The Interaction of Arousal, Musical Context, and Task Difficulty on Recognition

by
Tram Nguyen

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Department of Psychology
University of Western Ontario
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Thesis Advisor: Jessica Grahn, Ph.D.

Abstract

The influence of music on learning has been a growing area of research in psychology. While some researchers have reported that music can impede learning, others have claimed that music can facilitate it. The present study looked at the interaction of musical context, valence, arousal, and task difficulty on recognition. During the study phase, participants were presented with a series of face-name pairings. In the subsequent test phase, they were asked to recognize if the pairings matched the ones they saw during the study phase. Results revealed a significant interaction between arousal, musical context, and task difficulty on recognition performance. On the easy task, recognition performance was better for high arousal music compared to low arousal music when music was played during study only and during test only. On the hard task, performance was better for high arousal music compared to low arousal when music was played during test only, but the effect was reversed when music was played during study only. When music was present during both study and test, arousal did not have an effect on recognition performance on the easy task or the hard task. The results suggest that, in different stages of learning and memory, arousal affects how well information is encoded and retrieved.

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Simply —

Thank you!

The Interaction of Arousal, Musical Context, and Task Difficulty on Recognition

The influence of music on learning has been a growing area of research in psychology. Music is a universal medium and is an important way of life in all cultures. Humans have long believed that music has powerful effects on the mind. Even early literature has suggested that listening to music, especially classical music by Mozart, will increase cognitive performance (Rauscher, Shaw, & Ky, 1993). Today, research regarding music and learning goes far beyond just looking at the *Mozart effect*. In fact, subsequent studies have shown that different features of music can facilitate different aspects of cognition (Cockerton, Moore, & Norman, 1997; Angel, Polzella, & Elvers, 2010). However, other studies have shown that music can interfere with important processes required for learning (Salamé & Baddeley, 1989). Contradicting results have led many researchers to ask the following question: can music have beneficial effects on cognitive function?

Among those who have studied the effects of background music on cognitive performance, Cockerton et al. (1997) and Angel et al. (2010) are two groups of researchers to find that music does facilitate learning. More specifically, it has been shown that background music increases the speed of spatial processing and the accuracy of linguistic processing (Angel et al., 2010). However, other studies have shown that music can disrupt performance if it interferes with important processes of cognitive function. Salamé and Baddeley (1989) found that vocal and instrumental music interferes with short-term memory when compared to a silent control condition. Vocal music was also shown to be more disruptive than instrumental music. The results imply that the complex content of vocal and instrumental music serves as a potential interference that disrupts short-term memory rather than facilitating it. Clearly, evidence for the effects of background music on learning is still very inconsistent in the literature (Mowesisan &

Heyer, 1973; Cash, El-Mallakh, Chamberlain, Bratton, & Li, 1997).

Despite this inconsistency, an area of research that has been a growing interest is looking at the different characteristics of music and how they contribute to learning. In recent decades, researchers have begun to look at both the physiological and psychological effect that music has on the individual. Factors such as arousal, mood, musical experience, and personal preference are merely skimming the surface of music research. The aim of the current study is to explore how different characteristics of music influence behaviour. More specifically, the current study will look at the interaction of *musical context*, which is the presence of music during the time of learning, during the time of testing, or during both learning and testing; *valence*, which is the mood of a piece of music; *arousal*, which is the energy level of a piece of music; and *task difficulty*; which is the difficulty level of the learning task. By testing these variables at different levels, the present study aims to investigate how each of these variables affects performance on a recognition task.

According to the *encoding specificity theory* purposed by Tulving and Thomson (1973), memory is aided by the congruency of environmental cues during learning and testing. The idea behind the theory is that when a piece of information, called a *trace*, is encoded into memory, all contextual cues influenced by that trace are encoded into memory as well. Therefore, when the contextual cues become available during retrieval, the original trace will also be available. Music is one example of a contextual cue that can influence memory. Smith (1985) examined the use of background music for inducing context-dependent memory by exposing participants to different or similar music conditions during learning and testing. The results showed that recall was reduced when the background music during learning was different or absent during testing, compared to when the background music was kept the same. These findings indicate that a facilitation of memory through exposure of background music is a result of contextual cuing, consistent with the *encoding specificity theory*.

Smith (1985) also found that changing the genre of music between learning and testing also reduced verbal recall. However, Smith (1985) never tested whether a perceptually different cue belonging to the same category as the original cue can also be an effective retrieval cue. To address the limitation of Smith's (1985) study, Standing, Bobbitt, Boisvert, Dayholos, and Gagnon (2008) examined whether there was an effect on recall when music was conceptually similar (same genre) but was perceptually different (different song) during testing. The researchers found that recall was reduced when the background music during learning was different during testing, compared with when the background music was kept the same, even though the genre remained the same. The results imply that a perceptually different cue is not as effective a prompt as is repeating the original cue itself. Again, these findings are consistent with the *encoding specificity theory* purposed by Tulving and Thomson (1973).

