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Musical Mood and Musical Arousal Affects Different Stages of Learning and Memory Performance

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A thesis submitted in partial fulfillment of the requirements for the degree in Master of Science

MUSICAL MOOD AND MUSICAL AROUSAL AFFECT DIFFERENT STAGES OF LEARNING AND MEMORY PERFORMANCE

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by

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Abstract

This thesis examined whether the effect of music on memory is attributable to musical mood, musical arousal, context, or some combination of these factors. In Experiment 1, participants performed a face-name paired-association task while music was played in the background. In Experiment 2, the perceptual context (Experiment 2A) and emotional context (Experiment 2B) of music was examined more thoroughly. Experiment 3 examined whether the context effect of musical mood and musical arousal occurs in a recall task (Experiment 3A), a recognition task (Experiment 3B), and an association task (Experiment 3C). The results showed that low arousal music enhanced memory while high arousal music lowered memory, particularly when arousal was paired with negative mood. This effect was most robust when the context at study and at test was similar. The results suggested that musical mood and musical arousal affect different stages of learning and memory performance.

Keywords: arousal, association memory, context, learning, recall memory, recognition memory, mood, music, the arousal and mood hypothesis, the encoding-retrieval specificity hypothesis

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Chapter 1

General Introduction

Music is a universal and important way of life in all cultures around the world. Many have long believed that it has powerful effects on the mind. One area that has received much interest is the effect of music on learning and memory. Although many studies support the notion that listening to music can aid learning and facilitate memory (Greene, Bahri, & Soto, 2010; Halpern & Müllensiefen, 2008; Wallace, 1994), the mechanisms underlying the benefits of music on memory remain unknown. One possibility is that music modulates the listener's internal mood and arousal levels, which may then facilitate memory performance **(**Thompson, Schellenberg, & Husain, 2001**)**. For example, negative moods can worsen memory, whereas positive moods can improve memory (Rowe, Hirsh, & Anderson, 2007). Furthermore, extremely high and low levels of arousal can inhibit memory, whereas moderate levels can enhance memory (Berlyne, 1971). A second possibility is that music establishes a 'context' that, when reinstated, provides a memory cue (Smith, 1985). Thus, hearing a piece of music may prompt the recall of associated memories, as the contextual cue is reinstated. The lack of definitive evidence distinguishing these two possibilities is the motivation for this thesis. In particular, this thesis examines whether the effect of music on memory is attributable to musical mood, musical arousal, context, or some combination of these factors.

Mood and Memory

A mood is a short-term psychological state that can be triggered by a stimulus or event (Thayer, 1989). A positive mood elicits a euphoric emotion such as happiness, whereas a negative mood elicits a sombre emotion such as sadness (Ekman, 1994). In this thesis, mood is an affective dimension that extends from positive to negative. Therefore, a musical mood is the intended emotional state (either positive or negative) that is induced by a musical piece.

In general, the effect of mood on memory varies. Some studies show that participants in a positive mood have better recall compared to those in a negative or neutral mood (Nasby & Yando, 1982), and this suggests that positive mood facilitates memory. The facilitation of memory by positive mood may result from a broadening of attention, such that task-relevant information becomes more accessible and encoding and retrieval processes are consequently enhanced (Rowe et al., 2007). However, other studies demonstrate that positive mood reduces memory storage capacity because it also activates more task-irrelevant information; this in turn decreases the storage capacity for task-relevant information (Martin & Kerns, 2011). Furthermore, positive mood can have differential effects for different types of stimuli. For example, positive mood seems to improve memory for words, but has the opposite effect for faces (Gray, Braver, & Raichle, 2002). Other studies suggest that negative mood leads to better memory performance than positive mood (Basso, Schefft, Ris, & Dember, 1996; Biss, Hasher, & Thomas, 2010; Bless et al., 1996). Negative mood may lead to more detailed processing of the to-be-remembered items, which in turn leads to more detailed representations, and thus facilitates memory (Gasper & Clore, 2002). Overall, it is evident that mood affects memory, but the exact direction of the effect varies in the literature.

Mood is often induced using stimuli such as images, words, and videos, but it can also be induced by music (Blood & Zatorre, 2001; Blood, Zatorre, Bermudez, & Evans, 1999; Mitterschiffthaler, Fu, Dalton, Andrew, & Williams, 2007). Music is identified, amongst hundreds of strategies, as an effective method of inducing and regulating mood (Parkinson, Totterdell, Briner, & Reynolds, 1996; Parrott, 1993; Thayer, Newman, & McClain, 1994). In one exploratory study, participants listened to three types of music: (1) happy, (2) fearful, and (3) sad while self-reported ratings and psychophysiological responses were measured (Krumhansl, 1997). Compared to the no-music baseline, the three types of music had different effects on self-reported ratings of mood and measures of cardiac, vascular, and respiratory function. It seems that mood induced by music is faster, stronger, more pervasive, and lasts longer than mood induced by other stimuli (Krumhansl, 1997). If so, then the effect of musically induced mood should produce less variability on memory compared to the previously mentioned studies where mood was not musically induced.

Indeed, the effect of musical mood on memory is consistent in the literature. Music that evokes strong positive feelings activates general and specific details about the to-be-remembered items (Aubé, Peretz, & Armony, 2013; Janata, Tomic, & Rakowski, 2007; Jäncke, 2008). Likewise, positive music often elicits a strong feeling of knowing during memory retrieval (Peynircioğlu, Tekcan, Wagner, Baxter, & Shaffer, 1998). The memory enhancing effect of positive music not only influences the recollection of past memories, but also influences the recollection of the music itself (Cuddy & Duffin, 2005). For instance, positive music is remembered better than negative or neutral music (Batcho, 2007). Even when the emotional quality of the music is not actively attended to, mood is automatically induced and can improve memory (Eschrich, Münte, & Altenmüller, 2008). It is suggested that positive music enhances the richness of memory retrieval by eliciting memories associated with the positive mood (Armony, 2013). In this thesis, music is used to induce mood. Positive music should enhance memory performance because its effect is well-established in the literature. Alternatively, negative music could enhance memory, as negative mood can lead to more detailed processing of the to-be-remembered item, thus facilitating memory performance (Gasper & Clore, 2002). The aim of this thesis is to help establish how musical mood may affect memory performance.

