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The Effects of Music-Induced Emotion on Memory

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Abstract

Emotion can play a highly influential role when it comes to enhancing memory. Research has shown that emotional valence and emotional arousal are two key aspects of emotion responsible for facilitating this (APA, 2013). However, various studies have found contradicting results when it comes to which type of valence (positive or negative) and which level of arousal (high or low) have the greatest memory enhancing effects. Similarly, the majority of previous research has specifically investigated this emotion-memory relationship in terms of memory for emotional *content*. The present study aims to address this gap by separating emotion from the to-be-learned stimuli, instead investigating how one's emotional *state* while encoding *neutral* information, impacts memory for that information later on. After inducing specific emotional states via exposure to affectively-rated music, subjects were exposed to a video reel composed of various neutral clips of random scenes. Memory was then measured based on performance within a subsequently presented "yes"/ "no" recognition task. Characterizing "conditions" based on the four arousal-valence quadrants of Russell's circumplex model of emotion (1980): high arousal-positive valence, high arousal-negative valence, low arousal-positive valence, low arousal-negative valence, I predicted that, compared to the other groups, the subjects in the high arousal-negative valence condition would perform best on the memory task. Results did not support this hypothesis, yielding no significant differences in memory performance between the four conditions. The limitations of this study design are considered and suggestions are made for future research.

Keywords: valence, arousal, memory enhancement, emotional state, music-induced emotion

Introduction

Memory, in all its wide-ranging, multi-faceted glory holds an indisputable grasp on essentially all aspects of our lives. Whether we like it or not, a large portion of our lives is spent thinking *back* to things we've already learned, seen, and experienced. Our memory is a time capsule of dates, facts, snapshots, etc., all of which we've absorbed over time.

Understanding this to be true, the only seemingly reasonable thing to do next is to ask "why?". Why is it that our memory for certain information is retained better in one case than it is in another? Why is it that if I try, I can still picture Fred the Clown twisting balloons into a flower for me at my childhood birthday party, but can't remember how old I was turning? Why is it that I can vividly recall winning the state championship while playing basketball in high school, but I don't remember playing Ithaca at home for Bard two years ago? Why is it that in the hours before an important anatomy exam I am able to memorize a whole list of key vocabulary terms, yet that same day I have trouble memorizing my takeout order number? What differs between two circumstances of encoding—the actual storing of information in the brain—that determines whether or not something will remain in one's brain for a long period of time?

There are a range of different factors that all play a role in determining what we remember and how well we remember it. As I continued to consider many of my own most prominent memories, I began to recognize a pattern. One consistent theme stood out: that information, those events, etc. were all somehow tied to a heightened emotional state. This relationship between emotion and memory forms the basis of my research for this paper and my senior project study.

The idea that emotion—more specifically your emotional state, or the emotional value you attribute to certain material—can influence memory ability has had a long standing history within psychological research. This includes the effects of emotion on the memory process, and also applies to the category of emotional memory itself (Tyng, 2017). Both are aspects of the emotion-memory relationship and are based on research that investigates whether or not our affective state—our mood at a certain point in time—impacts how well you'll remember corresponding information later on. Additionally, research has also looked at *why* your particular affective state might have an impact on your memory in the first place. Take for instance the memory examples listed above. The common denominator found within all of them is that they were all in some way influenced by emotion, either directly or indirectly.

On the day that my team won the state championship, naturally my emotional state was heightened. The parameters surrounding the event—a packed arena, the prospect of winning the first state championship for girls basketball in our high school's history, and just how much this title meant to me and my time playing basketball up until that point—all determined the emotional state I had been in throughout the game, and in that final, culminating moment as I was handed the trophy. On the day that I was able to memorize the list of important terms before my test, my emotional state had also been heightened, not as a direct result of the word list (the material), but rather as a result of the pressure of having to cram for my test (my affective state). Once again, external factors—the pressure of a time crunch and the impending fate of my grade in the class if I were to do poorly—had all decided for me the type of emotional state I would be in while studying the information.

On the other hand, the regular season game and the number for my takeout order did not involve highly emotional content, nor did they evoke a heightened emotional state. As much as I had wanted to win, I knew that no huge consequences awaited me if we didn't. As much as I was looking forward to my pad Thai noodles, had I forgotten my number, I knew there were other ways that the restaurant could determine which order was mine.

In general, the influence of emotion on memory is a concept that has been supported throughout research time and time again. Most notably, it has been applied to explain the flashbulb memory phenomenon. Research on flashbulb memories has found that emotional events leave a strong, long-lasting impression on individuals' memory, allowing them to recall vivid, almost photographic memories of the experience (Brown & Kulik, 1977). This concept encompasses the more overarching idea behind this relationship, however, there are many subcomponents that require much more in-depth research.

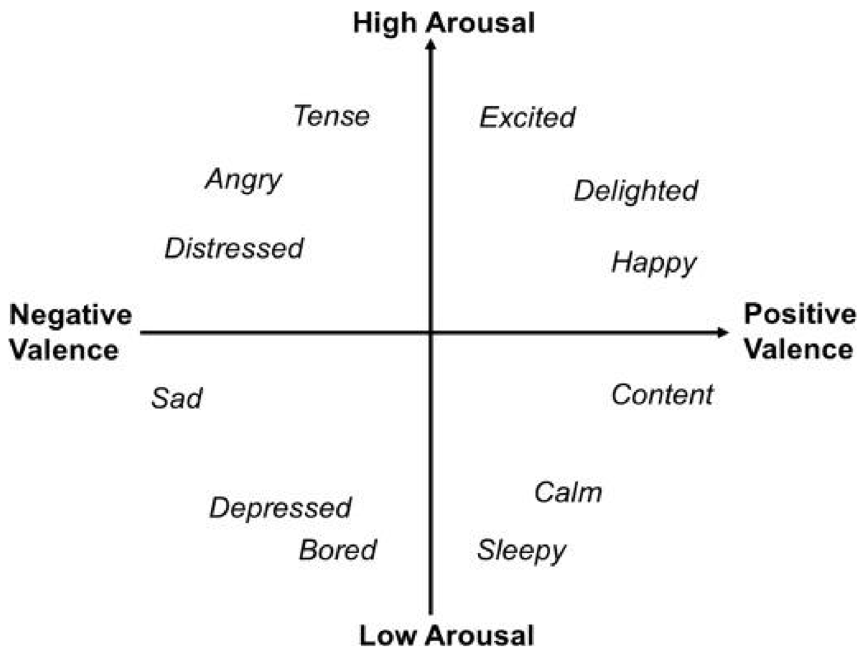
Although we understand emotion to be one of the main factors associated with more efficient and accurate recall—the process of retrieving information that was previously encoded and stored— of certain memories, a more specific question still remains: During encoding, which particular emotional state leads to the best (most accurate) recall later on?

Measuring Emotion

In order to attempt to answer the above research question, we must first determine the most effective way to break the concept of an "emotional state" down into classifiable, testable measures. The results of diverse research to date converge on the idea that emotionally enhanced memory benefits from two fundamental neurophysiological systems in particular: valence and arousal. Russell's (1980) circumplex model (see Figure 1 for a variation) offers the foundational idea that all emotional states can be best characterized by looking at these two key components of emotion. Specifically, this model serves to effectively represent affective states, where the systems of valence and arousal create two bipolar dimensions in a circular space (see Figure 1).

Figure 1

Two-Dimensional Model of Affective State



First introduced by Lewin (1950), the term "valence" was originally used to understand the force that drives us towards various objects, places, people, etc (Cummings et al., 2015). He believed that our level of attraction to various objects is a direct result of how much we desire that object. At the same time, he believed that there is an opposing force that drives us away from undesirable objects. He determined that this "force" was actually valence, where positively valenced objects pulled us in, and negatively valenced objects pushed us away. Over time, these ideas were extended to provide a potential way of understanding emotion—that is, how we perceive and process emotional stimuli, responses and experiences—as "positive" and "negative", which ultimately became synonymous with "attractive" and "aversive", "good" and “bad”, etc. (American Psychological Association, 2013; Kauschke, 2019). In turn, the valence dimension can be measured on a continuum from “negative” to “positive”, as seen on the model.

When applying these ideas of valence to the real world, a positively valenced emotional state can be evoked by exposure to positively valenced events, objects, or situations, i.e. you receive an email from your dream company saying that they want to offer you a job. This situation is positive, pleasant, “good”—thus your affective state becomes positively valenced as a result. At the center of this continuum is the point of “neutral” valence. This state can be defined as indifference, or rather experiencing neither positive or negative feelings following exposure to something. On the opposite end of the continuum, an example of an experience perceived to be “negatively valenced” would be a situation in which someone is exposed to something that is particularly unpleasant, i.e. you receive an email from your dream company that you did *not* in fact get the job you so badly wanted.

The second dimension, emotional arousal, is defined in terms of physiological “excitement”, and is determined based on your level of stimulation. It is often determined by reported measures of increased skin conductance (SCL) and heart rate (HR) (Lang et al., 1993), as well as brain activity (Keil et al., 2001). In a state of high arousal, emotions are heightened, and a high level of stimulation is experienced. High arousal is often associated with terms such as “excitement” or “fear”. A potential example of when you would experience a state of high arousal could be while watching an intense action film. On the other end of the spectrum, in direct contrast to high arousal is low arousal, which can be thought of as how calm or “sleepy” (Russell, 1980) one is. In a state of low arousal you experience little to no stimulation. It is often associated with terms like “boredom” or “relaxation”. A potential example of when you would experience a state of low arousal could be while watching the tide come in at the beach, accompanied by the soothing sounds of waves crashing on the shore.

Something else to consider when attempting to understand and categorize emotional states using this model is that both the measures of valence and arousal are aspects of affect that can be considered independently from one another. As a result, gauging one's emotional state requires taking a measure of both systems individually. In turn, the model can be adapted to create a quadrant-based system that designates four testable combinations of the two measures: high arousal-negative valence, high arousal-positive valence, low arousal-positive valence, low arousal-negative valence. For example, a high arousal-negative valence state could be the affective state that is experienced by someone in a car crash, where their heart is racing, and they are extremely stimulated, while at the same time the circumstance is unpleasant or "bad".

Emotional Arousal and Memory

The relationship between emotional arousal and memory is a key component within the overall concept of emotion-memory enhancement. The majority of research suggests that emotional arousal aids in memory processes as a result of the enhancing effects it has on selective attention (Chun and Turk-Browne, 2007). Selective attention is where the brain filters through information it is exposed to, granting certain information greater perceptual attention, and other materials less. By choosing to pay greater attention to certain information, you're choosing to allocate your processing resources strictly to that material. Information that receives more attention or is more intensely focused on, is then more effectively encoded, which increases the likelihood that it will be remembered later on (Tyng, 2017). According to William James, a classic figure within the world of psychology, “we cannot deny that an object once attended to will remain in the memory, while one inattentively allowed to pass will leave no traces behind.”

The change blindness and inattentional blindness phenomena evidence the power of selective attention, suggesting that when attention is allocated toward specific information, changes/additions happening outside of your focus can go completely unnoticed. In “The Invisible Gorilla Experiment” (Chabris & Simons, 2010), subjects were shown a video of a group of children passing a basketball back and forth and were told to count the number of passes that were made. At one point during the film, a gorilla enters the scene. Later on, subjects were asked whether or not they noticed anything interesting while counting the passes, and half of the respondents said no. These results support the ideas of change blindness and inattentional blindness where, since participants' selective attention was so focused on the task assigned to them, a very obvious, but goal-*irrelevant* shift in the scene was entirely overlooked.