Along the same line, Balch and Lewis (1996) also looked at context-dependent memory and how it is influenced by changes in tempo (the speed or pace of music) and timbre (the quality of music—for example, people can easily distinguish a violin from a flute because they differ in timbre, even if both instruments are playing notes at the same pitch and loudness). While changes in timbre did not have a significant effect on memory, changes in tempo did. The results showed that recall was better when tempo was kept the same during learning and testing compared to when the tempo was changed. The outcome suggests that tempo is an important contextual cue that plays a significant role on memory. Furthermore, Balch and Lewis (1996) found that musical selections with a faster tempo had a higher arousal rating than musical selections with a slower tempo. The researchers concluded that tempo has an effect on the arousal dimension of mood. It may be that the changes in arousal (created by changes in tempo) disrupted the contextual cues established during learning to interfere with memory, which provides support for the context-dependent memory hypothesis.

Valence or mood is a contextual cue that can also facilitate memory. The *encoding specificity theory* states that memory can be facilitated when the emotional state during learning is similar to the emotional state during testing (Tulving & Thomson, 1973). Maljkovic and Martini (2005) examined the effects of valence on memory to find that different valences are encoded differently. Positive and neutral information are encoded into memory at a steady rate, whereas negative information is encoded at a slower rate to start but gradually increases with time. In line with these findings, Dolcos and McCarthy (2006) found that images that induce negative emotions impair performance on facial recognition compared to images that induce positive or neutral emotions because of a phenomenon known as the *attention-capturing effect*. Dolcos and McCarthy (2006) proposed that the encoding process for a negative stimulus requires a greater attention span than for a positive stimulus. Therefore, if attention is not adequately focused on the negative stimulus memory for that stimulus will decline.

From a musical perspective, Greene, Bahri, and Soto (2010) looked at the effects of valence and arousal on memory processes. Participants were exposed to music that varied in both mood and arousal dimensions: positively valenced-low arousal music, positively valenced-high arousal music, negatively valenced-high arousal music, and negatively valenced-low arousal. The researchers found that valence alone did not enhance memory. Instead, the interaction of valence and arousal was the most critical factor of memory enhancement. In fact, cognitive performance was best shown by the positively valenced-high arousal music and negatively valenced-low arousal music groups, relative to the other two groups.

Along the same line, Hirokawa (2004) looked at the effects of music on arousal and working memory. In this study, four categories of arousal were measured: energy, tiredness, tension, and calmness. Music was found to significantly increase arousal levels (categorized as energy), whereas silence was found to significantly decrease arousal levels (categorized as tiredness). Nevertheless, results did not indicate a statistically significant relationship between arousal levels and memory. While previous studies have shown that arousal does not influence memory, Hockey and Hamilton (1970) challenged these findings with their research on arousal and short- and long-term memory. The researchers found that arousal can have predictable effects on memory. High arousal items were found to be less accessible when recall immediately followed learning, but were more accessible when recall was delayed. Hockey and Hamilton (1970) proposed the idea that the higher state of arousal resulted in a more active encoding of the stimuli so recall was better for those stimuli, but only once the consolidation process has been completed. Therefore, recall for high arousal items is always better upon delay.

Learning and memory have also been thought to be influenced by task difficulty. While task difficulty has been studied extensively in many different contexts, very little has been done in terms of music research. Davies, Lang, and Shackleton (1973) are amongst the very few groups of researchers to look at the effects of music and task difficulty on performance. Participants were asked to detect and respond to changes to the brightness of a light in the presence of either music or white noise. The differences in brightness were much larger in the easy condition than in the hard condition, making the differences in brightness much easier to detect in the easy condition. The researchers found that in the absence of music, detection was better when the task was easy, but in the presence of music, detection was better when the task was hard. Davies et al. (1973) concluded that any minor improvements made on the harder task were seen as significant compared to any minor improvements made on the easier task. Thus, performance in the hard task is improved in the presence of music while performance in the easy task is maintained at the same level throughout the experiment because it would require big improvements to be statistically significant.

Another group of researchers that also looked at the effects of music and task difficulty on performance is Angel et al. (2010). In this study, performance was measured by two different cognitive tasks: spatial processing and linguistic processing. The results showed a significant main effect of task difficulty for both types of processing. In both cases, response speed was increased with task difficulty but response accuracy was decreased. Performance in the easy task improved with the presence of music while performance in the harder task declined. These findings challenge the previously held view established by Davies et al. (1973) that in the presence of music, performance is better when the task is harder. However, interpretation for the causes of the observed effects is limited because of the researchers' chosen methods. Davies et al. (1973) looked at performance as the proportion of correct detections relative to a control condition, whereas Angel et al. (2010) looked at performance as a measure of response time and response accuracy. Nevertheless, evidence for the effects of music and task difficulty on memory is still inconsistent in the literature (Davies et al., 1973; Angel et al., 2010).