Arousal and Memory

Like mood, another important aspect of emotion is arousal (James & Lange, 1922). Arousal is a physiological and psychological state of being reactive to a stimulus or event (Thayer, 1989). Therefore, descriptions of arousal states often use adjectives such as distressed or anxious (high arousal) and relaxed or calm (low arousal) (Sloboda & Juslin, 2001). Like mood, arousal can elicit emotions. The James-Lange theory posits that emotions are triggered by a physiological change that comes from an arousing experience (James & Lange, 1922). For simplicity, arousal is described in this thesis as an affective dimension that extends from high to low. Thus, musical arousal is the intended energy (either high or low) that can be triggered by a musical piece.

In general, arousal is important in regulating many cognitive processes (Cahill & McGaugh, 1998). When a stimulus or an event is perceived as important, arousal is increased to help the body prepare for action (Yoon, May, & Hasher, 1999). According the Yerkes-Dodson law, there is an inverted-U relationship between arousal and task performance (Yerkes & Dodson, 1908). Specifically, too little or too much arousal can have adverse effects on performance. The initial upward slope of the curve is associated with the energizing effect of arousal while the later downward slope is associated with the stressful effect of arousal. Moderate levels of arousal, on the other hand, can lead to better memory encoding, which can improve the retention and retrieval of learned items (Diamond, Campbell, Park, Halonen, & Zoladz, 2007; Dutton & Carroll, 2001; Ochsner, 2000). Increasing arousal also increases attention, providing another mechanism to improve memory (Eysenck, 1976). For example, participants are better at recognizing arousing information compared to neutral information, which can be associated with the selective attention processes during encoding (Nielson, Yee, & Erickson, 2005). In one cleverly designed experiment, participants fixated on a neutral word in the center of the screen, while arousing and other neutral words were quickly presented in the periphery (Sharot & Phelps, 2004). Arousing words were better retrieved than neutral words, supporting the idea that the arousing information is selectively attended to. Moreover, arousing information is remembered more vividly and accurately (Jeong & Biocca, 2012). However, when arousal is too high or too low, attention is easily diverted (Dutton & Carroll, 2001). Arousal, like mood, affects memory performance.

Previous literature shows that significant changes in physiological arousal can be elicited by arousing music (Schmidt & Trainor, 2001). Participants show increased skin conductance when exposed to arousing music compared to relaxing music (Rickard, 2004). There is also a positive correlation between ratings of arousal and physiological measures of cardiac, musculoskeletal, and respiratory function when participants listen to arousing music (Salimpoor, Benovoy, Longo, Cooperstock, & Zatorre, 2009). However, participants prefer music that elicits a moderate level of arousal (Berlyne, 1971). Similar to the Yerkes-Dodson law, the relationship between the listeners' arousal level and preference is also represented as an inverted-U curve. If the arousal level of the music is too high or too low, listening preference declines. Previous work demonstrates that music can increase arousal and moderate arousal can affect memory (Diamond et al., 2007; Rickard, 2004; Salimpoor et al., 2009); therefore, it is possible that music can affect memory through changes in arousal.

Studies examining the effect of musical arousal on learning and memory are limited in the literature, but the effect is consistent. Participants learn and recall more items after they are exposed to arousing music compared to silence (Morton, Kershner, & Siegel, 1990). Music enhances memory performance by increasing arousal, which in turns increases attention (McConnell & Shore, 2011). Arousal is important for attention because it reduces the distractibility of task-irrelevant information (Eysenck, 1976; LaBar & Phelps, 1998; Sharot & Phelps, 2004). Using music to increase arousal, the experiments in this thesis will help determine how musical arousal affects memory performance. One possibility is that musical arousal increases attention, thereby improving memory performance (McConnell & Shore, 2011). Alternatively, it is possible that arousing music might distract participants during the memory task, thus negatively affecting memory performance (Dutton & Carroll, 2001).

The Arousal and Mood Hypothesis

The effect of music on cognition is likely mediated by changes in the listener's mood and arousal states (Husain, Thompson, & Schellenberg, 2002). Music that is happy and fast in tempo is likely to enhance mood and increase arousal, and thus improves memory performance. In comparison, music that is sad and slow in tempo is likely to dampen mood and decrease arousal, and thus inhibits memory performance. The positive changes in mood and arousal induced by the music seem to have a beneficial effect on cognition (Schellenberg, Nakata, & Hunter, 2007). For example, music improves short-term memory performance in elderly individuals by modulating their mood and arousal states (Mammarella, Fairfield, & Comoldi, 2007). The arousal and mood effect is also shown in children (Hallam, Price, & Katsarou, 2002). Memory performance is enhanced when the background music is perceived by children as pleasant, calming, and relaxing. In contrast, poorer performance is observed when the background music is unpleasant, arousing, and aggressive. Pleasant and calming background music improves memory performance, whereas unpleasant and arousing background music reduces memory performance. Thus, music enhances memory through the modulations of mood and arousal.

The effect of music on memory is most robust when both dimensions of mood and arousal are manipulated (Greene et al., 2010). When the manipulation is weak or when the manipulation is only effective for one of the two dimensions, no significant differences in memory are reported (Husain et al., 2002). However, when both mood and arousal are effectively manipulated by music, memory performance is significantly affected (Schellenberg et al., 2007). The interactive effect of mood and arousal seems to be critical for improved memory performance. For example, when musically induced mood and arousal are independently manipulated recognition performance is not affected, but together their effects are significant (Greene et al, 2010). Recognition performance is enhanced when participants listen to high arousal positive and low arousal negative music compared to when participants listen to high arousal negative and low arousal positive music (Figure 1). The interaction of mood and arousal suggests that particular combinations of mood and arousal, particularly high arousal positive and low arousal

