</table>

Note. The reaction time means are means of the median for each participant.
**Table 2**

*Results of Mixed Measures ANOVA for Reaction Time.*

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>F</th>
<th>p</th>
<th>$\eta^2_p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valence</td>
<td>2,67</td>
<td>2.72</td>
<td>.073</td>
<td>.075</td>
</tr>
<tr>
<td>Valence*Mood</td>
<td>2,67</td>
<td>.401</td>
<td>.671</td>
<td>.012</td>
</tr>
<tr>
<td>Content</td>
<td>2,67</td>
<td>.718</td>
<td>.491</td>
<td>.012</td>
</tr>
<tr>
<td>Content*Mood</td>
<td>2,67</td>
<td>.756</td>
<td>.473</td>
<td>.022</td>
</tr>
<tr>
<td>Content*Valence</td>
<td>4,65</td>
<td>2.58</td>
<td>.045</td>
<td>.137</td>
</tr>
<tr>
<td>Content<em>Valence</em>Mood</td>
<td>4,65</td>
<td>.426</td>
<td>.789</td>
<td>.026</td>
</tr>
</tbody>
</table>

Note. Partial eta squared ($\eta^2_p$) denotes effect size.
Table 3

Results of Mixed Measures ANOVA for False Alarms

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>F</th>
<th>p</th>
<th>$\eta_p^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valence</td>
<td>2,76</td>
<td>.19</td>
<td>.827</td>
<td>.005</td>
</tr>
<tr>
<td>Content</td>
<td>2,76</td>
<td>3.47</td>
<td>.036</td>
<td>.084</td>
</tr>
<tr>
<td>Content*Valence</td>
<td>4,74</td>
<td>3.23</td>
<td>.017</td>
<td>.151</td>
</tr>
</tbody>
</table>

Note. Partial eta squared ($\eta_p^2$) denotes effect size.
Table 4

*Results of Mixed Measures ANOVA for Hits.*

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>F</th>
<th>p</th>
<th>$\eta_p^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valence</td>
<td>2, 76</td>
<td>8.49</td>
<td>.005</td>
<td>.183</td>
</tr>
<tr>
<td>Content</td>
<td>2, 76</td>
<td>5.21</td>
<td>.08</td>
<td>.121</td>
</tr>
<tr>
<td>Content*Valence</td>
<td>4, 74</td>
<td>2.70</td>
<td>.037</td>
<td>.127</td>
</tr>
</tbody>
</table>

Note. Partial eta squared ($\eta_p^2$) denotes effect size.
APPENDIX A

DETAILED TASK ORDER

Fixation cross  Valence Stimuli (500 ms)  2500 ms

*Stimuli matches 2 times ago

* Denotes critical response