To summarize, recent years have seen incredible growth of research in the area of music and learning. Many researchers are starting to question what characteristics of music might influence learning. However, with new research come contradictions to previously held findings and theories. Literature has shown that valence can influence cognitive function both positively and negatively. For example, findings from Dolcos and McCarthy (2006) indicate that images that induce negative emotions impair performance, whereas findings from Gotoh, Kikuchi, and

Olofsson (2010) indicate that images that induce negative emotions can actually facilitate performance. Other variables such as arousal and task difficulty have been shown to have contrasting effects on cognitive performance as well (Hockey and Hamilton, 1970; Hirokawa, 2004; Davies et al., 1973; Angel et al., 2010). However, it is this inconsistency in previous literature that motivates further research to be conducted and clearer answers to be uncovered.

Therefore, the aim of the current research is to look at the interaction of musical context, valence, arousal, and task difficulty on cognitive performance. Previous literature has shown that musical context, valence, arousal, and task difficulty can separately influence learning and memory but has never looked at these variables as an interactive whole. To add to existing literature, the current research will look at the interaction of these variables to see if they have a combined effect on recognition from a musical standpoint. The current research will fill a gap in existing literature and help the progression for future research in music by examining the effects of different characteristics of music on recognition performance.

The present study aims to answer the following research question: how does musical context, valence, arousal, and task difficulty affect memory? To answer the question, each of the four variables will be manipulated and performance will be measured. In the present study, performance will be determined by a face-name pair recognition task. During the study phase, participants will be presented with a series of face-name pairings and in the subsequent test phase, they will be asked to recognize if the pairings matched the ones they saw during the study phase. Meanwhile, musical context will be varied during the study phase and the subsequent test phase. Three different musical contexts will be used: music present during learning, music present during testing, or music present during both learning and testing. The rest of the variables will each have two levels: valence, music that will be negatively valenced or positive valenced; arousal, music with high arousal and music with low arousal; and task difficulty, an easy task (faces will be presented right-side up) or a hard task (faces will be inverted 180 degrees). Therefore, the present study is a 2 x 2 x 2 x 3 experimental design.

Based on previous literature, we predicted that recognition will be significantly better when music is kept the same during learning and testing. The idea is that music is a contextual cue that can influence performance, therefore changing the cue will make recognition less effective because the original retrieval cue is lost. This prediction is consistent with the *encoding specificity theory* purposed by Tulving and Thomson (1973). Furthermore, performance is predicted to be greatest when positively valenced music is paired with high arousal and when negatively valenced music is paired with low arousal. Music with complementary dimensions of valence and arousal should show better recognition because attention demand is minimized, thus maximizing retention (Greene et al., 2010). Finally, we also predicted that recognition will be significantly better when the cognitive task is easy. This prediction is consistent the findings of Angel et al. (2010). Combining all these variables, recognition is predicted to be best when positive-high arousal music and negative-low arousal music is kept the same during learning and testing for a cognitively easy task. Therefore, we hypothesized that there will be an interaction of musical context, valence, arousal, and task difficulty on the learning of face-name pairs.

Methods

Participants

Participants were 32 first year undergraduate students (19 females, 13 males, M_{age} = 18.83 years, *SD* = 2.44) from the University of Western Ontario. They were recruited from the Psychology Research Participation Pool and were compensated one research credit for one hour of participation. Half of the participants were randomly assigned to the easy task condition and the other half were randomly assigned to the hard task condition. This research was approved by the Ethics Review Board at the University of Western Ontario, and all participants provided written informed consent.

Materials and Procedures

Visual stimuli. Participants were presented with two different visual stimuli: one name paired with one black and white image of a face. The images were obtained from the FERET database (Phillips, Moon, Rizvi, & Rauss, 2000) and the names were chosen from freely available lists of names on the Internet. The names and faces were paired with the sole restriction that the name matched the gender of the face. For the easier task the images of the faces were presented right side up and for the harder task the images of the faces were presented upside down. Inversions of the images for the harder task were prepared using the Irfanview (4.28) program (Skiljan, 2010). The faces were always presented on the right side of the computer screen, and the names were always presented on the left side of the computer screen. The pairings were presented at the rate of 3 seconds per pair with an inter-stimulus interval of 0 seconds. Both stimuli were presented on a PC laptop using E-prime (2.0) software (Psychology Software Tools, 2002).