Emotional arousal serves to modulate selective attention, helping to determine what an individual narrows their focus on/how intense that focus is, and in turn, what gets most efficiently encoded into memory. The Arousal-Biased Competition Theory (Mather & Sutherland, 2011) provides one potential explanation for this, suggesting that emotional arousal assigns perceptual contrast between high and low priority information, which allows high priority information to receive greater focused attention. In a study (Bannerman et al., 2008) aimed to investigate the competitive advantage arousal grants to relevant information, two face stimuli, with grating circles positioned on the nose, were simultaneously presented to subjects' left and right eye. One of the faces was emotionally arousing and one was emotionally neutral. Subjects were instructed to indicate the grating orientation, which in turn made the gratings the “goal-relevant” stimuli. Subjects reported more accurate grating orientations when presented on the emotionally arousing face versus the emotionally neutral face. In turn, this supports the idea that emotional arousal increases the ability to hone in on information deemed important in high-stress situations. When considering this relationship evolutionarily, it makes sense that our brain and body would allocate its most perceptive faculties to information deemed crucial to “survival”, or success when in a heightened emotional state (Tyng, 2017).

Additionally, one study (Sutherland and Mather, 2011) exposed subjects to either arousing or non-arousing sounds before presenting them with a memory task. During the study phase, they were shown an array of various letters, where the goal-relevant information was presented in high contrast colors, and low priority information was presented in low contrast colors. When asked to recall the letters later on, subjects that heard the arousing sounds were more likely to report the high priority letters over the low priority letters. These findings also support the idea that an arousing experience leads to a priority contrast advantage that is applied to how we perceive information.

Top-down modulation is believed to be the primary mechanism underlying selective attention, responsible for deciphering between priority of simultaneously presented information by releasing signals that increase brain activity in relation to goal-relevant information, suppressing activity for low priority information. Arousal is believed to enhance this top-model signaling, creating even greater neural contrast between high priority and low priority information (Gazzaley et al., 2012). In the context of a memory recognition task where two visual stimuli are presented, arousal would direct attentional faculties to the “goal-relevant stimuli”—in this case, the pre-designated “target cue”— instead of the low-priority stimuli—in this case, the“lure cue”. In the case of a single stimuli trial where no other information is present to compete with, the material categorized as “goal-relevant” would be the information central to the stimuli.

Importantly, many of the studies that have tested the link between emotion and attention/memory have failed to separate emotion from the attention-focused (or “to-be-learned”) stimuli. This is to say that in many studies, the stimuli that evokes an emotional response also doubles as the stimuli that the subject's memory is later tested for, i.e. emotional pictures, words, videos, etc. One study (Laretzaki et al., 2010) aimed to fill this gap, instead using acute threat to induce arousal, and then testing subjects’ attention for unrelated neutral stimuli. Attention was measured using Visual Evoked Potential (VEP) recordings, where by connecting electrodes to the subject's head, researchers were able to assess how long it took for the brain to perceive visual information based on the time it took for visual neural pathways to elicit activity. This within-subject study first exposed participants to the low-contrast stimuli without evoking arousal. Then, when placed into the threat condition, a current square was placed on one of their wrists, and subjects were told to expect 1-3 electric shocks at some point throughout the duration of the task that would vary in degrees of pain—but were not told exactly when they would be administered. The results of the study showed that the state of heightened arousal experienced as a result of anticipating the shock in the threat condition, led to a decrease in the amount of time it took subjects to direct their attention to the neutral stimuli versus when in the non-threat condition. This further supports the idea that external arousal enhances attention at early stages of perception, even for nonemotional stimuli.

Another study that also used neutral stimuli to investigate how emotional arousal affects memory when elicited in a way that is not a direct result of the content that is being encoded, presented subjects with neutral target and cue stimuli, and then evoked emotional arousal in one group, *post*-encoding. The ABC theory suggests that "[in] studies that ask participants to learn emotionally neutral material, the highest priority information [is] found among the neutral to-be-learned material due to its top-down goal relevance, and therefore gain[s] from arousal-biased competition" (Mather & Sutherland, 2011). The results of this study support this claim, finding that a post-encoding trigger of arousal *did* serve to enhance memory for high priority information. This suggests that in a memory task where all information presented during the encoding phase is neutral, the information that subjects are specifically instructed to remember—rather the "target" or what is "goal-relevant" to the task—benefits from arousal biases, where memory resources are directed strictly towards the goal-relevant information despite it not being emotional itself. These findings also suggest that arousal serves to enhance consolidation processes of goal relevant information as well, whereby allowing it to be more strongly represented, it is transformed into a more stable and long-lasting form, allowing it to be retrieved more vividly than low priority information.

Emotional arousal also impacts the release of stress hormones and brain activation in regions that play a very influential role in memory processes. When the body enters into an emotionally arousing state, stress-related hormones (e.g. adrenaline and cortisol) are secreted in response. These hormones set off a chain reaction within the brain and the body, activating the amygdala—responsible for detecting and processing stress and fear—which is a brain region that is crucial to forming and consolidating emotional memories (McGaugh, 2004; Schmidt & Saari, 2007). However, since emotional memories require processing of additional contextual information which takes place in other regions of the brain, the amygdala must transmit associated information to those other regions as well. This transmission, also known as neural plasticity, refers to the restructuring or forming of pathways/connections between various regions of the brain after exposure to new learned information, skills, etc which enables the material to be more effectively consolidated into a memory (Hermans et al., 2014). In turn, emotional arousal strengthens neural plasticity in the amygdala, as neurons are prompted to fire, which facilitates interactions with other regions of the brain. This allows the amygdala to more efficiently transmit necessary information, allowing for effective memory consolidation of the encoded material. Furthermore, emotional arousal is believed to allocate more specific attentional and organizational cognitive processes to information appraised as high priority, also resulting in better consolidation of the information into early and long term memory (Talmi et al., 2007).

Arousal is also believed to trigger the secretion of other stress-induced hormones, such as norepinephrine, that have been found to enhance memory representation of goal-relevant stimuli, suppressing memory representation of goal-irrelevant information (Mather et al., 2016). Arousal triggers the release of norepinephrine which then triggers an increase in the firing of glutamate—the brain's main excitatory neurotransmitter. This increase is associated with active neural representation, which then triggers additional norepinephrine release. Norepinephrine is believed to favor perception of/memory for important information. One study found that rats injected with norepinephrine while encoding, resulted in enhanced memory performance later on (Hatfield & McGaugh, 1999; LaLumiere et al., 2003). The positive feedback loop created between glutamate firing and norepinephrine release creates a hotspot of glutamate signal firing, strengthening neural plasticity. These higher concentrations of norepinephrine represent high levels of cognitive activity, attracting resources to those specific regions of the brain. This results in a concentration of brain activity that amplifies the contrast between high and low priority. Thus, by entering an arousal evoking affective state, which highlights regions responsible for processing goal-oriented, salient information, attentional faculties can prioritize that activity, increasing focus and attention, aiding in encoding and consolidation to ultimately allow for more efficient retrieval in the future.

Previous research may be thought to contradict such attention related theories, arguing that memory for emotionally-arousing stimuli may actually be weakened by a state of high arousal (Fecteau & Munoz, 2006). However, supporting evidence for this has only been found when the arousal-eliciting stimuli and the task-relevant stimuli are in direct competition with one another where both stimuli are considered high priority. For instance, consider a task that asks you to differentiate between pictures of two similar houses while you are simultaneously presented with two emotional distractor faces (Vuilleumier et al., 2001). Here, both tasks, one goal-oriented (deciphering between homes) and the other, emotionally arousing (emotional expression on the faces), are in direct *visual* competition, perceived and processed in the same way, by way of the same systems. However, research has found that when arousal is induced in a way where the arousing stimuli are not in direct competition with the task-relevant stimuli, or rather are not processed in the same way, processing of neutral goal-relevant stimuli is actually enhanced (Chajut & Algom, 2003).

When talking about the memory enhancing effects of emotional arousal, an important distinction must be made between memory for items and memory for events. In the first situation, attention is focused on individual elements alone, however, with memories for specific events (episodic memories), attention must be paid not only to individual elements, but their associations with one another and the context as a whole. For example, think about an image of a single apple vs. a videorecording of a person picking apples. Findings suggest that accurate memory for individual elements employs different regions of the brain than memory for an event, as well as different processes. One concept that refers to the way in which multiple elements, along with their context and associations, are remembered is known as memory binding (Nashiro, 2011).

Whether or not emotional memory enhancement for objects also applies to memory for events (or memory binding) is a topic of debate (Mather, 2011). On one hand, research has found that arousal enhances memory binding, as it links individual details of the events to the episodic context that is surrounding the stimuli itself at the time of encoding. In one study (McKay et al., 2004), where a memory recognition task had subjects encode a list of taboo (arousing) words and neutral words and associated them with a color, the colors of the arousing words were better remembered than neutral words, as well as their surrounding context—where or when the particular word was presented in the experiment. This suggests that as arousal hones attention for emotional and high priority stimuli, the surrounding context associated with the important stimuli (neutral or low priority information) may take priority by way of association, and is efficiently encoded as a result of also being actively attended to.

In another study (Mather and Nesmith, 2008) participants were presented with both emotionally arousing, and non-arousing, pictures during an incidental encoding task. The images appeared in different locations on a screen within the same encoding trial. When later asked to recognize the location of the stimuli, participants performed better when reporting the location of the emotionally arousing pictures than the non-arousing ones. These findings support the idea that arousal enhances memory for emotional content, since the subjects accurately remembered the individual element. At the same time, these findings also suggest that emotional arousal enhances memory for context as well since, when presented simultaneously with other neutral pictures, memory was still accurate for the location of emotionally arousing pictures which arguably requires memory for contextual, associated details as you would have had to also remember where other images were positioned to know where the emotional image was in relation.

However, results from a different study (Nadel & Moscovitch, 1997) contradict these findings, instead suggesting that acute stress actually impairs regions of the brain involved in the memory binding process (prefrontal cortex and hippocampus), which actually impairs encoding of the surrounding contextual information. A study by Kensinger and Schachter (2006) exposed subjects to emotionally arousing and neutral words and asked them to categorize them. Later on, participants were surprised with a recognition task and were instructed to recall which category they had placed each word in. Findings revealed that recognition memory (where they indicated whether or not they had previously seen the word) was enhanced for emotionally arousing words compared to the neutral words. However, when asked to recall the specific category that they had placed each word into, emotional arousal did not enhance performance compared to memory for the categories of the neutral words. As memory for category was utilized as a way to measure context memory (the association between word and category) these findings suggest that emotional arousal *does not* have a between-binding effect (memory for associations between other details).

In an additional study (Kensinger et al., 2007) subjects were shown various objects, some of which were neutral and some emotionally arousing. Later they were presented with images of either the same object they had been shown, or an object that was similar. Subjects were more accurate when correctly identifying objects that they actually had seen, when that object was emotionally arousing. Researchers believe that the more accurate recall of the photo association for emotional objects was due to the emotional object having triggered enhanced memory for specific visual details specific to the object itself during initial encoding. These findings suggest that although emotional arousal may not enhance between-object memory binding, it does however enhance within-object memory binding.