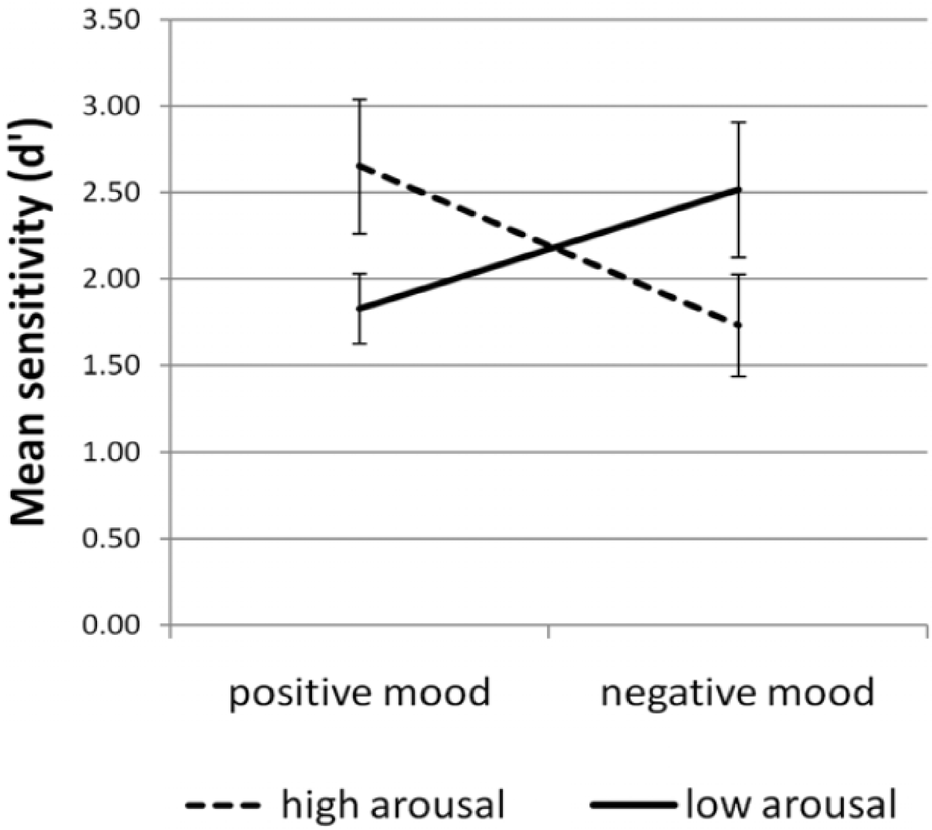

Figure 1. Mean sensitivity (d’) to old/new differences in the four mood and arousal conditions (adapted from Greene et al., 2010). Recognition performance for abstract shapes was enhanced when participants listened to high arousal positive and low arousal negative music compared to when participants listened to high arousal negative and low arousal positive music.

negative music, are critical for enhanced memory performance.

Previous research examining the effect of emotions on memory often neglects to differentiate mood from arousal and vice versa, frequently combining them into a single measure of emotion (Liu, Graham, & Zorawski, 2008; Anderson, Wais, & Gabrieli, 2006; Judde & Rickard, 2010). In this thesis, mood and arousal are independently manipulated, but their combined effects are examined. Therefore, mood and arousal are combined to create four music conditions: (1) high arousal positive (HAP) music, (2) high arousal negative (HAN) music, (3) low arousal positive (LAP) music, and (4) low arousal negative (LAN) music. To ensure that the music does elicit the expected mood and arousal states, the mood and arousal levels of short musical excerpts are rated in a pilot experiment presented in this thesis.

The Encoding-Retrieval Specificity Hypothesis

Musical mood and musical arousal can enhance memory (Greene et al., 2010), but another way that music can enhance memory is by establishing a ‘context’ that, when reinstated, provides a memory cue (Standing, Bobbitt, Boisvert, Dayholos, & Gagnon, 2008). One way that music can serve as a context is by having a specific musical piece played at encoding and at retrieval (Smith, 1985). When background music during encoding and retrieval is kept the same, memory recall is improved. Even when the background music is conceptually similar (same genre) but is perceptually different (different song), memory recall is significantly reduced (Standing et al., 2008). Therefore, a perceptually different cue is not as effective as repeating the original cue because retrieval cues are more effective when they trigger the same contexts that were experienced during encoding. The memory enhancement of a contextual cue is consistent with the encoding-retrieval specificity hypothesis (Tulving & Thomson, 1971). The encoding-retrieval specificity hypothesis posits that memory is facilitated when the retrieval contexts are consistent with the encoding contexts (Tulving & Thomson, 1973).

The encoding-retrieval specificity hypothesis also applies to mood and arousal states (Bower, 1981; Bower, Monterio, & Gilligan, 1978; Clark, Milberg, & Ross, 1983). Therefore, another way that music can serve as a context is by having the same mood and arousal states at encoding and at retrieval. For instance, participants' memory is significantly better when the musical mood is congruent (happy-happy or sad-sad) rather than incongruent (happy-sad or sad-happy) between study and test (Mead & Ball, 2007). Similarly, memory performance is enhanced when the musical arousal at encoding and retrieval is congruent (Balch & Lewis, 1996). Participants recall more items when the arousal level is the same (high-high and low-low) compared to when the arousal level is different (high-low and low-high) between study and test. An associative network theory is proposed to account for the encoding-retrieval specificity effect of mood and arousal. According to the theory, an emotion serves as a contextual cue that enters into association with the learned information (Bower, 1981). Therefore, reinstating a specific emotional state would activate the contextual cue that can aid retrieval of the information associated with the cue.

A good way to study the effect of context on memory is to use an association memory task (Dalton, 1993). Association memory is the ability to learn and remember the relationship linking two pieces of information (Kohonen, 1984). Learning and recalling the name of a person is an example of an association memory. When only the name of the person or the face of the person is available, the missing piece of information should be reliably recalled through association. In a series of experiments that used a paired-association task involving faces, changing the context of the faces slightly between study and test was detrimental for the recognition of the learned faces (Watkins, Ho, & Tulving, 1976). When two faces are learned together but are not presented together during retrieval, recognition memory for the faces is reduced (Bower & Karlin, 1974). Changing context between study and test, either by removing the context or by substituting the context, hinders memory performance (Winograd & Rivers-Bulkeley, 1977). In this thesis, a paired-association paradigm using faces and names is used to measure recognition memory. The paradigm is used to study the effect of context on memory with high ecological validity.