Musical stimuli. Participants were also exposed to different selections of music that were chosen based on previous ratings of valence and arousal (e.g. positively valence music versus negatively valenced music and high arousal music versus low arousal music). The musical extracts were instrumental pieces drawn from a variety of different genres (e.g. blues, classical, electronica, jazz, and rock) and were normalized to control for volume. The presence of the music varied depending on the experimental conditions: music was presented during study, during test, or during both study and test. Participants were provided with Sennheiser HD

280 headphones to minimize external noises. Participants were told that music would be playing in the background as they performed the task but they did not need to pay any attention to the music because they would not be asked to make any decisions about the music.

Study phase and test phase. During the study phase of the experiment, participants were presented with a series of 24 randomly selected face-name pairs. Participants were asked to decide whether the name suited the face it was paired with. All responses were made using the keyboard: participants were instructed to press 1 if the name suited the face and press 0 if the name did not suit the face. The decisions of fit that participants made during the study phase were designed to get participants to deeply think about the items in preparation for a subsequent recognition test, so there was no right or wrong decision. Following the study phase, a red screen appeared for 1 second indicating that the study phase was over and the test phase would begin.

During the recognition test, participants were presented with the same 24 face-name pairs, but some of the pairs were changed. Of the 24 face-name pairings, 16 pairs were kept the same from the study phase to the test phase and 8 pairs were different. Participants were asked to indicate, using the keyboard, if the test phase pairing was the same as the study phase pairing by pressing 1 if it was the same or pressing 0 if it was different. Responses for each trial were automatically recorded.

The experiment consisted of 13 blocks of studying and testing, in which music exposure varied to account for each of the 12 valence, arousal, and musical context conditions and one silent condition. Each participant was exposed to all 13 experimental conditions. Between each block of study and test a white screen with the word “break” in capitalized letters appeared for 5 seconds to indicate that the participant was moving on to a new list of items. The order of the 13 conditions was randomly selected by the E-prime (2.0) software for each participant. Before beginning the actual experiment, participants performed a practice trial that consisted of 12 face-name pairs to ensure comprehension of the task instructions. All participants were fully debriefed following the experiment.

Design

Recognition performance was analyzed with two different approaches: percent correct and corrected hit rate. Any stimuli that did not elicit a response were excluded from the analysis. Each participant's data yielded 26 scores: two (percent correct and corrected hit rate) for each of the 12 valence, arousal, and musical context conditions and also for the silent control condition. Percent correct was calculated as the number of correct responses divided by the total number of responses, multiplied by 100.

Corrected hit rate was also used in order to correct for any response bias that may have been present in the percent correct scores. The corrected hit rate for each condition was calculated by subtracting the number of incorrect responses on correctly matched pairs divided by the total number of responses to matched pairs for that condition (false alarm rate) from the number of correct responses on a mismatched pair divided by the total number of responses to mismatched pairs for that condition (hit rate). To simplify, corrected hit rate was computed by subtracting the proportion of false alarms (number of incorrect response/number of matched pairs responded to) from the proportion of hits (number of correct responses/number of mismatched pairs responded to). Both percent correct and corrected hit rate for each condition were expressed as difference scores, relative to the silent control condition (experimental condition score – silent condition score). The difference scores were analyzed statistically.

Recognition performance was analyzed using two 2 (valence) x 2 (arousal) x 2 (task difficulty) x 3 (musical context) repeated measure analysis of variance (ANOVA), one for percent correct and one for corrected hit rate. Valence, arousal, and musical context were within subjects factors and task difficulty was a between subjects factor. All hypothesis tests used $\alpha = 0.05$ for significance. Data was analyzed using SPSS.

Results

Analysis of recognition performance using percent correct and corrected hit rate showed comparable results; therefore, only the analysis of corrected hit rate is reported. Data from two participants was removed from the analysis. One data set was removed due to response bias, and the other data set was removed due to a large number of missing responses. The results showed no main effect of musical context, $F(2, 56) = 0.12$, $p = 0.89$, at study only ($M = 0.13$, $SE = 0.05$), at test only ($M = 0.12$, $SE = 0.05$), and at both study and test ($M = 0.12$, $SE = 0.05$). There was also no main effect of valence, $F(1, 28) = 0.34$, $p = 0.57$, for positively valenced music ($M = 0.13$, $SE = 0.05$) and negatively valenced music ($M = 0.11$, $SE = 0.05$). High arousal music ($M = 0.13$, $SE = 0.05$) and low arousal music ($M = 0.12$, $SE = 0.05$) also did not differ, so there was no main effect of arousal, $F(1, 28) = 0.23$, $p = 0.64$. Finally, there was also no significant main effect of task difficulty, $F(1, 28) = 1.55$, $p > 0.05$, but it was interesting to note that task difficulty was approaching significance. Recognition performance was better on the harder task ($M = 0.18$, $SE = 0.07$) compared to the easy task ($M = 0.06$, $SE = 0.07$) across all 12 music conditions relative to silence. Music therefore appears to have a greater impact (generally positive) on recognition performance for the hard task condition compared to the easy task condition. However, the lack of significant main effects must be interpreted in light of two significant interactions.