In a subsequent study by Kensinger and Schachter (2005), an experiment was conducted in which participants were either shown pictures of an object, or were asked to imagine a named object. Half of the items were emotional and half were neutral. In the test phase, participants heard the object names and had to state whether or not they had seen a photograph of it. The emotional effect of each object was rated using fMRI scans that measured the activity in emotion-processing regions of the brain such as the amygdala and orbitofrontal cortex. A positive correlation was later found between the emotional activity a word had elicited and subjects' accuracy during later recall. As subjects during retrieval were less likely to falsely remember having seen an image during the encoding phase when the object was emotional, findings suggest that emotion enhances memory for item specific detail by increasing activation seen between the amygdala and other emotion-processing regions (neural plasticity).

To summarize, the majority of research converges to support the idea that increased emotional arousal enhances memory for emotional stimuli, as well as neutral stimuli that is deemed "goal-relevant". Important to note however, is that studies have also provided findings that contradict this claim, where although increased emotional arousal enhances memory for central information, it has actually been found to compromise memory for peripheral information, suggesting that surrounding contextual information associated with an emotional memory may actually be worsened. Also important to acknowledge is that the majority of research on this topic to date has focused on enhanced or suppressed encoding of emotional stimuli as a result of the emotional arousal that stimuli evoke within subjects. Few studies have looked at how the emotional state subjects are experiencing as they encode unrelated, neutral information impacts their ability to recall the information later on.

Emotional Valence and Memory

The impact of emotional valence on memory is another subtopic of interest for researchers when it comes to understanding the relationship between emotion and memory. Like emotionally arousing stimuli, studies have also shown that emotionally valenced stimuli are better remembered compared to neutral stimuli. Additionally, studies have dug deeper into this idea by more specifically investigating which state of emotional valence—positive versus negative—has the greatest impact on memory (Ford, 2012). Overall, results across various studies have found contradicting evidence, leaving arguments for one over the other to be deemed inconclusive. While some have found that negative valence enhances memory, others have found that in certain situations, negative valence can actually inhibit certain aspects of memory. The same goes for positive valence.

One study (Anderson and Shimamura, 2005) compared the effects of emotional valence on memory, inducing valence via emotional videos. They categorized a series of emotional film clips as either neutral, positive, or negative. As the subjects viewed the various clips, they listened to the recitation of random neutral words which they were later assessed on. They were then asked to complete two memory tasks. The first was a word recall task where they freely recalled as many words as they could. The second was a context recognition task, where they identified the video clip that had been playing when they heard a particular word. The findings revealed that memory for words associated with emotionally negative film clips was worse than memory for words associated with the emotionally neutral and positive film clips.

However, the findings from a different study (Kensinger and Corkin, 2003) found negative valence to have the opposite effect on memory. In the first part of this multi-part experiment, subjects' memory for studied words was compared based on whether the words were negatively or neutrally valenced. Interestingly, something else the researchers tested for was *how well* the subjects remembered each word, asking them to indicate if they vividly *remembered* the word*, knew* that the word was familiar, or thought that the word was *new* (had no prior memory of the word). Not only did this portion of the study find that subjects' memory for negative words was better than it was for neutral words, but also that negative words were more frequently reported as *remembered* rather than *known.* These findings suggest that negative valence not only impacts the accuracy of memory, but also allows it to be more detailed.

Further supporting the idea that emotional valence impacts memory, the second part of the experiment tested subjects' source memory, or rather perceptual details associated with the context in which the stimuli was presented. To do this, they asked subjects to study a list of words, again either negatively or neutrally valenced, but this time presented them in either blue or red font. Presenting the word in a specific color provided additional contextual detail they could use to test subjects (source memory) aside from just memory accuracy for the words themselves. Results found that for negative words, both memory for the words, as well as for their color was significantly better than it was for neutral words. These findings support that negative valence enhances memory for specific information, as well as contextual detail associated with negative stimuli (Kensinger and Corkin, 2003).

Khairudin et al. (2012) also used word stimuli to assess the effects of emotional valence on memory. In the first portion of the experiment, subjects were exposed to positive, negative and neutrally valenced words. On a subsequent recognition task, the results of the study revealed that emotion had a significant effect on memory performance, where both positive and negative valence enhanced recognition accuracy for words compared to the neutral condition. Interestingly, in this case it was also found that the positively valenced content was actually remembered better than the negatively valenced content.

Additional research has found that emotional valence also serves to enhance another mechanism that is key to memory processing known as recapitulation (Buchanan, 2007). Buckner and Wheel (2001) proposed that the concept of recapitulation, defined as the “re-engagement of neural activations and patterns" is essential when it comes to retrieving episodic memories since, when the neural patterns activated while encoding information match the neural patterns that are reactivated when later recalling that information, both the encoding and the retrieval of that memory are more efficient and accessible (Morris et al., 1977). Research has found that when recalling an emotionally valenced memory, activation patterns in the amygdala more closely match those previously elicited during encoding (recapitulation). In turn, that amygdala activation can trigger the same autonomic and somatic responses that the individual experienced when they initially encoded the event. This suggests that one way emotion valence influences memory is by recapitulating the specific emotional state an individual had experienced when initially exposed to information/an event (Buchanan, 2007).

Additional research (Smith et al., 2004) found that amygdala activation when retrieving neutral content that had been encoded within an emotional context also matched amygdala activation patterns elicited during retrieval. The same was not found when retrieving neutral information that had been encoded in a neutral context. These findings further support the idea that emotional valence increases reactivation of neural networks at retrieval, evidencing enhanced recapitulation, key to enhancing memory.

More specifically, research has found that neutral valence enhances recapitulation of content details pertaining to specific memories, where the retrieval of negative memories compared to positive memories elicits greater activation on visual processing regions of the brain, resulting in stronger sensory signatures (Beyeler et al., 2016). In one study (Fenker et al., 2005), subjects were presented with neutral words, paired with either neutral or emotional face stimuli during a series of encoding trials, and during the retrieval phase, were once again presented with the words (without the faces), and asked whether or not they recognized them. fMRI results showed that despite subjects not being asked to recall the facial stimuli, the fusiform gyrus—the region of the brain responsible for face processing, which had been activated during encoding—experienced greater activation when asked to recall words that had been paired with emotional faces than when recalling words paired with neutral faces. Amygdala activation—which had also been previously elicited during encoding—was also greater for words that had been presented in pairs with an emotional face. In another study (Kark & Kensinger, 2015), greater retrieval recapitulation was again found in regions of the brain associated with visual processing for previously encoded negative images versus positive images, which was linked to greater memory success and confidence.

A follow-up study (Bowen & Kensinger, 2018) wanted to test this enhancing effect of negative valence on recapitulation processes within sensory regions by using a different form of cue other than images. Subjects encoded neutral words in the context of negative, positive, or neutral faces and scenes and were then asked about the word. Again, recapitulation was greater in the visual processing regions when retrieving words that had been shown in the negative context versus positive and neutral. These findings suggest that negative valence not only enhances sensory recapitulation for image cues, but other visual cues such as words, scenes, and faces as well.

Interestingly, research also found emotional valence to have this retrieval-enhancing recapitulation effect, despite not using emotional cues during the retrieval phase. This further suggests that emotion has a lasting impact on memory, where the sensory signatures imprinted during encoding in the presence of emotional stimuli are still strong enough to be reactivated when presented with neutral stimuli that had been associated with the emotional stimuli during encoding, later during retrieval. To summarize, these findings support the idea that negative emotional valence has greater memory enhancing effects than positive valence due to its ability to enhance sensory cortices during encoding, creating a stronger neural profile, which leads to enhanced recapitulation of sensory regions during retrieval.

Despite all the above research, the argument between whether positive or negative valence leads to more successful encoding is still up for debate. For instance,while various studies (Weymar et al., 2013; Ritchey et al., 2011) have found that performance on recognition memory tasks is better for negative images versus positive and neutral, at the same time, other recognition tasks have found that memory performance is better for positive images, versus negative and neutral images (Fernandez-Rey et al., 2007; Glaser et al., 2012).

Not only has various research been found to support the superiority of positive valence, but research has actually suggested negative events to have potential inhibitory effects on memory. Specific to forming episodic memories is “coherent spatio-temporal context” which refers to the associations between various items and the surrounding environment that allows memories to be processed holistically. This concept, similar to memory binding which was touched upon previously in reference to arousal (Baddeley et al., 2011), is also believed to be impacted by emotional valence. Contrary to the findings in the above research, specifically the NEVER model, an alternate view proposed by (Bisby & Burgess, 2017) suggests that negative emotion enhances memory only for the negative content from an event (due to amygdala activation), but weakens memory for the event's surrounding context. This was seen in a previous study conducted by Bisby and Burgess (2014), where encoding of item-context pairs resulted in improved memory for the negative item portion of the pair, but worse memory for the associated context half of the pair.

Similar studies have focused on memory for neutral peripheral information when simultaneously presented with negative central stimuli and found similar context impairment. In another study (Bisby & Burgess, 2018) that focused on memory for item coherence, subjects were asked to encode events based on three key details of person, location, and object. Findings showed that for any event in which at least one of the three items was negative, memory coherence—or rather how well all three aspects of the event were remembered together—decreased compared to when all items were neutral. Important to note however, is that the event context was manually created by combining three separate representative images. Obviously, such manufactured contextual encoding cannot be fairly equated to the real-life experience of encoding that takes place upon attending an actual event. Similarly, it can be argued that subjects were not given a realistic chance to create tangible associations between the three aspects of the "event", whereas in real-life, "negative content" has potential to elicit extremely memorable reactions, which could potentially result in greater cohesive memory.

Bisby and Burgess (2013) also addressed the inhibitory effects of negative valence. The results of their study suggest that due to the salience of emotional items which attract enhanced selective attention, when encoding item pairs, memory is blinded for neutral items when paired with negative items, while memory for the negative items is enhanced. Similar to high arousal, this is believed to be a result of the inhibitory effects of negative stimuli on activity in hippocampal regions, which are the regions of the brain responsible for associative memory. Even still, this research does state that “the storage of negative sensory/perceptual representations is spared or even strengthened,” which does serve to support certain aspects of the previously mentioned NEVER model (Bowen et al., 2019).

To review, similar to what was found for high versus low arousal, research remains quite mixed when it comes to determining whether a particular state of valence is responsible for greater memory enhancing effects. This is believed to be attributed to the different systems responsible for processing both negative versus positive stimuli. As research has shown, negative stimuli do enhance recapitulation of key visual details by eliciting a closer resemblance between the sensory *encoding* signatures, and the sensory *retrieval* signatures, which allows recall of the memory information to be more accurate and accessible. At the same time however, negative valence has proven to have harmful effects on memory, where, due to negative stimuli taking priority over attention, other unrelated surrounding information can be overshadowed, resulting in potentially fragmented memory as opposed to a more holistic memory for events. In turn, findings remain inconclusive and require further research in order to truly determine whether or not particular types of valence are beneficial or detrimental to memory.