Overview of Thesis

The experiments in this thesis examine whether the effect of music on memory is attributable to musical mood, musical arousal, context, or some combination of these factors. Specifically, musical mood, musical arousal, and context are manipulated and their effects on memory performance on a face-name paired-association task are assessed. Four music conditions are created by combining mood and arousal: (1) HAP music, (2) HAN music, (3) LAP music, and (4) LAN music. In Experiment 1, there are three different contexts: (1) music played during studying only, (2) music played during testing only, and (3) music played during both studying and testing. Based on previous literature, the predictions for this thesis are as follows:

(1) Memory performance for the HAP and the LAN music conditions should be better than memory performance for the HAN and LAP music conditions. Previous work demonstrates that HAP and LAN music elicited better memory

performance than HAN and LAP music (Greene et al., 2010). Therefore, the interactive effect of mood and arousal should be significant, as together mood and arousal seems to be critical for improved memory performance (Greene et al., 2010).

(2) Music should establish a context that when reinstated, aids memory performance. Therefore, when the same music is played at both study and test, it should serve as a contextual cue that can enhance memory performance (Smith, 1985).

Since music is subjective, the manipulation of mood and arousal might not necessarily be the same across all participants. Experiment 1 also examines the effect of musical selection on memory. Participants are tested with music that is 'experimenter-selected' and with music that is 'participant-selected'. Experimenter-selected music is chosen based on ratings from participants in a pilot experiment (Experiment 1A). Participant-selected music is chosen based on ratings that the participants completed prior to the memory task (Experiment 1B).

(3) Tailoring the music to each participant should increase the strength of the mood and arousal manipulation, as well as reduce variability in the data (Greene et al, 2010).

In Experiment 2, the effect of context is examined more thoroughly. Two types of musical contexts are examined. Experiment 2A examines the perceptual context of reinstating a specific musical piece at test while Experiment 2B examines the emotional context of reinstating the same mood and arousal state at test.

(4) There are potentially two ways that context can enhance memory: (1) through

the perceptual context of a specific musical piece and (2) through the emotional context of musical mood and musical arousal. Thus, hearing the same piece of music at study and test should improve memory performance (Smith, 1985). Similarly, reinstating the same emotional state (mood and arousal) should also enhance memory performance (Balch & Lewis, 1996; Balch, Myers, & Papotto, 1999; Mead & Ball, 2007).

Finally, to assess whether the effect of musical mood, musical arousal, and context occur in other memory types, the contextual effect of musical mood and musical arousal is examined in a recall (Experiment 3A), a recognition (Experiment 3B), and an association memory task (Experiment 3C).

(5) The effect of musical mood, musical arousal, and context should apply to all three memory tasks (recall, recognition, and association). Memory performance should be significantly better when participants listen to HAP and LAN music compared to HAN and LAP music (Greene et al., 2010). Furthermore, music will serve as a context that when reinstated, enhances memory (Smith, 1985).

Overall, the aim of this thesis is to examine whether the effect of music on memory is attributed to musical mood, musical arousal, context, or some combination of these factors.

Chapter 2

Experiment 1

As mentioned in Chapter 1, listening to music can facilitate memory performance (Greene et al., 2010; Halpern & Müllensiefen, 2007; Wallace, 1994). However, the cognitive mechanisms underlying the benefits of music on memory remain unknown. One possibility is that music elicits changes in the listener's internal mood and arousal levels, which in turn enhances memory, as both factors have been demonstrated to facilitate memory performance (Chanda & Levitin, 2013). For example, previous work demonstrated that HAP and LAN music elicited better memory performance than HAN and LAP music (Greene et al., 2010). Another possibility is that music establishes a context that, when reinstated, provides a cue that can also enhance memory performance (Smith, 1985). Thus, hearing the same piece of music at study and at test may prompt the recall of associated memories, as the contextual cue is reinstated. The lack of definitive evidence distinguishing these two possibilities has motivated the investigation of Experiment 1. Experiment 1 examined whether the effect of music on memory is attributable to musical mood, musical arousal, context, or some combination thereof. However, the perception of musical mood and musical arousal might vary across participants. Therefore, the effect of musical selection was also compared. Experiment 1A used 'experimenter-selected' music chosen based on ratings from other participants in a pilot experiment and Experimenter 1B used 'participant-selected' music chosen based on ratings that each individual participant made prior to the memory task. Otherwise, the two experiments were identical.

Pilot Experiment

A pilot experiment was conducted to ensure that the music used in this thesis elicited the expected levels of mood and arousal. Participants rated the mood and arousal levels of various musical excerpts. The excerpts that were rated, on average, as most representative of the four musical conditions (HAP, HAN, LAP, and LAN) were used in the experiments presented in this thesis, except for Experiment 1B.

Method

Participants

Participants were 15 students (10 females and 5 males) from the University of Western Ontario (M_{age} = 22.20 years, *SD* = 3.51 years). They were recruited by the experimenter and were compensated $10.00 for one hour of participation. There were no exclusion criteria for the pilot experiment. The experiment was approved by the Psychology Ethics Review Board at the University of Western Ontario.

Materials

Musical stimuli. A total of 150 musical excerpts were used. The excerpts were 90-second instrumental clips drawn from a variety of different genres (e.g., blues, classical, jazz, metal, and rock). All musical excerpts were cut so only the first ten seconds of the clip were used. The excerpts were also normalized to control for volume using Audacity (http://audacity.sourceforge.net).

Visual stimuli. Two separate scales were used to obtain mood and arousal ratings for each of the musical excerpts. The mood scale ranged from -3 (very negative) to +3 (very positive), with 0 considered as neutral mood. The arousal scale also ranged from -3 (very low arousal) to +3 (very high arousal), with 0 considered as moderate arousal.

Procedure

Participants were seated in front of the laptop. The musical excerpts were presented one at a time through the headphones at a comfortable listening volume. Participants were instructed to rate the musical excerpts according to what they thought the music expressed or conveyed and not what they personally felt when listening to the music. As a reference, participants were told that mood referred to the emotional tone of the music while arousal referred to the energy level of the music. For example, a positive piece would bring to mind the word "happy" and a negative piece would bring to mind the word "sad". Correspondingly, a low arousal piece was something that was considered "calming" while a high arousal piece was something that was considered "distressing". To ensure that ratings of mood did not confound with ratings of arousal and vice versa, the rating order was counterbalanced across all participants. Therefore, participants listened to each of the musical excerpts twice, each time for ten seconds before making their ratings for either mood or arousal. A screen prompted the participants to make their response. The numbers -3 to +3 were arranged horizontally (left to right) on the laptop screen and participants responded using the number keys on the keyboard. Participants were given a ten minute break between ratings of mood and arousal. All participants provided written informed consent and were fully debriefed after the experiment.