There was a significant two-way interaction between arousal and context on recognition performance, $F(2, 56) = 3.94$, $p = 0.03$, $\eta^2 = 0.12$. In general, performance was better for low arousal music compared to high arousal music when music was played during study only. However, the effect was reversed when music was played during test only. Performance was better for high arousal music compared to low arousal music under the test only context. Also, when music was present during both study and test, recognition performance was slightly better when low arousal music was presented. However, the two-way interaction should be interpreted with caution because of a significant three-way interaction between arousal, musical context, and task difficulty on recognition performance, $F(2, 56) = 4.04$, $p = 0.02$, $\eta^2 = 0.13$. The three-way interaction indicated that the interplay between arousal and context was different for the hard task condition compared to the easy task condition.

At the easy task level, recognition performance was better for high arousal music compared to low arousal music under the study only context (Figure 1). The same trend for performance was also seen when high arousal music compared to low arousal music was played under the test only context. When music was present during both study and test, however, arousal had no effect on performance. At the hard task level, recognition performance was better for high arousal music compared to low arousal music under the test only context, but the effect was reversed under the study only context (Figure 2). When music was played during study only, recognition performance was better for low arousal music compared to high arousal music. Similar to the easy condition, arousal had no effect on recognition performance on the harder task when music was played during both study and test.

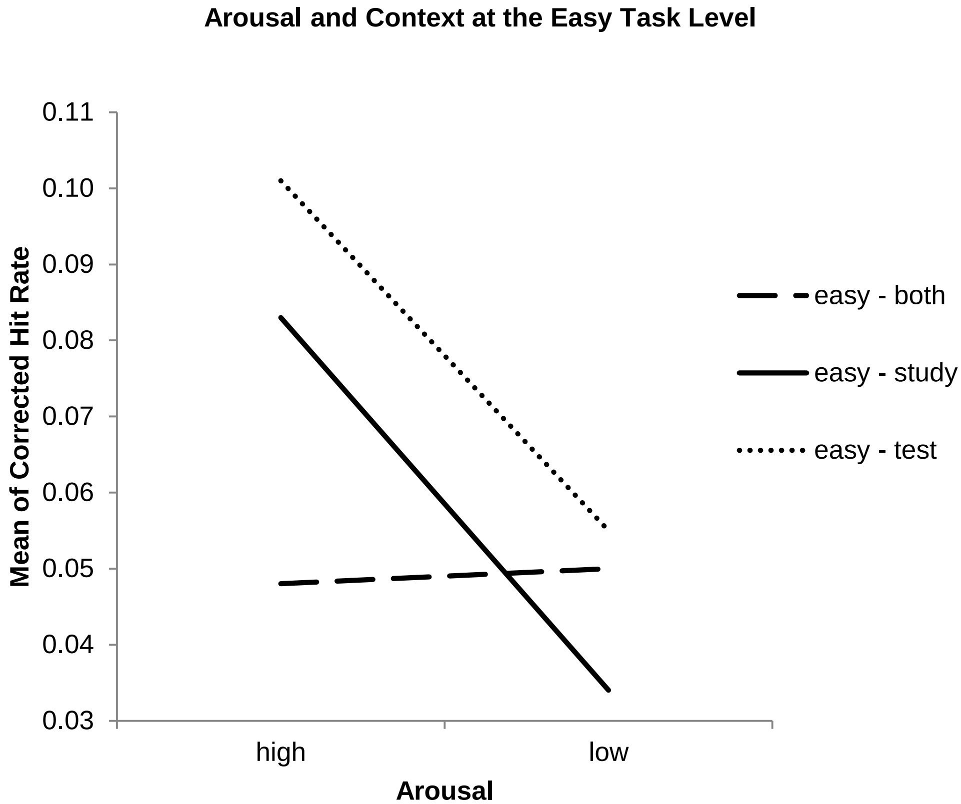

Figure 1. Arousal and Musical Context at the Easy Task Level.

Performance was better for high arousal music compared to low arousal music when it was presented during the study only phase or during the test only phase. When music was presented during study and test, arousal had no effect on performance.