The Present Study

For the purposes of the present study, an important distinction must be made between stimulus-driven and state-dependent emotional effects. As seen throughout many of the supplementary studies provided, the majority of research up until this point has investigated the connection between emotion and memory, specifically in terms of memory for emotional *content* (stimuli-driven). However, the aim of the present study is to separate emotion from the memory focused stimuli, to see how emotional state during the encoding process affects recall later on.

As stated by Mather (2007), "the role of endogenous levels of arousal on encoding and short term retention processes is difficult to evaluate because only a few studies have manipulated human participants' arousal levels and then examined how the levels influence memory."

The present study, in an attempt to also address this gap, aimed to induce subjects' into certain emotional states via exposure to specific musical stimuli. Previous research has supported the idea of emotion induction through music (EIM) as an effective way to manipulate people's affective states (Ribeiro et al., 2019) The effectiveness of music to act as an emotion-inducing stimulus has been proven throughout many studies in which subjects are exposed to various music, and measures of self-report, as well as more physiological measures of brain activation, skin conductance (SCL) (Khalfa et al, 2002) and heart rate (HR) (Lundqvist et al., 2009) monitor and confirm these effects. For example, research has determined that songs with reported negative valence ratings result in lower HR and decreased SCL compared to songs with positive valence ratings (Krumhansl, 1997). Interestingly, this emotion-inducing impact has actually been found to be one of the key reasons that people report even listening to music at all. An additional study found that subjects believe one of the main underlying functions of music is to regulate arousal and mood (Schäfer et al., 2013).

In order to induce emotional states that fit into classifiable conditions in the present study, four samples of music were chosen and matched to the circumplex model of emotion (see Table 1), where each affective state induced was respective of one of the four arousal-valence quadrants: high arousal-negative valence, high arousal-positive valence, low arousal-negative valence, low arousal-positive valence. In addition, to isolate music as the only emotion inducing stimuli, subjects were shown a video reel composed of neutral clips, serving as the visual material that was used to test memory in an assessment completed post-film. As they watched the video reel, subjects were simultaneously exposed to the music.

More than just providing additional support for the influence of emotion on memory performance, this study could help further distinguish the difference between the relationships of emotional content on memory, and emotional state on memory. Furthermore, based on what we know about the independent effects of arousal and valence on memory, this study could add to the conversation surrounding which level of each measure of arousal and valence most effectively impact memory. Lastly, from that, whether emotional states that are created out of specific combinations of levels of both valence and arousal are actually even more effective.

Moreover, this study may not only offer interesting implications for explicit memory, but implicit memory as well. Despite the fact that subjects in the present study were informed ahead of time that their memory would be tested for the information they viewed later on (explicit memory), findings related to the concept of encoding when in a specific emotional state could play an especially important role when thinking about unintended encoding when exposed to various information throughout the day (implicit memory). For example, consider if additional findings suggest that encoding when in a state of high arousal-negative valence is most memory-effective (Hoscheidt et al. (2013). What could this mean for a person that is studying for a test on a day that they are extremely stressed out and in an unpleasant mood?

Overall, the present study aims to answer the questions: Does your emotional state while encoding information impact your ability to accurately remember the information? And if so, does this depend on the particular emotional arousal level or type of emotional valence?

Method

Participants

Participants (n=72) were recruited through Prolific, an online data collection platform. Participants were randomly assigned to one of four conditions: high arousal-positive valence, high arousal-negative valence, low arousal-positive valence, low arousal-negative valence. All participants participated remotely on their home computers through the Gorilla™ online experiment builder (Anwyl-Irvine et al., 2020; Bridges et al., 2020). Participants reported living in the United States and were between the ages of 18 and 30. Only individuals with normal or corrected-to-normal vision, without any hearing difficulties, were considered for this study. Of the 52 participants included, 63.8% identified as female, 34.4% identified as male, and 1.7% participants reported their gender identity as “other”. The reported breakdown of study participants' ethnicities was as follows: White (60.3%), Black (8.6%), Asian American (25.9%), American Indian (3.4%), and 1.7% reporting more than one ethnicity. Additionally, the reported breakdown of study participants' locations was as follows: Northeast (24.%), Northwest (6.9%), Midwest (27.6%), Southeast (27.6%), Southwest (12.1%), and South (1.7%). All participants were compensated $2.50 for their participation in accordance with the New York State Minimum Wage rate.

Materials

Video Stimuli. All stimuli used to create the video clip reel shown to each subject during the study phase were extracted from a database of emotional videos created specifically for the purpose of providing usable stimuli for future research studies in need of categorized emotional stimuli (Ack Baraly et al., 2020). The videos were selected from a mixture of Canadian or foreign movies and documentaries—generally excluding Hollywood and internationally-known films—as well as from online sources such as YouTube, Vimeo, etc. The clips depict random, real-life events including scenes of human interactions, animals, nature, and food/drink (i.e. sorting through a refrigerator or two colleagues conversing).

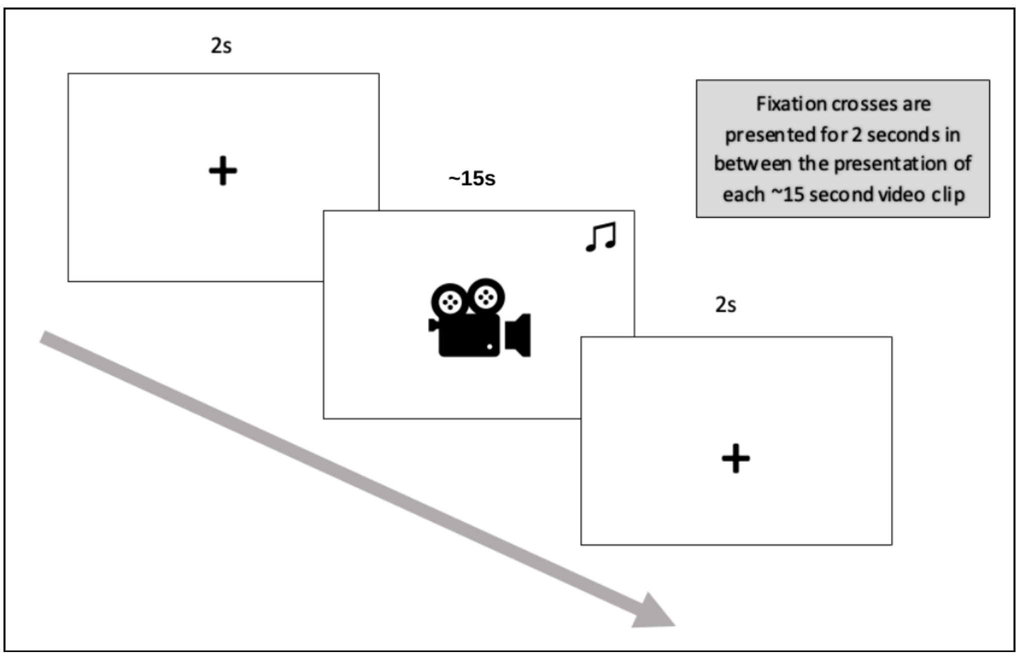
The database provided data from over 154 people, including the averaged ratings of valence, on a scale from 1 (positive) to 9 (negative) and arousal, on a scale from 1 (excited) to 9 (calm), for each video. The database was structured in a way that designated videos to one of three "clusters", for their valence and then for their arousal levels. Cluster 1 represented high arousal or negative valence, cluster 2 represented low arousal or positive valence, and cluster 3 represented either neutral valence or neutral arousal. Clips with reported valence ratings between 3.5-6.5 and arousal ratings between 1-3.5 ("low") were considered neutral.

For the present study, 22 video clips were selected out of the 291 total that were provided by the database. The 22 selected clips were all chosen from Cluster 3—the neutrally rated cluster. As the video stimuli that subjects were exposed to also acted as the material the subjects were later tested on across conditions, it was important to ensure the most homogenous visual experience across all participants. Additionally, it was crucial that the videos were neutral to ensure that the music was isolated as the only emotion inducing stimuli.

The full video reel, composed of the selected video clip stimuli, was created in iMovie. Each of the 22 video clips were cut in half, and both the first half (the first few seconds of the clip) and the second half (the subsequent few seconds of the clip following what happened after the first half clip cut-off) were trimmed down to ~3 second segments and then looped four times to create ~15 second clips. In the study phase, the 22 first half clips were then compiled into one reel, where all clips played in succession with a 2 second fixation cross shown in between. The order of the clips was randomized. During the test phase, the first half clips previously viewed during the study phase were considered "targets". The second half of the clips which had not been previously viewed in the study phase were used as "lures" in the test phase later on (see Figure 2).

Figure 2

Study Phase of Recognition Task



Musical Stimuli. All musical excerpts were extracted from the MediaEval Database for Emotional Analysis in Music (Soleymani et al., 2016). The DEAM database consists of annotated excerpts of 1,802 songs (58 full-length songs and 1,744 excerpts of 45 seconds) from a variety of popular music genres (rock, pop, electronic, country, jazz, etc). All music was retrieved from sources such as *freemusicarchive.org* (FMA), *jamendo.com*, and the medleyDB dataset which provide royalty-free excerpts. The annotations of the music were collected over a 3 year period (2013-2015) through crowdsourcing using Amazon Mechanical Turk, where participants reported measures of valence (positive or negative emotion of the music) and arousal (energy of the music), while simultaneously listening to each song (Aljanaki et al., 2017). After fielding and converging all annotations for each piece, the database was created characterizing the emotional rating of each song based on numerical values of valence from 1 (positive) to 9 (negative) and arousal from 1 (low arousal) to 9 (high arousal).

From this database, four songs were selected and matched to one of the four conditions: high arousal-positive valence, high arousal-negative valence, low arousal-positive valence, low arousal-positive valence. All audio samples chosen reflected the closest possible ratings for their respective condition. Table 1 depicts the emotion state matched with its respective condition number, along with its respective valence and arousal rating as listed in the database.

After selecting the piece of music that best fit each valence-arousal quadrant based on its affective ratings, each of the four pieces were trimmed down to 15 second snippets that were played repeatedly as each individual video clip was presented.