Results

Ratings of mood and arousal for each excerpt were averaged across all participants. A cut-off criterion of ± 2.00 on the mood and arousal scales was used to select the excerpts for each of the four music conditions (e.g., the HAP excerpts scored higher than 2.00 on both the mood and arousal scales, while the LAN excerpts scored lower than 2.00 on both the mood and arousal scales). If the criterion was too stringent to satisfy the number of stimuli for a condition, it was lowered or raised by 0.25 points until the 12 highest rated excerpts for each of the four conditions (three per condition) were selected. Using the least stringent criterion of ± 0.25 on both the mood and arousal scales, 117 of the 150 musical excerpts were categorized as such: 47 excerpts were categorized as HAP, 23 excerpts were categorized as HAN, 14 excerpts were categorized as LAP, and 33 excerpts were categorized as LAN (Figure 2). The three excerpts that participants rated as most representative for each of the four music conditions were used in Experiments 1A and 3 (Table 1 in Appendix A). The 12 top rated excerpts (three per condition) were used in Experiment 2A (Table 2 in Appendix A), and the 20 top rated excerpts (five per condition) were used in Experiment 2B (Table 3 in Appendix A).

Discussion

The pilot experiment resulted in a selection of music that could be used in the subsequent experiments to elicit the required mood and arousal states.

Experiment 1A

Experiment 1A investigated how musical mood, musical arousal, context, or some combination of those factors might influence learning and memory. Participants performed a paired-association task that required learning and recognizing face-name pairs. The task consisted of multiple blocks of studying and testing. After studying 24 face-name pairs in the study phase, participants immediately completed the test phase, in which they determined whether the face-name pairings in the test phase matched the study phase. While participants performed the memory task, silence or one of four music conditions was present in the background. The four music conditions were created by

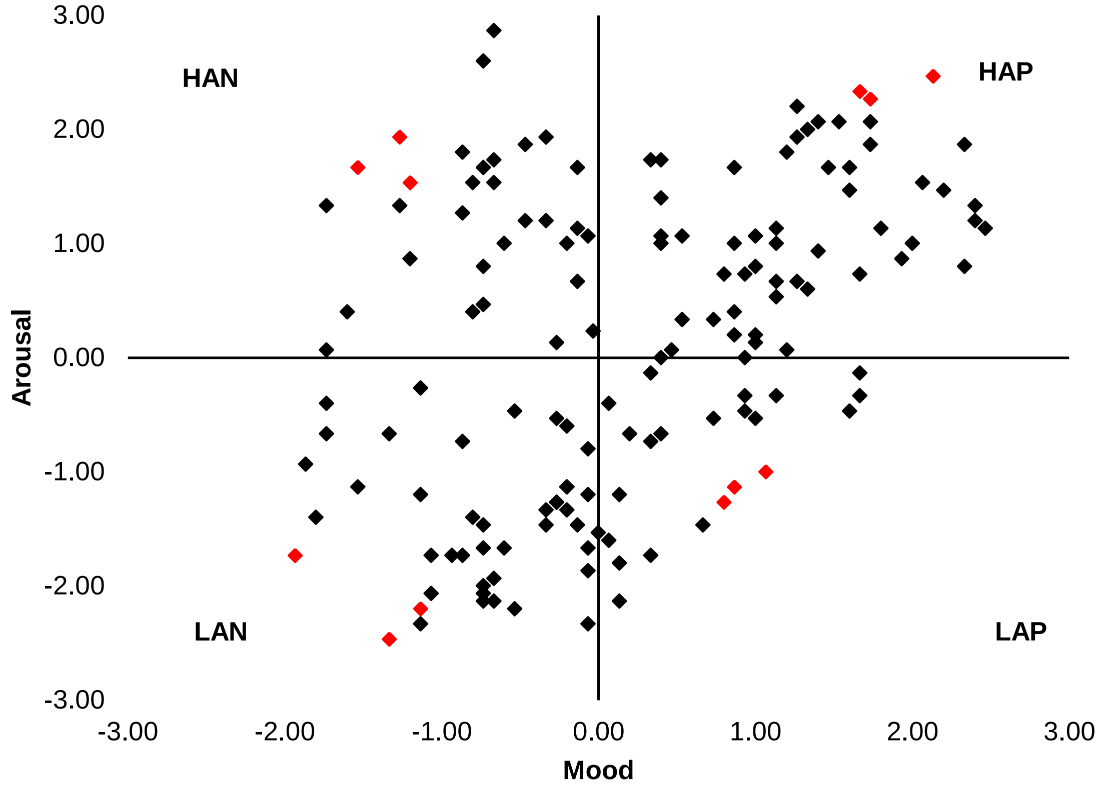

Figure 2. Mean ratings of mood and arousal for the 150 musical excerpts used in the pilot experiment. The red data points represent the 12 top rated musical excerpts (three per conditions) used in Experiments 1A and 3.

combining the two levels of mood and arousal: (1) HAP music, (2) HAN music, (3) LAP music, and (4) LAN music. The music was selected based on the ratings of mood and arousal described in the pilot experiment. To study the contextual effect of music concurrently with mood and arousal effects, the presence of music at the study and test phases was used to manipulate context: (1) music played at study only, (2) music played at test only, and (3) music played at both study and test. When music was played at both study and test, the context at encoding matched the context at retrieval. However, when music was played during study only or during test only, the context at encoding was different from the context at retrieval. The aim of Experiment 1A was to determine which variable (musical mood, musical arousal, or context) might influence memory.