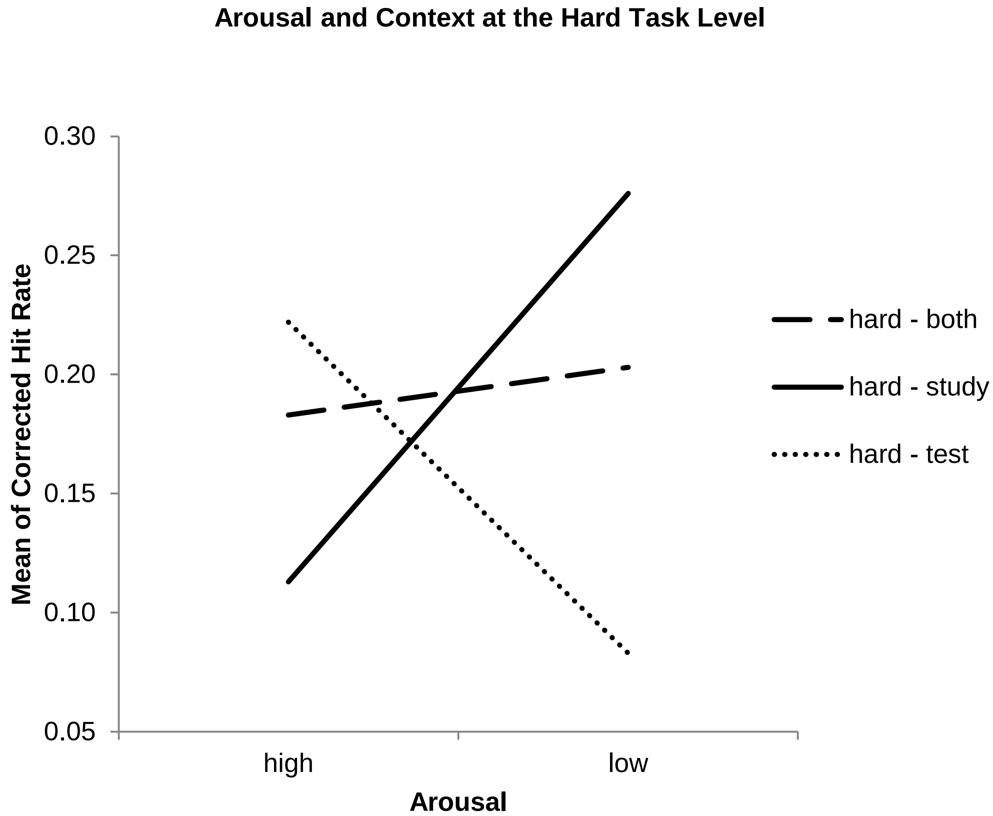

Figure 2. Arousal and Musical Context at the Hard Task Level.

Performance was better for high arousal music compared to low arousal music when presented during the test phase only, but the effect was reversed when music was presented during the study phase only. When music was presented during study and test, arousal had no effect on performance.

To investigate the three-way interaction, six separate paired t-tests (three for the easy task condition and three for the hard task condition) were conducted to explore the simple main effects of arousal at each level of context. In the easy task condition, there was no simple main effect of arousal when music was played during study only, $t(29) = 1.14$, $p = 0.26$. Therefore, recognition performance at high arousal and low arousal was not significantly different when the music was presented during study only. When music was played during test only and during both study and test, there was also no simple main effect of arousal, $t(29) = 0.93$, $p = 0.36$ and $t(29) = -0.03$, $p = 0.98$, respectively. Thus, recognition performance was not significantly different for high arousal music and low arousal music at any level of context on the easy task condition.

In the hard task condition, there was also no simple main effect of arousal when music was present during both study and test, $t(29) = -0.03$, $p = 0.98$. However, there was a simple main effect of arousal when music was played during study only, $t(29) = -3.11$, $p = 0.01$. The results indicated that performance under the study only context was significantly different between high arousal and low arousal. Under the study only context, performance was better for low arousal music compared to high arousal music. Recognition performance was also significantly different between arousal levels when music was played during test only, $t(29) = 2.10$, $p = 0.05$. Under the test only context, performance was better for high arousal music compared to low arousal music. Post-hoc tests showed that the three-way interaction between arousal, musical context, and task difficulty was driven by a significant difference between high arousal and low arousal for the study only context, as well as an opposite (but equally as strong) significant difference between arousal levels for the test only context in the hard task condition.

Discussion

The purpose of the present study was to examine how music affects memory for previously learned items. In particular, the present study examined the interaction of musical context, valence, arousal, and task difficulty on the recognition of face-name pairs. Based on previous literature, we predicted that recognition performance would be significantly better when music was kept consistent during learning and testing. Music is believed to be a contextual cue; therefore, changing such cue would make recognition less effective according the *encoding specificity theory* (Tulving & Thomson, 1973). Furthermore, we predicted that recognition performance would be better when positively valenced music was paired with high arousal and negatively valenced music was paired with low arousal (Greene et al., 2010). Combining all the experimental variables of the study, we hypothesized that there would be a significant interaction between musical context, valence, arousal, and task difficulty on the recognition of face-name pairs. That is, we predicted performance to be greatest when positive-high arousal music and negative-low arousal music was kept the consistent between learning and testing for a cognitively easy task compared to a cognitively hard task.