Table 1

Musical Stimuli Emotional Rating

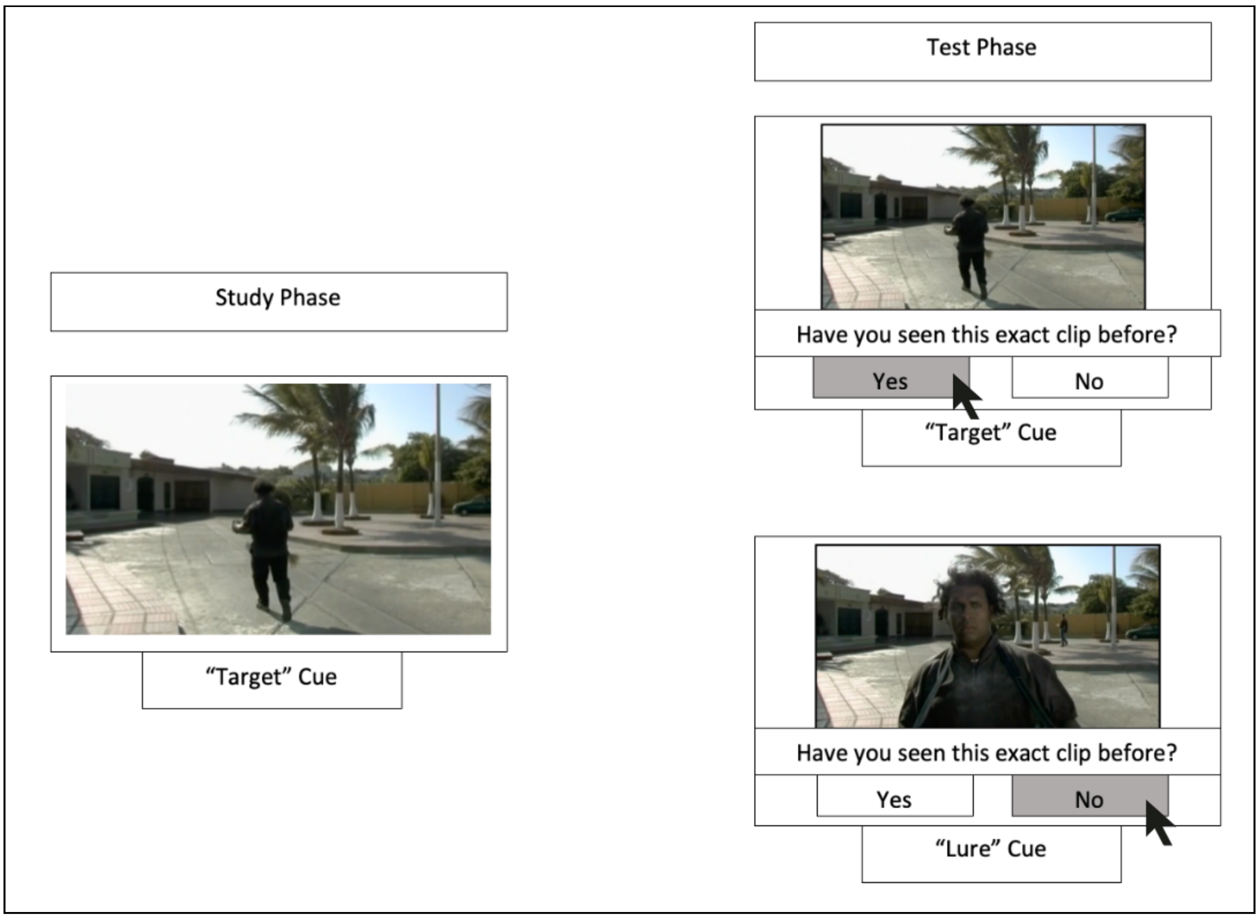
Condition #	Emotional State	Arousal	Valence
1	High Arousal-Positive Valence	7.8	8.4
2	High Arousal-Negative Valence	6.9	3.2
3	Low Arousal-Positive Valence	4.7	7.9
4	Low Arousal-Negative Valence	2.8	1.9

Testing Stimuli. The stimuli used in the “yes”/ “no” recognition task consisted of an equal mixture of target and lure cues. In the test phase, the target cues were made up of the first half (first few seconds) of each of the clips which participants *had* viewed previously during the study phase. The lure cues shown in the test phase were not previously viewed by participants in the study phase, but were the second half of the video clips that they had viewed in the study phase—composed of what happened in the seconds of the video clip following the end of what had been shown in the clip during the study phase. From the same movie, featuring the same characters, the first half and second half clips varied only slightly, differing only for the specifics of the events that transpired immediately following the cut off of the first half clip (see Figure 3).

For the target cues, a correct answer was marked by a “yes” response to the prompt “have you seen this exact clip before?” For the lure cues, a correct answer was marked by a “no" response.

Figure 3

Study Phase Stimuli vs. Test Phase



Note. The video clips presented to the subjects during the study task that represent the "target cues" consist of the first few seconds from a video clip (left side). During the test phase, participants are shown a mixture of "target cues" (top right) which they viewed previously, and "lure cues"—which are similar to the target cues, but actually consist of the next few seconds of the video clip that happened after the target cues. Since the clips are from the same video clips, just seconds apart, the cues are quite similar, meant to ensure that the task upholds some level of difficulty.

Likert Scale Affective Questionnaire. Following the study phase (video reel + music), before entering into the test phase, participants were asked to rate their affective state. Two likert scales were provided to gauge participant's arousal and valence. On the first scale, participants were asked to rate their level of emotional arousal (excitedness) on a scale from 1 (very calm) to 7 (very excited). On the second scale, participants were asked to rate their level of emotional valence (negative vs. positive) on a scale from 1 (very negative) to 7 (very positive) (See Appendix C).

Design and Procedure

All participants self-selected to participate in this experiment online by selecting the link to the study via the Prolific online recruiting platform. From Prolific, the link then directed participants to the experiment housed on the Gorilla experimental programming site. In the experiment consent form, participants were told that the study would be investigating the effects of emotion on memory ability. After giving their informed consent, subjects were asked to fill out a demographic questionnaire that included basic questions regarding their age, gender, race, and location. Participants were then brought to the main experiment which consisted of two phases: the memory encoding (study) phase, followed by a target/lure recognition task (test phase) (see Figure 4 for full procedure).

In the first phase, participants were randomly assigned into one of four conditions respective of the emotion-inducing music they would be exposed to. Each condition matched a quadrant on the 2-dimensional valence and arousal circumplex model (see Table 1). The subjects were then presented with a video reel, which was accompanied by the music of their specific condition. The music played simultaneously with the video clip, stopping at the end of each clip and then restarting when each new clip began. No music played during the presentation of the fixation crosses. The set of 22 clips that comprised the reel were the same across participants, however the order in which they were presented was randomized for each individual showing. Prior to the video reel beginning, subjects were instructed to pay close attention to each clip as they watched and were told that they would later be asked questions regarding what they saw. Following the end of the last clip, the participants were directed to fill out the Likert Scale Affective Questionnaire (see Appendix C).

Immediately following the questionnaire, they were brought to the next screen where they were prompted to begin the target/lure recognition task, testing their memory for the clips they had just seen. The task included a set of 22 trials, where they were presented with 11 lure cues and 11 target cues. Upon each trial they were prompted to press play, and either viewed the first half clip they had seen (target cue) or the second half clip they had not seen (lure cue). The format of the test stimuli were structured the same as the study stimuli—each clip looped 4 times for a total length of about 15 seconds. Following the viewing, subjects were asked to respond to the question “Have you seen this exact clip before?”, by clicking a box labeled “yes” or a box labeled “no” (see Figure 5).

Figure 4

Procedural Design of the Experiment

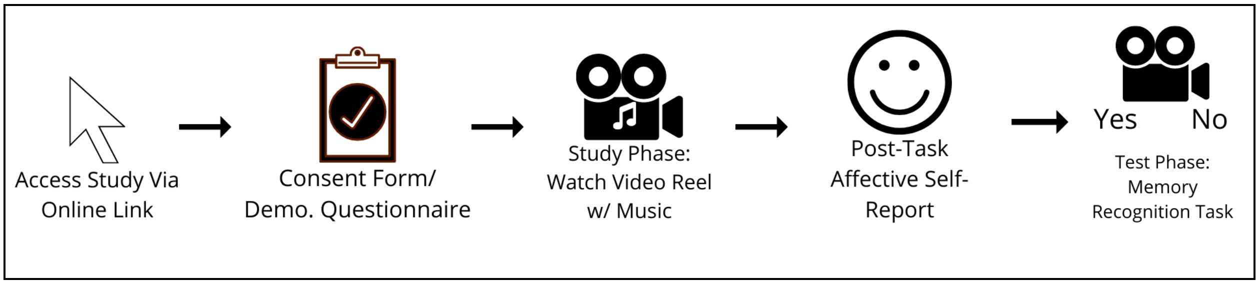
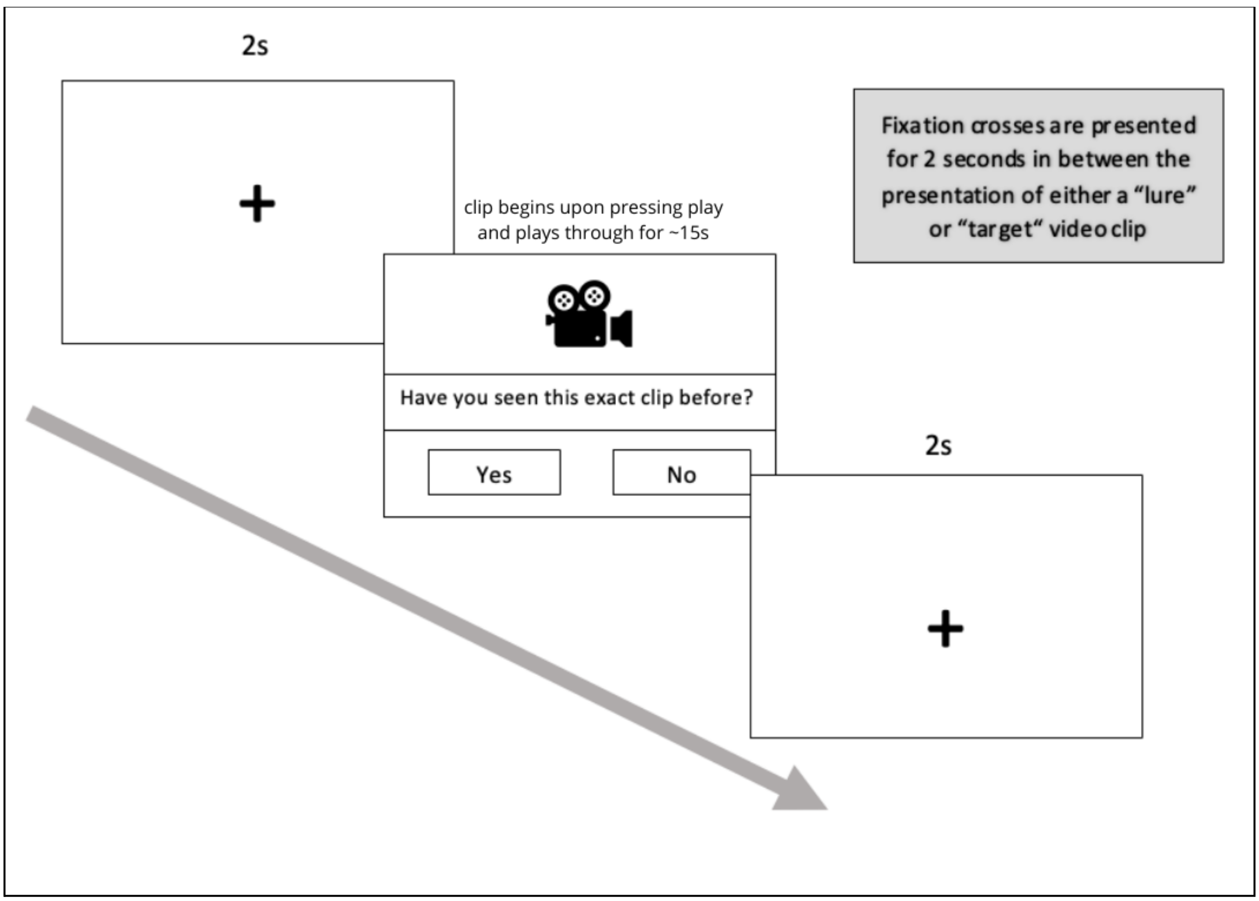


Figure 5

Test Phase of Recognition Memory Task



Results

After excluding participants (n=17) that experienced an audio malfunction while participating in the study, and participants (n=7) that performed below the baseline (accuracy score < .5) on the memory task, data from 52 participants was analyzed. Participants were randomly assigned into the high arousal-positive valence condition (n=14), high arousal-negative valence condition (n=11), low arousal-positive valence condition (n= 15), and low arousal-negative valence condition (n=12).