Recognition performance with HAP and LAN music should be better than recognition performance with HAN and LAP music. Previous literature have demonstrated that HAP and LAN music elicited better memory performance on a recognition task than HAN and LAP music (Greene et al., 2010). In addition, music may serve as a contextual cue that can also influence memory (Smith, 1985). Therefore, when the same music is played at both study and test, it should serve as a contextual cue that can enhance memory performance compared to when music is played at study only (music-silence) or test only (silence-music). Altogether, HAP and LAN music should elicit better recognition performance than HAN and LAP music, especially when the music is played at both study and test.

Method

Participants

Thirty undergraduate students (19 females and 11 males) from the University of

Western Ontario (M_{age} = 20.33 years, *SD* = 2.99 years) participated in the experiment. They were recruited from the Psychology Research Participation Pool and were compensated one research credit for one hour of participation. None had participated in the pilot experiment. The experiment was approved by the Psychology Ethics Review Board at the University of Western Ontario.

Materials

Musical stimuli. A total of 12 musical excerpts were used (Table 1 in Appendix A). The excerpts were 90-second instrumental clips chosen based on ratings of mood and arousal in the pilot experiment. Three excerpts were chosen for each of the four music conditions (HAP, HAN, LAP, and LAN).

Visual stimuli. A total of 322 face-name pairs were used. The pairing consisted of one black and white image of a face and one name. 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 faces and names were paired with the sole restriction that the gender of the face matched the name. Equal numbers of male and female face-name pairs were used.

Procedure

The experiment consisted of 13 blocks of studying and testing: 12 experimental blocks and one silent block. Each participant was exposed to all 13 blocks that were randomly ordered by the E-Prime (2.0) program (Psychology Software Tools, 2002). During the study phase of each block, participants were presented with a series of 24 randomly ordered face-name pairs. The faces were always presented on the right side of the laptop screen, and the names were always presented on the left side of the laptop screen. The pairings were presented at the rate of three seconds per pair with an inter-stimulus interval of zero seconds. Participants were asked to decide whether the name suited the face it was paired with. Participants were instructed to press the key labeled on the laptop keyboard as ‘yes’ if the name suited the face and press the key labeled ‘no’ if the name did not suit the face. The decision made during the study phase was designed to encourage encoding of the studied material. After the study phase, a red screen appeared for three seconds to indicate that the study phase for that block was over and the test phase for that block would begin.

During the test phase of each block, participants were presented with the same 24 faces and names, but some of the pairings were swapped. Of the 24 face-name pairs, 16 pairs were kept the same between the study phase and the test phase and eight pairs were swapped. For example, the face which was originally paired with the name “John” in the study phase could be paired with the name “Luke” in the test phase and the face originally paired with “Luke” could be paired with the name “John”. Participants were asked to indicate, using the keyboard, if the test pairings were the same as the study pairings. Participants pressed the key labeled ‘yes’ if the pairing at testing was the same as the pairing at studying and pressed the key labeled ‘no’ if the pairing was different. Again, the pairings were presented at the rate of three seconds per pair with an inter-stimulus interval of zero seconds. Between each block of study and test, a white screen with the word ‘break’ in capital letters appeared for five seconds to indicate that the participant was moving on to a new block. Participants were told that sometimes music would be playing in the background as they performed the task but they did not need to pay any attention to it because they would not be asked to make any decisions about it.

Before beginning the actual task, participants performed a practice block in silence that consisted of 12 face-name pairs to ensure comprehension of the task (Figure 3). All participants provided written informed consent and were fully debriefed after the experiment.

Statistical Analysis

Recognition performance was analyzed using percent correct and corrected hit rate. Percent correct was calculated as the number of correct responses divided by the total number of responses, multiplied by 100. Corrected hit rate was used to correct for any response bias. The corrected hit rate for each block was calculated by subtracting the false alarm rate from the hit rate. The false alarm rate was calculated by dividing the number of incorrect responses on the number of correctly matched pairs. The hit rate was calculated by dividing the number of correct responses on the number of incorrectly matched pairs. The proportion of false alarms (number of incorrect responses/number of matched pairs responded to) was subtracted from the proportion of hits (number of correct response/number of mismatched pairs responded to) to get the corrected hit rate for each block. Both percent correct and corrected hit rate for each block were expressed as difference scores, relative to the silent block (experimental score – silent score). The 12 difference scores (one for each block relative to silence) were analyzed statistically. Recognition performance was analyzed with a 2 (*musical mood*: positive and negative) x 2 (*musical arousal*: high and low) x 3 (*context*: music played at study only, music played at test only, and music played at both study and test) repeated measures analysis of variance (ANOVA) for the percent correct and corrected hit rate scores. All hypothesis tests used $\alpha = 0.05$ for significance and all post-hoc comparisons were corrected using