Contrary to our hypothesis, the results showed a significant three-way interaction between arousal, musical context, and task difficulty. The corrected hit rate was significantly better when participants were exposed to high arousal music during testing and low arousal music during studying on the cognitively harder task. When music was presented during both learning and testing, recognition performance was not significantly better than when music was presented during learning only or testing only. This finding was inconsistent with the *encoding specificity theory* stipulated by Tulving and Thomson (1973). According to the *encoding specificity theory*, any surrounding stimuli that occur during the encoding process will become linked with the learned stimuli. Therefore, presenting any of the surrounding stimuli at some later time will also elicit memory for the learned stimuli. However, the *encoding specificity effect* is not always predictable or can be absent when the learned stimuli are familiar to the participants (Dalton, 1993). In her investigation of context-dependent recognition, Dalton (1993) found that changes in context impaired recognition for unfamiliar stimuli, but not for familiar stimuli. Therefore, stimulus familiarity was believed to be an important factor in modulating context-dependent recognition. Although there is no way of confirming (without future research) if the stimuli presented in the present study were familiar or novel to the participants, Dalton's (1993) findings suggest that the *encoding specificity theory* is not always predictable without considering all the parameters of the theory.

Other studies have also suggested that context effects may not be as readily obtainable as implied by the *encoding specificity theory*. McDaniel, Anderson, Einstein, and O'Halloran (1989) found that the dependence on contextual cues only emerges when the encoding task does not involve imagery or self-referencing. The researchers concluded that imagery and self-referent tasks place less emphasis on the encoding activities of the environmental cues and more emphasize on internalizing the stimuli. In a series of eight experiments, Fernandez and Glenberg (1985) also failed to find any variations in memory performance as a result of changing context. Similarly, no significant effects were found when Saufley, Otaka, and Bavaresco (1985) studied the performances of students who took tests in rooms different from their lecture rooms. Collectively, these studies suggest that changing environmental context does not reliably affect memory performance which is consistent with the findings of the present study.

Studies of valence influencing memory have been greatly inspired by the *encoding specificity theory* (Tulving & Thomson, 1973). Memory can also be facilitated by the congruency of valence during learning and testing. However, previous studies examining the effects of mood on memory have also looked at the *mood-congruent theory*. According to this theory, people are better at remembering materials that are congruent with their own emotional state (Mayer, McCormick, & Strong, 1995). Therefore, happy individuals are better at remembering happy material and melancholic individuals are better at remembering sad material. Given that manipulations of valence for the present study were designed to elicit positive and negative emotions while the face-name stimuli were neutrally valenced, the congruency between the participants' emotional state and the learned items was probably never established. The *mood-congruent theory* would then explain why the present study had no significant main effect of valence and why valence was not a parameter in the significant three-way interaction. Although the *mood-congruent theory* accounts for the present study's findings, we cannot say with certainty that it is the only explanation for our findings.

Previous literature has stated that the interaction of valence and arousal was critical for memory enhancement (Greene et al., 2010). Contrary to previous literature, results from the present study showed that arousal, independent of valence, was an important factor driving the significant three-way interaction. While the results were inconsistent with the findings seen by Greene et al. (2010), they were consistent with the model suggested by Hockey and Hamilton (1970). The researchers found that arousal alone can have predictable effects on memory. Recall performance for high arousal stimuli was worse compared to low arousal stimuli. However, high arousal stimuli were recalled more readily than low arousal stimuli when there was a delay between learning and testing. Hockey and Hamilton (1970) explained that the higher state of arousal resulted in a more active encoding of the stimuli so recall was better for those stimuli, but only once the consolidation process had been completed. Hockey and

Hamilton's (1970) findings suggest an explanation for why recognition performance in our study was better for low arousal music compared to high arousal music during study only on the hard task. Based on Hockey and Hamilton's (1970) model, high arousal music presented during learning would require a longer delay between learning and testing for the stimuli to be properly encoded into memory. This model would explain why recognition performance was significantly better when low arousal music was presented during learning compared to high arousal music. However, the theory does not account for the pattern of performance in the easy task condition.

Memory has also been thought to be influenced by task difficulty. To examine the link between memory and task difficulty, Angel et al. (2010) looked at the effects of music on performance levels of an easy and a hard processing task. The researchers found that performance for the easy task improved with the presence of music while performance for the harder task declined. The findings established by Angel et al. (2010) are inconsistent with the findings from the present study. Although there was no significant main effect of task difficulty in the present study, it is interesting to note that relative to silence, recognition performance improved more on the harder task compared to the easier task across all 12 music conditions. Therefore, results from the present study are consistent with the findings from Davies et al.'s (1973) study. The researchers asked their participants to detect changes to the brightness of a light in the presence of either music or white noise. They found that in the absence of music, detection was better when the task was easy, but in the presence of music, detection was better when the task was hard. Davies et al. (1973) explained that any small improvements made on the hard task were seen as significant. However, to get the same effect on the easy task bigger improvements had to be made because the task was already easy to start. Thus, performance in the hard task is improved in the presence of music while performance in the easy task is maintained at the same level throughout the experiment. These findings are comparable to the findings for task difficulty in the present study.