Memory Performance Data Analysis

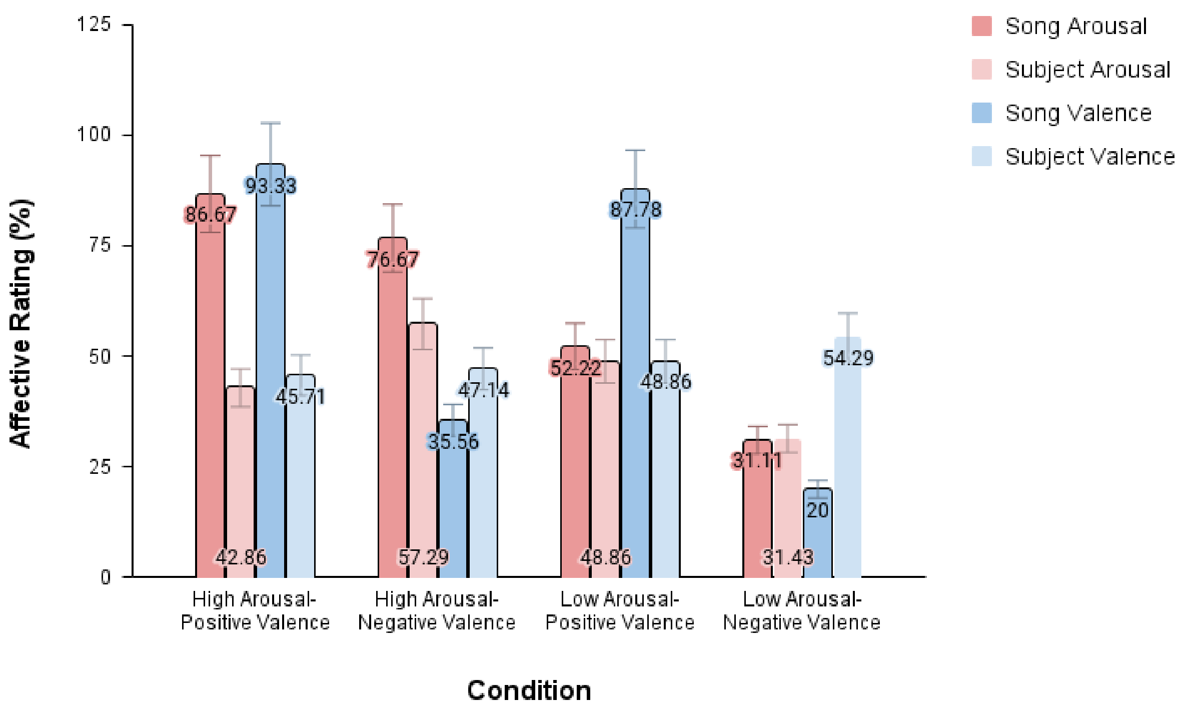
The average scores for each participant across 22 test trials were calculated and then separately aggregated to reveal average scores per condition. To assess whether emotional state (induced by music) improves performance on a memory recognition task, accuracy (proportion of video clips correctly identified as lures and cues), and signal detection (Pr) data were analyzed in two 2 Valence (positive, negative) X 2 Arousal (high, low) repeated measures Analysis of Variances (ANOVAs). An alpha level of .05 was used for all reported results.

Emotional Manipulation Check

To prime affective state, participants were exposed to particular songs—which had been previously rated according to their arousal and valence (Soleymani, 2018)—depending on their randomly assigned condition. To assess whether or not the music effectively induced participants into the intended emotional state per condition, subjects were asked to self-report their emotional state immediately following exposure to the music in the study phase by rating their valence level from 1 (very negative) to 7 (very positive), and their arousal level from 1 (very calm) to 7 (very excited). The individual participant ratings of both valence and arousal were then separately aggregated into a valence average and an arousal average for each condition. The condition averages for both valence and arousal were compared to the initial valence and arousal ratings reported by Soleymani et al., (2018) (see Figure 5). Since Soleymani and colleagues (2018) had asked their subjects to rate the songs based on valence and arousal scales ranging from 1 to 9, and participants in the present study were asked to rate their valence and arousal on scales ranging from 1 to 7, ratings were converted to percentages to allow for comparison. Participants randomized into the high arousal-positive valence condition reported an arousal rating that was lower on average (*M* = 3, 42.86%) than the song's arousal rating as reported in the database (*M* = 7.8, 86.67%), and reported a valence rating that was also lower on average (*M* = 3.21, 45.71%) than the song's valence rating as reported in the database (*M* = 8.4, 93.33%). Participants randomized into the high arousal-negative valence condition reported an arousal rating that was lower on average (*M* = 4.01, 57.29%) than the song's arousal rating as reported in the database (*M* = 6.9, 76.67%), and reported a valence rating that was higher on average (M = 3.3, 47.14%) than the song's valence rating as reported in the database (*M* = 3.2, 35.56%). Participants randomized into the low arousal-positive valence condition reported an arousal rating that was lower on average (*M* = 3.42, 48.86%) than the song's arousal rating as reported in the database (*M* = 4.7, 52.22%), and reported a valence rating that was also lower on average (*M* = 3.42, 48.86%) than the song's valence rating as reported in the database (*M* = 7.9, 87.78%). Participants randomized into the low arousal-negative valence condition reported an arousal rating that was lower on average (*M* = 2.2, 31.43%) than the song's arousal rating as reported in the database (*M* = 2.8, 31.11%), and reported a valence rating that was higher on average (*M* = 3.8, 54.29%) than the song's valence rating as reported in the database (*M* = 1.8, 20%). These results confirm that the music was not effective in inducing the intended emotional states as intended by each song.

Figure 5

Emotional Manipulation Check Via Affective Music



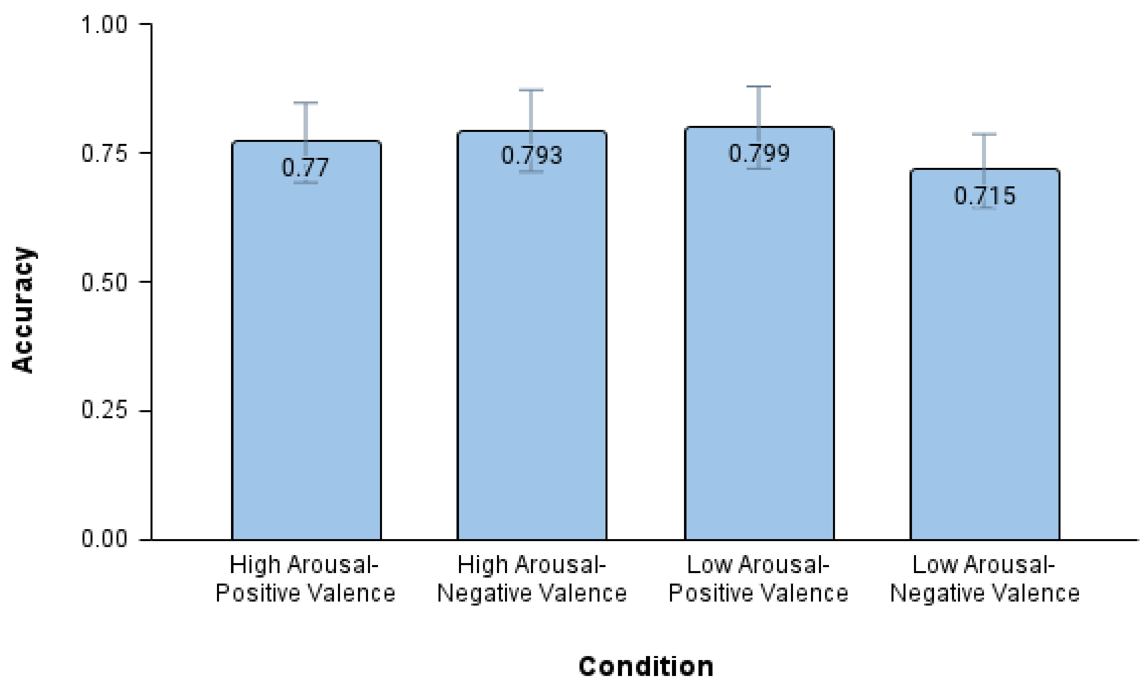
Note. This figure demonstrates the effectiveness of the music to induce participants into their intended emotional state respective of their randomized valence-arousal condition. The "song arousal" (dark pink) and "song valence" (dark blue) values reflect the average affective ratings of each song (%) previously determined by subjects in the Soleymani et al. (2018) study. The "subject arousal" (light pink) and "subject valence" (light blue) values reflect the averaged self-reported affective ratings of participants per emotional condition following exposure to the condition-respective music.

Recognition Task Accuracy

The 2 Valence (positive, negative) X 2 Arousal (high, low) repeated measures ANOVA on mean accuracy revealed a non-significant main effect of valence, $F(1, 48) = .772$, $p = .384$, indicating that accuracy was equivalent for positively valenced and negatively valenced conditions (see Figure 6). Similarly, the main effect of arousal was not significant, ($F(1, 48) = .504$, $p = .481$), indicating that accuracy was equivalent for high arousal and low arousal conditions. Finally, there was not a statistically significant interaction between the effects of valence and arousal ($F(1, 48) = 2.378$, $p = .13$).