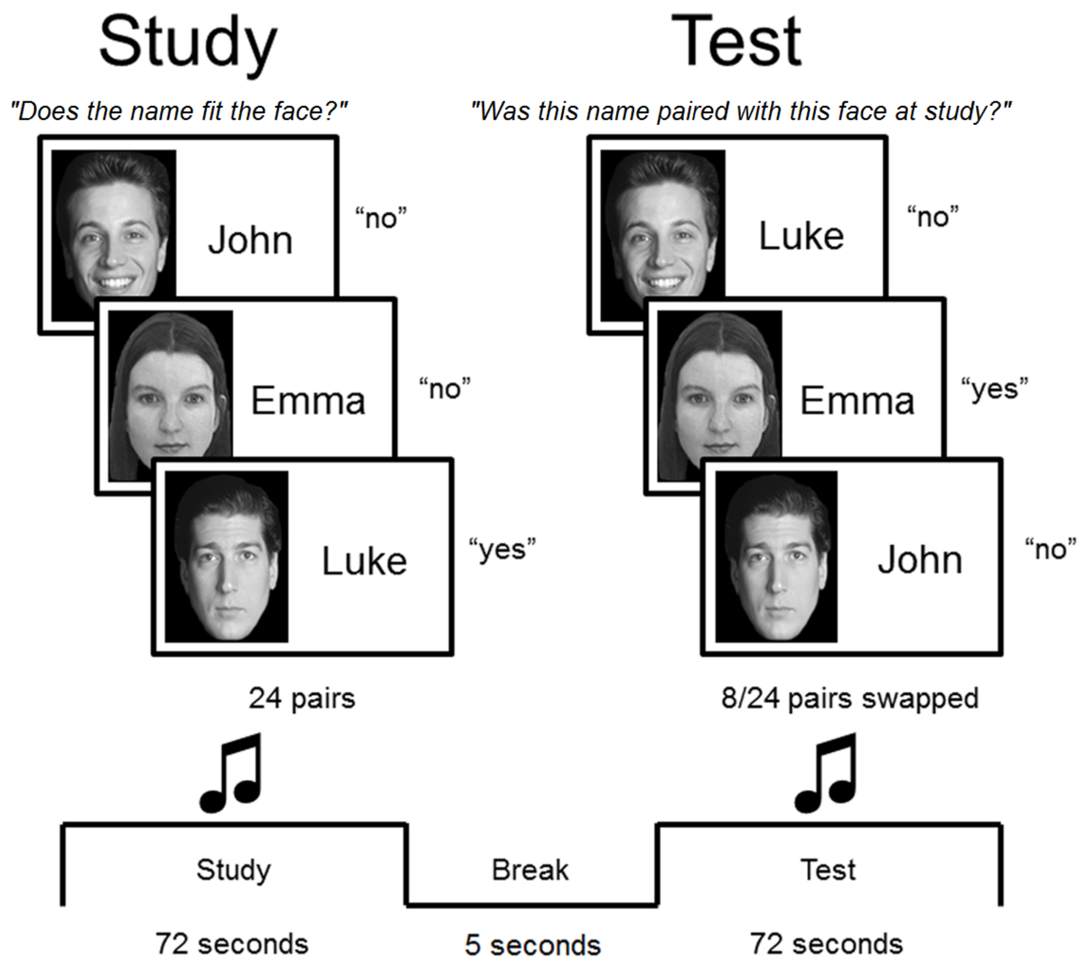

Figure 3. A diagram of the experimental design.

Bonferroni correction. Data were analyzed using SPSS (20.0) software.

Results

The analyses for recognition performance using percent correct and corrected hit rate showed comparable results; therefore, only the analysis using corrected hit rate is reported. All data sets were included in the analysis. Mauchly's Test of Sphericity indicated that the assumption of sphericity had not been violated, $\chi^2(2) = 0.701$, $p = 0.704$, and therefore, all statistics are reported with sphericity assumed. The results showed no main effect of musical mood, $F(1, 29) = 0.075$, $p = 0.786$. There was also no main effect of context, $F(2, 58) = 0.835$, $p = 0.439$. However, there was a significant main effect of musical arousal, $F(1, 29) = 8.413$, $p = 0.007$. Participants performed better with high arousal music ($M = 0.029$, $SE = 0.047$) compared to low arousal music ($M = -0.029$, $SE = 0.047$). However, the significant main effect of musical arousal must be interpreted in light of a significant two-way interaction.

The two-way interaction between musical mood and musical arousal was significant, $F(1, 29) = 10.722$, $p = 0.003$, $\eta^2 = 0.270$. Performance was significantly better with HAP music compared to LAP music, $t(89) = 3.657$, $p < 0.001$, but there was no significant difference in performance between HAN and LAN music, $t(89) = 0.257$, $p = 0.798$ (Figure 4). No other two-way interactions were significant: musical arousal and context, $F(2, 58) = 2.511$, $p = 0.090$, $\eta^2 = 0.080$, and musical mood and context, $F(2, 58) = 1.877$, $p = 0.162$, $\eta^2 = 0.061$. However, in light of a significant three-way interaction, the two-way interaction should be interpreted with caution.

There was a significant three-way interaction between musical mood, musical arousal, and context, $F(2, 58) = 8.363$, $p = 0.001$, $\eta^2 = 0.224$. When music was played at

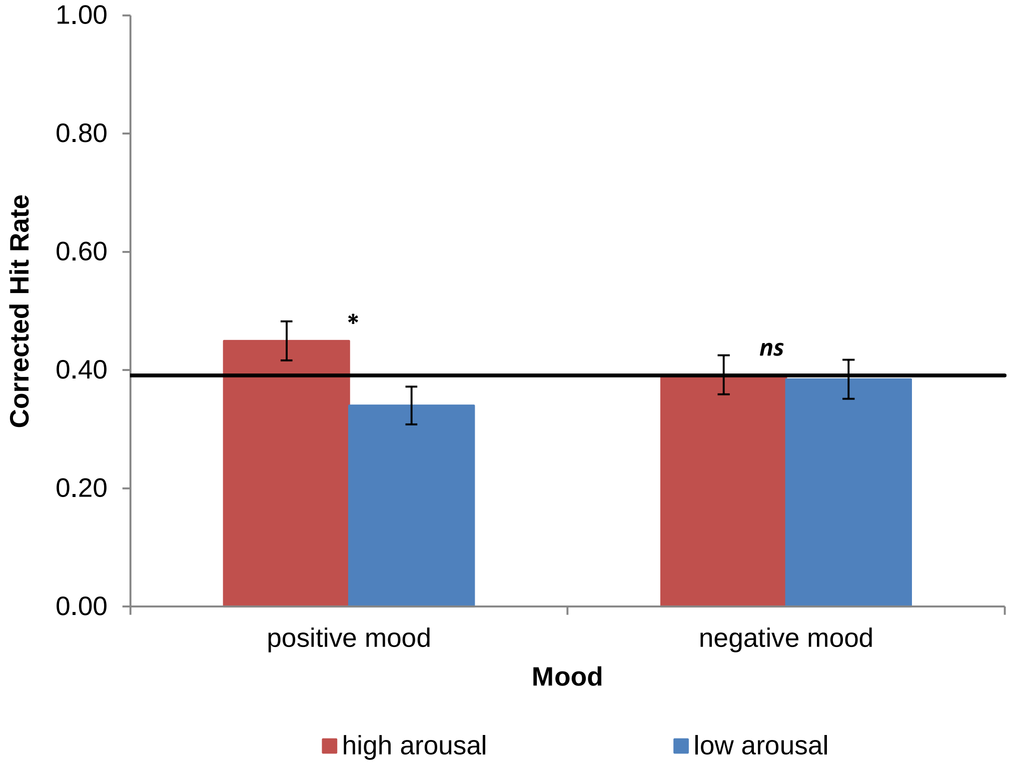

Figure 4. The significant two-way interaction between musical mood and musical arousal for Experiment 1A. Recognition performance was significantly better with HAP music compared to LAP music, but there was no significant difference in performance between HAN and LAN music. The solid black line represents performance in the silent condition. Error bars indicate standard error of the mean. * $p < .05$.