Results from the present study and other similar studies have provided valuable insight in the formation of memory. In particular, the present study has helped to determine how different types of music, played during different contexts, affect recognition performance of face-name pairs. Research on music and memory are vast, but the findings are contradicting. Some researchers have reported that music can impede memory, while others have reported that music can facilitate it (Cockerton et al., 1997; Angel et al. 2010). With further research and stronger manipulations, we will soon be able to determine the effect of music on memory. Although the present study does bring us one step closer to a clearer answer, it does not fully resolve the contradictions found in a lot of the literature. In order for future research to be conducted, we will address the limitations of the present study.

One limitation was that the experiment was conducted on a small sample size of undergraduate students, the majority of which were females. Although previous literature did not mention the effect of gender on memory, having an uneven sample of males and females could have skewed the results of the data. Furthermore, having a small data set for comparison could have affected the outcome of the experiment, if major patterns failed to emerge. The experiment was also conducted solely on undergraduate students and this sample may have had a better working memory than the average person, as they practice at storing and retrieving information. In future research, increasing the sample size and broadening it outside of a specific population would likely yield more generalizable conclusions about the experiment.

Another limitation is the strength of the manipulations. Due to time constraints, participants were exposed to different selections of music that were previously rated for different levels of valence and arousal. An important limitation of previous studies on mood and memory is the attempt to distinguish between valence and arousal states in the manipulation. Therefore, it remains unclear which variable, valence or arousal, has the most significant effect on memory. Future research should consider replicating the procedure developed by Greene et al. (2010) to increase the strength of their manipulation for valence and arousal states. In the study conducted by Greene et al. (2010), participants listened to short musical extracts and gave each extract a rating of valence and arousal. The selection process continued until the participant had assigned at least one piece of music to represent the four dimensions of valence and arousal that the researchers wanted to assess. This procedure ensured that each participant was exposed to music with the appropriate manipulations. Future research would also benefit from using experimental conditions that controlled for variables such as tempo and timbre because context-dependent memory can be influenced by changes in tempo (Balch & Lewis, 1996).

The final limitation of the present study was the manipulation of task difficulty as a between-subjects variable rather than as a within-subjects variable. Participants were either tested on the easy task or the hard task due to time constraint. One advantage of having task difficulty as a between-subjects variable is the exclusion of practice effects and carry-over effects. Practice effects are sensitive in research regarding memory, especially if the learned stimuli are repeated from conditions to conditions. However, within-subjects variables are more statistically powerful given a smaller sample size. To improve on task difficulty as a between-subjects variable, future research would benefit from matching subjects with each other for the different groups. Matching will control for some of the variability such as age and gender that are found between subjects. Another approach to improving the task difficulty manipulation would be to increase the sample size in each condition. A larger sample size would yield more statistically powerful results.

Future research will benefit from following up on the results of the present study. To be more specific, future works should place emphasis on the interaction of arousal and memory. Perhaps the higher state of arousal is only beneficial during testing, but low arousal music is required to optimize learning. According to Hockey and Hamilton (1970), more active encoding occurs during high arousal but the consolidation process is slower. Therefore, low arousal music is more beneficial during study when testing immediately follows. Future research may want to test the effects of arousal on a more delayed recall to determine if arousal affects memory differently. The present study found that the effects of arousal and context to be disproportionately influential in the hard task. Future research may want to be critical on choosing a method to analyze variables such as task difficulty. Davies et al. (1973) chose to examine performance as the proportion of correct detections relative to a control condition, whereas Angel et al. (2010) chose to examine performance as a measure of response time and response accuracy. These two groups of researchers found opposing effects for task difficulty, based on the methods that they used. Analysis of recognition performance for the present study employed the same method that was used by Davies et al. (1973) and found the results to be consistent with their results. Future works may want to consider the methods used by Angel et al. (2010) to see if the same pattern of results holds across different methods.

The present study demonstrated that the presence of music had more beneficial effects on performance when the recognition task was harder. That is, music appeared to have a greater positive impact on recognition performance in the hard condition than the easy condition. A significant three-way interaction also showed that when the task was cognitively harder, listening to low arousal music during learning improved recognition performance. However, when music was present during testing, recognition performance improved with high arousal music rather than low arousal music. Finally, the present study demonstrated that arousal did not affect performance when music was played during learning and testing on both the easy and hard task. The practical implications of our findings suggest that in different stages of learning and memory (studying and testing) arousal levels can affect how well information is encoded and recalled. Therefore, future research will be required to validate the findings of the present study under different circumstances.

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