Figure 6

Average Recognition Accuracy Scores Per Condition (error bars represent SD)



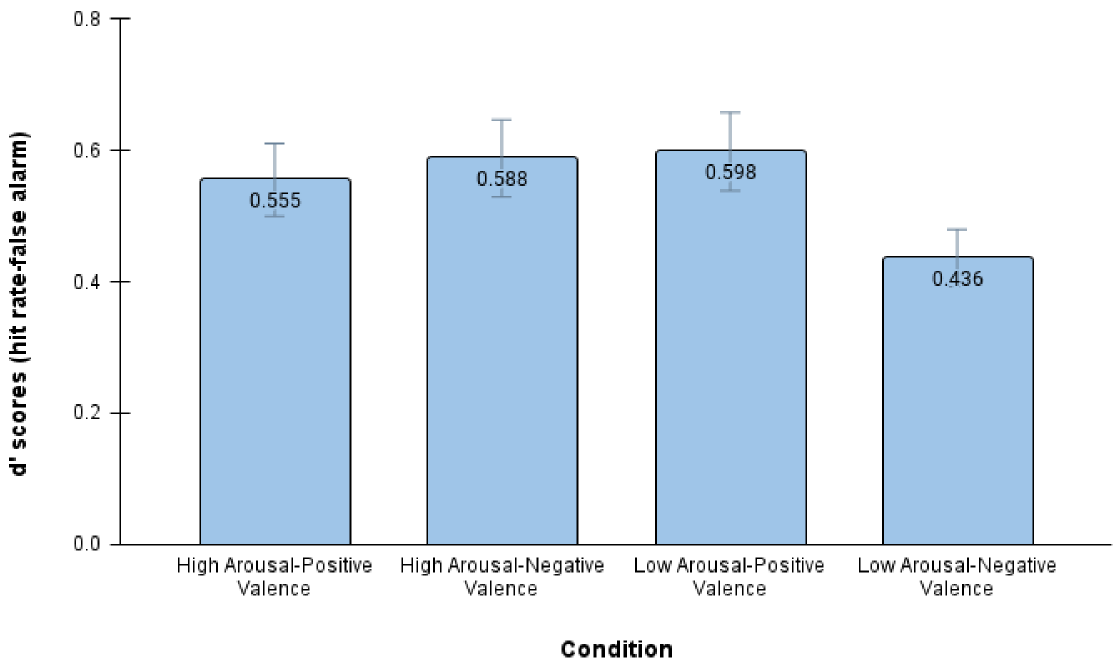
Recognition Task Signal Detection (Pr)

After calculating the average hit rates and false alarm rates per participant, the data was separately aggregated, and used to determine the average signal detection scores (Pr)—which is a common accuracy score, representing the difference between hits and false alarms (Goldinger et al., 2009) per condition (see Figure 7). A two-way ANOVA revealed that there was not a statistically significant interaction between the effects of valence and arousal ($F(1, 48) = 1.944$, $p = .170$). Simple main effects analysis showed that valence did not have a statistically significant effect on signal detection ($F(1, 48) = .870$, $p = .356$). Simple main effects analysis also showed that arousal did not have a statistically significant effect on signal detection ($F(1, 48) = .602$, $p = .442$).

These analyses revealed findings which were contrary to what was hypothesized: for performance on the recognition memory task, there was no significant difference found between the high arousal-negative valence condition and the other three conditions in their accuracy and Pr scores. These results show that, contrary to the hypothesis, memory performance scores were not significantly different across valence-arousal conditions.

Figure 7

Average Signal Detection (d') Scores Per Condition



Discussion

This study's hypothesis was based on a combination of theories that support the role of both high arousal and negative valence in enhancing memory performance. In general, supporting literature that looks at the effects of arousal on memory has found that when in a state of high arousal, stress responses are triggered throughout the brain and body which in turn divert attentional resources towards goal-relevant stimuli. In turn, essential cognitive processes are enhanced, leading to more efficient memory encoding, and consolidation. Similarly, research has found that negatively valenced emotion enhances brain activation in regions responsible for sensory detail, allowing a deeper neural imprint to be made on the brain than for details experienced in a state of positive emotion. Thus serving to not only enhance encoding and storage, but also retrieval (Bowen et al., 2018). Additionally, when induced together (high arousal and negative valence), fMRI scans taken during a follow-up recognition task found that subjects exposed to negative arousing emotional images elicited increased connectivity between the amygdala and other regions in the brain. Such neural activity is known to lead to enhanced memory. Conversely, arousal served to weaken amygdala connectivity for positive information (Mickley Steinmetz & Kensinger, 2009).

That being said, it has been found that high stress, as well as negative valence, can sometimes have opposing effects when it comes to associative memory, where they can actually inhibit hippocampal activity, weakening encoding of peripheral details and context. As people that experience PTSD have been known to have memory for only negative, highly arousing fragments of traumatic events (Rubin, 2008), this offers a potential explanation.

The current study extended previous research on the relationship between emotion and memory and, more specifically, aimed to contribute to the debate regarding, not only positive vs. negative valence and high vs. low arousal, but also whether or not certain levels of arousal *combined with* certain measures of valence might create an emotional state that modulates memory capability.

To test this idea, I conducted a study based on measures of the circumplex model of emotion (Russell, 1980), in which emotional state was primed by affective music. It was expected that, as argued by specific theories such as the Arousal-Biased-Competition -Theory, as well as the NEVER model, and evidenced by the findings from studies such as Mickley Steinmetz & Kensinger (2009) and Hoscheidt et al. (2013), by primining participants into an emotional state of both high arousal *and* negative valence, the experience of the particular emotional state would trigger enhanced selective attention processes during encoding of the neutral video clip stimuli.

Since all “to-be-learned" information was neutral, presented in the absence of any other negative or high stress visual information that could potentially beat out the neutral stimuli in biased competition for visual representation (Mather, 2011), it was predicted that all neutral video stimuli receive “high priority”. Additionally, since the emotional music stimuli were presented in a sensory form that was perceived differently—auditorily—than the “to be learned” material—which was presented visually—the emotional music would not out compete the neutral stimuli for processing resources, but would rather serve to enhance perception/processing of the visually presented information (Chajut & Algom, 2003). Therefore, all attentional faculties would be diverted to encoding the information within each scene. In turn, due to the influence of the negative valence that was expected to be experienced by participants in this group, the specific sensory (visual) details of the clips were expected to be even more efficiently encoded, which would result in enhanced recapitulation during retrieval in the later test phase (Bowen et al., 2018). The culmination of these anticipated effects was then expected to increase accuracy scores, as well as Pr scores, for participants in the high arousal-negative valence condition compared to other groups.

In the present study, this effect did not emerge for participant scores in the high arousal-negative valence group. The hypothesis of this study was not supported by the data as there were no significant effects of condition observed by the measures. Neither accuracy scores, nor Pr scores, from participants differed significantly between the mixed arousal-valence conditions.

Limitations

The sample size gathered for the current study (N=52) after exclusions could be considered relatively small considering that each condition contained 15 or fewer participants. Further research should therefore aim to obtain a larger sample of participants that could then be assigned to each condition.

Also worth noting is a potential confound of time between the gathering of data for conditions 1, 2, and 4 versus condition 3. Due to an audio malfunction, participants assigned to condition 3 in the initial running of the experiment had to be excluded. In order to obtain data for this missing condition, the study was reposted a day later (after the audio had been fixed), done so in a way that only allowed participants to be assigned to the previously missing condition (3). As a result, there is a potential confound of time between when the groups accessed the study, however, since the time difference was a matter of less than 24 hours, it is unlikely to have had any significant effect.

One potential explanation for finding no significant differences in memory performance between groups is that the priming of subjects' emotional state via music did not appear to be successful. Key to the study's hypothesis are the memory enhancing effects of the particular high arousal-negative valence state which subjects were supposed to experience while they encoded the visual stimuli during the study phase (Mickely Steinmetz & Kensinger, 2009). Therefore, the negative arousing experience was necessary to trigger the expected responses in the body and brain that would hone subjects' focus on the video clips, increasing their ability to accurately distinguish between target and lure scenes in the test phase later on. However, results from the music-emotion manipulation check found that subjects' self-reported affective ratings following exposure to the musical stimuli had not successfully induced them into the intended emotional state. This was found not only for the hypothesized group, but across the other three groups as well.

When initially compiling the database (Soleymani et al., 2018) from which the music used in the present study was taken from, subjects had listened to each of the four songs used at present and rated their perception of the valence and arousal levels of each. For the present study, the songs that were elected to represent each emotional state were chosen based on those ratings, as it was expected that in accordance with those ratings, the songs would successfully induce the same emotional experience of arousal and valence when applied here, that they had for subjects in the previous study. However, when comparing the affective ratings per song (Soleymani et al., 2018) to the affective ratings self-reported by each participant following exposure to the songs in the present study (Figure 5), both the arousal and valence means were significantly different.

A potential explanation for this unsuccessful priming could be attributed to the fact that in the initial study (Soleymani et al., 2018) subjects had been exposed to each song in its entirety. When applied to the present study, after each of the four songs were selected based on which best matched each respective condition, each song was then cropped down to a 15 second snippet that was repeatedly played behind each video clip throughout the study phase. This was done in an attempt to control for any confounding effects that could have arisen if specific parts of a song for some reason had an independent effect on memory, which would have skewed how the simultaneously presented video would have been remembered. However, in order to keep the same snippet playing across clips per condition, the length of the song had to match the length of each clip, and therefore had to be trimmed down to only a small sample of the full song. That being said, it is possible that since subjects' listening experience in the present study did not mimic the listening experience of subjects that had initially rated the songs, the music was not perceived in the same way emotionally.

At the same time however, it is important to note that the affective ratings per participant in the present study were self-reported *after* exposure to the music and not *while* listening to the music. Therefore, it is possible that their affective state while encoding had reached the desired valence and arousal levels irrespective of the music, but could have shifted during the time between the end of the study phase (exposure) and when they responded to the affective questionnaire. If this were the case, findings would rather suggest that emotional state does not actually enhance or inhibit memory, but rather has no effect. In turn, future research could attempt to replicate this study, however, doing so in such a way that allows subjects to be exposed to the full musical samples, and also takes affective ratings while subjects are simultaneously being exposed to the emotion-inducing music.

Implications for Future Studies

Despite the results of the present study, I still contend that the emotional state you are in while encoding information has potential to affect memory. However, in order for an experiment to support this, researchers would need to ensure that subjects are successfully primed into their designated emotional state. If future research is able to reveal a correlation between emotional state and memory, while simultaneously isolating which particular states enhance these effects the most, the real-world applications would be endless. Such findings would provide insight into a potential way for us to more efficiently encode information, regardless of whether or not the content was emotional, thus enhancing memory overall.

The implications of this potential research could, for instance, change the way students study. Picture this: two weeks from now you have a huge anatomy exam. In order to do well, you must encode an overwhelming amount of information, and be able to accurately recall that information come exam day. If you know that you can effectively prime your emotional state to achieve arousal and valence levels that are optimal for memory processing, playlists of state-specific music could be curated and listened to, to ensure effective studying sessions. In a workplace setting, the once intimidating task of memorizing the names of high-priority clientele attending an important upcoming function could be made easier. By employing the power of state assisted memory, you would know what to have playing through your “Alexa” as you review the guest list.

At the same time, the design of the present study focused on emotional state defined by the dimensions of arousal and valence (Russell, 1980). Central to the majority of previous research supporting emotional memory enhancement is the idea that emotion serves to hone attention on information relevant to a present goal or task. Also, in the present study, arousal and valence were primed via music. In the future, another potential avenue of investigation when it comes to emotional state and memory, could aim to prime emotional state by way of specific arousal and valence inducing behavioral or motivation goals.

One study has already tested something similar, where the effects of hunger were investigated on memory for food related information (Higgs, 2018). In this case, satiety could be considered the “motivation”, where the emotional state was dependent on the need to achieve that “goal”. As a result, during the encoding phase, the body and brain’s response to the hunger-induced emotional state lead to subjects’ selectively attending to food-related information, which in turn led to enhanced memory for related material compared to non-food related material.

Similar to the present study, this mimics the notion of arousal biased competition, however in this case, a state of high arousal was induced in response to an internal cue (hunger) as opposed to an external cue (music). Building upon this study, researchers could compare the effects of emotional state on memory depending on the various motivational cues that trigger an emotion state. For example, comparing memory for information encoded while in a state of arousal induced by the desire to satisfying hunger needs, versus memory for information encoded while in a state of arousal induced by say, the desire to satisfy sexual needs. In this example, it would be interesting to see which of these two fundamental human motivations takes perceptual priority when associated information is presented in competition. Such results could reveal interesting findings regarding how emotional state is modulated by survival instincts and how that can influence how attention and memory are modulated.

Conclusion

By conducting this study, I had aimed to examine the effects of music-induced emotional states on memory ability, which I believe is an area of research that can provide crucial insight, not only in terms of how we perceive information throughout our daily lives, but when trying to understand which pieces of information actually get remembered. Overall, the findings of this study suggest that further research is still needed in order to determine whether or not one's emotional state elicits the same memory-enhancing effects that have been shown for emotional content. Additionally, further research is needed in order to pinpoint which combinations of emotional valence and emotional arousal allow for peak memory enhancement.

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Appendix A:

IRB Proposal Form

Section 1: Contact Information

1. **Name**: Jess Rylander

2. **Email**: jr9398@bard.edu

3. **Academic Program**: SMC - Psychology

4. **Status**: undergraduate student

5. **Advisor**: Thomas Hutcheon

6. **Advisor email**: thutcheo@bard.edu

7. **Individuals involved in this project**: Jess Rylander, student

Section 2: External Funding

Yes; Lifetime Learning Institute Grant - $400

Budget Breakdown:

$1.19 per participant to use gorilla to present and collect data

$2.50 per person in compensation to be distributed by Prolific

$0.80 per person paid to Prolific to recruit participants and administer payment.

Section 3: Title of Project and Dates of Project

Title of your project: The Effects of Music-Induced Emotion on Memory

Start Date: February 1

Section 4: Research Questions

Does your emotional state while encoding information impact your ability to accurately remember the information? And does this depend on the valence or level of arousal of the emotion?

Section 5: Specific population and Recruitment Procedure

I will recruit participants from the United States using an online link through ProlificTM online recruitment tool, which will direct participants to my experiment created using Gorilla Experiment BuilderTM. All participants will be compensated $2.50 for 15 minutes of participation. This is in accordance with the New York State Minimum Wage rate.

Section 6: Vulnerable or protected populations?

No

Section 7: Estimated Number of Participants

~140 participants

Section 8: Procedure

Prior to the start of the task, participants will be asked to read and indicate that they understood the consent form. Next, participants will be asked to complete a demographic questionnaire containing questions regarding their age, gender, race, and where they are from (see Questionnaire document emailed separately). Participants will then be randomly assigned to one of four conditions. Depending on which condition (high arousal - negative valence, high arousal - positive valence, low arousal-positive valence, low arousal - negative valence) they are randomly placed in, participants will be asked to watch a video reel of neutral clips, with music playing throughout who's previously rated valence and arousal matches their respective condition. The types of music will include blues, classical, metal, and pop. The clips that make up the video reel will include excerpts of random scenes for example: a man putting shoes on, a man lighting a cigarette, etc. Following the video, they will be asked to complete a 2 question likert scale affective self-report assessment (valence and arousal ratings) which will be used to gauge their emotional state after watching/listening to the video/music (see **Appendix C**). Next, they will be asked to complete a memory recognition task. The task will use a “target”/”lure” format, where “target” cues will consist of clips the subjects were shown, to which they will answer “yes” or “no” when asked whether or not they have seen the clip before. The “lure” cues will consist of the second half (not seen) of the clips that they did see, to which they will also be asked to respond “yes” or “no”. After completing this, participants will be debriefed about the purpose of the study.

Section 9 : Risks and Benefits for Participants

It is possible that the music could induce a very mild state of emotional discomfort. However, the music subjects will be exposed to is not dissimilar to music they could potentially be exposed to while flipping through normal radio stations. While no direct benefits to the participants are expected, participants may receive indirect benefits from learning about the research process as well as about the background motivating the present work on emotion and memory performance.

Section 10: Plan to Mitigate Risks

A debriefing process will be included at the very end of the experiment in order to inform participants about the reason behind the emotion manipulation, as well as the overall purposes of the study.

Section 11: Consent Process

The Consent form will be provided to participants in the first part of the survey, and their informed consent will be required before they are able to continue on into the study. The form will inform participants about the possible risks of participating in this study. **See Appendix B.**

Section 12: Confidentiality Procedure

No identifying information will be collected for the Prolific portion of the study, so participants' data will remain anonymous. Demographic survey data will also be anonymous. Data will be stored on a password-protected computer.

Section 13: Deception

No

Section 14: Debriefing statement

Please see the attached debriefing statement in **Appendix D.**

Appendix B:

Informed Consent Form

This form will inform you about the possible risks and benefits of participating in this study. Your informed consent will be asked for before continuing to the survey.

Project Title: The Effects of Music-Induced Emotion on Memory

Researcher: Jess Rylander

Faculty Adviser: Thomas Hutcheon

I am a student at Bard College and I am conducting an experiment to study the effects of emotion on memory ability.

If you agree to participate in this experiment, you will watch and listen to a series of videos. The videos will depict scenes of people performing random, everyday tasks. You will then complete a memory recognition task on the various clips you will have just seen. This experiment is designed to last approximately 15 minutes. Your answers will be completely anonymous and confidential. The experiment will take place online once you sign the consent form and press “continue” to the next page.

Potential risks of participation include extremely mild emotional discomfort when listening to potentially unfamiliar music. If at any point while watching the video you begin to feel uncomfortable, please feel free to exit the experiment by closing your browser.

After completion of the experiment, you will receive $2.50 for your time.

All the information you provide will be anonymous and confidential. I will keep all survey data secure in a password-protected file on my personal computer. Only my faculty adviser and I will have access to this information.

Furthermore, it is suggested that you make a copy of this consent form to keep for yourself.

Participant’s Agreement:

I understand the purpose of this research. My participation in this experiment is voluntary. If I wish to exit the study for any reason, I may do so without having to give an explanation.

I understand the relevant, potential risks as they are described above. I am aware the information will be used in a Senior Project that will be publicly accessible online and at the Stevenson Library of Bard College in Annandale, New York.

If I have questions about this study, I can contact the researcher at jr9398@bard.edu or the faculty adviser at thutcheo@bard.edu. If I have questions about my rights as a research participant, I can contact the chair of Bard's Institutional Review Board at irb@bard.edu.
I am at least 18 years of age and I consent to participate in today's study.
___ I consent to the study. [Participants will be asked to "click agree to consent"] By clicking next, I consent to participate in this study:

Appendix C:

Likert Scale Affective Questionnaire

1) Rate your level of emotional arousal (excitedness) on a scale from 1 (very calm) to 7 (very excited).
2) Rate your level of emotional valence (negative vs. positive) on a scale from 1 (very negative) -7 (very positive).

Appendix D:

Debriefing Statement

Thank you for your participation in this experiment. The goal of this study was to determine the effect of various music-induced emotional states on participants' memory ability. In this experiment, you were asked to watch a video reel of random, neutral clips, while music played in the background. This music served the purpose of inducing a particular emotional state. The question about this task at the end of the survey was included for the purpose of ensuring that the emotion induction was effective. You were then asked to answer questions regarding whether or not you recognized certain video clips, some of which you were shown, and some of which you were not. The clips you were not actually shown consisted of the second half of clips you were shown. I was interested in seeing how well you would perform on the memory task, or rather how many clips you would accurately report recognizing, depending on your emotional state while viewing the film. If you have any additional questions about this study, please contact jr9398@bard.edu. If you have any further questions or concerns regarding the consent form/process, please contact my advisor thutcheon@bard.edu or the Bard Institutional Review Board IRB@bard.edu. Your participation is greatly appreciated and could possibly aid people in the future.

Appendix E:

IRB Approval

Bard College Institutional Review Board

Date: March 24, 2022
To: Jessica Rylander
Cc: Tom Hutcheon, Deborah Treadway
From: Brandt Burgess, IRB Coordinator
Re: The Effects of Music-Induced Emotion on Memory

DECISION: APPROVED

Dear Jessica,

The Bard Institutional Review Board (IRB) reviewed the revisions to your proposal entitled, “The Effects of Music-Induced Emotion on Memory.” Your proposal is approved through March 24, 2023. Your proposal number is 2022MAR24-RYL

Please notify the IRB if your methodology changes or unexpected events arise.

We wish you the best of luck with your research.

Brandt Burgess, Ph.D.
IRB Coordinator
bburgess@bard.edu

PO Box 5000, Annandale-on-Hudson, New York 12504-5000

Appendix E:

Preregistration

Project working title: The Effects of Music-Induced Emotion on Memory
Authors: Jessica Rylander
Affiliation: Bard College, Senior Project

1) Has any data been collected for this study already?
No, but will be following pre-reg.

2) What's the main question being asked or hypothesis being tested in this study?

a) Main research questions: Does your emotional state while encoding information impact your ability to accurately remember the information? And if so, does this depend on the particular emotional valence or emotional arousal level?
b) Specifically, participants assigned to the group where they will listen to music expected to induce an emotional state of high arousal-negative valence are expected to perform best on the memory recognition task later on in the experiment.
c) I hypothesize that by inducing stress as well as negative valence, selective attention will be better focused on the presented visual material and will lead to better recall when asked to recognize it later

3) Describe the key dependent variable(s) specifying how they will be measured.
The dependent variable in this experiment is memory performance (accuracy and signal detection) on a "yes"/"no" memory recognition task. Both accuracy and signal detection will be measured for all four arousal-valence conditions. Accuracy will be measured as the proportion of video clips correctly identified as lures and cues. Signal detection (Pr) will be measured as the difference between hit rate and false alarms.

4) How many and which conditions will participants be assigned to?
The experiment will consist of four conditions consisting of combinations of valence and arousal, which will be analyzed using a 2 Valence (positive vs negative) x 2 Arousal (high vs low) repeated measures ANOVA. The four conditions are as follows: high arousal-positive valence, high arousal-negative valence, low arousal-positive valence, and low arousal-negative valence. Each of the four conditions will be respective of the song subjects will listen to in the study phase while viewing emotionally neutral video clips. The songs were chosen based on valence and arousal rating from subjects in a previously conducted study (Soleymani et al, 2020). Participants will be randomly assigned to one of these four conditions. Therefore this experiment will be conducted as a between-subject design.

5) Specify exactly which analyses you will conduct to examine the main question/hypothesis.

A two-way Analysis of Variance (ANOVA) will be used to interpret the accuracy scores as well as the Pr scores. This will compare the mean differences between the two independent variables: valence and arousal, and compare them to the dependent variable, memory performance (accuracy and Pr) across conditions.

6) Describe exactly how outliers will be defined and handled, and your precise rule(s) for excluding observations.

Participants who perform below the baseline, achieving accuracy scores > .5 will be excluded.

7) How many observations will be collected?.

~140 observations will hopefully be collected. All subjects will be solicited using the Prolific online recruiting platform. From Prolific, participants will be directed to the Gorilla experimental program where they will participate in the study. Subjects will be selected strictly from the U.S between the ages of 18 and 30. All subjects will be required to have normal or corrected-to-normal vision and be free from any hearing loss.

8) Anything else you would like to pre-register?

This study will also include an affective self-report questionnaire that will assess subjects' emotional state following their exposure to emotion-inducing musical stimuli. The questionnaire will use two likert scales to measure valence from 1 (very negative) to 7 (very positive) and arousal from 1 (very calm) to 7 (very excited).