study only, there were no significant differences in recognition performance across the different musical mood and musical arousal conditions. When music was played at test only, recognition performance was significantly worse with LAP music compared to the two high arousal music conditions: HAP music, $t(29) = -3.125$, $p = 0.004$, and HAN music, $t(29) = -3.247$, $p = 0.003$. When music was played at both study and test, performance was significantly better with HAP and LAN music compared to HAN and LAP music. That is, recognition performance was better when participants listened to HAP music compared to when participants listened to HAN music, $t(29) = 3.681$, $p = 0.001$, and LAP music, $t(29) = 3.354$, $p = 0.002$, at both study and test. Moreover, participants performed better on the task when they listened to LAN music compared to when they listened to HAN music, $t(29) = 3.535$, $p = 0.001$, and LAP music, $t(29) = 2.449$, $p = 0.021$, at both study and test. The post-hoc comparisons showed that the three-way interaction was driven by significant differences in recognition performance for HAP and LAN music compared to HAN and LAP music, when the music was played at both study and test, but not when music was played at study only or test only (Figure 5).

Discussion

In Experiment 1A, participants performed a paired-association task while listening to music in the background. Performance on the task was significantly better when participants listened to HAP and LAN music compared to HAN and LAP music, but only when the music was played at both study and test. The results were consistent with the prediction that HAP and LAN music would enhance recognition performance compared to HAN and LAP music. However, it was predicted that the effect would be observed in all contexts (when music was played at study only, at test only, and at both

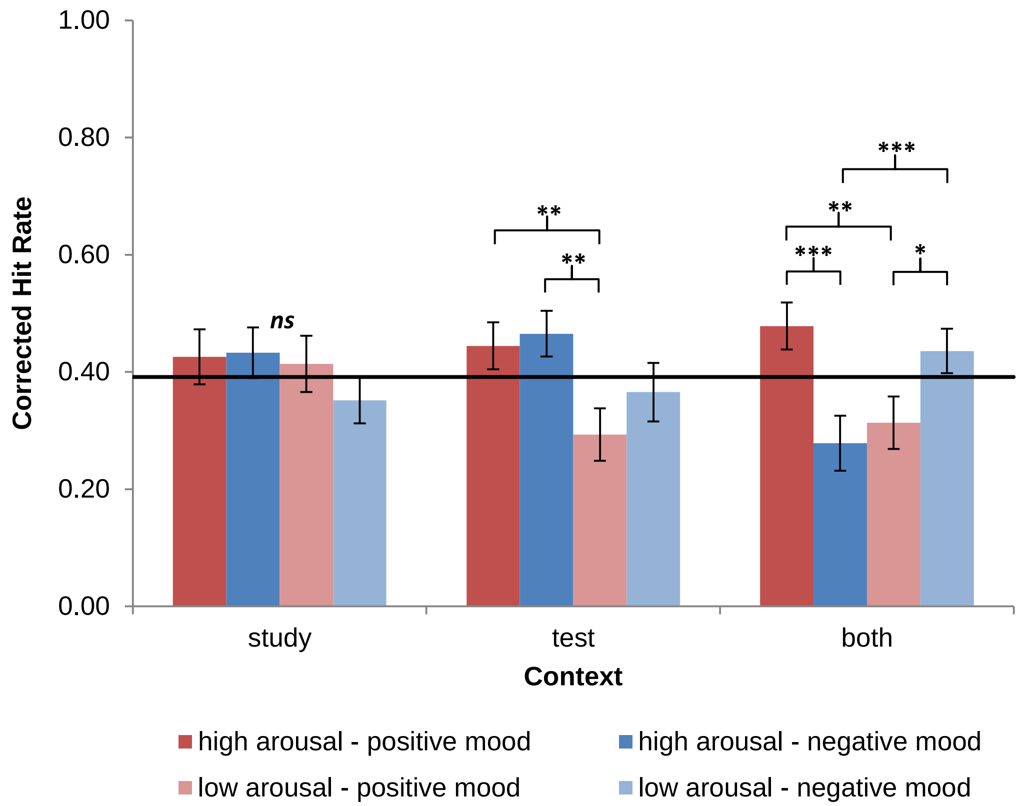

Figure 5. The significant three-way interaction between musical mood, musical arousal, and context for Experiment 1A. When music was played at study only, there were no significant differences in recognition performance across the different musical mood and musical arousal conditions. When music was played at test only, recognition performance was significantly better with the two high arousal music conditions compared to the LAP music condition. When music was played at both study and test, performance was significantly better with HAP and LAN music compared to HAN and LAP music. The solid black line represents performance in the silent condition. Error bars indicate standard error of the mean. * $p < .05$. ** $p < .01$. *** $p < .001$.

study and test). Previous work demonstrated that HAP and LAN music elicited better memory performance, but context was not manipulated (Greene et al., 2010). The results of Experiment 1A showed that the memory effect of HAP and LAN music was only observed when the music was played at both study and test. Perhaps when the music was played during the study phase, a contextual cue was established. Therefore, when the music was played again during the test phase, the contextual cue was reinstated, and this may have enhanced memory performance (Smith, 1985). However, if that was the case, then context should have improved performance in all four music conditions. One possible reason why the effect was only observed for the HAP and LAN conditions could be due to the selection of music. In Experiment 1A, the music was chosen based on other participants' ratings of mood and arousal in the pilot experiment. However, the perception of musical mood and musical arousal is subjective (Scherer & Zentner, 2001). It is possible that the music selection in Experiment 1A was more successful for the HAP and the LAN conditions compared to the HAN the LAP conditions. In the pilot experiment, participants categorized more excerpts as HAP and LAN compared to HAN and LAP, so the selection criteria had to be less stringent for the latter conditions. As a result, the effect of musical mood and musical arousal may not have been well represented for all four conditions.

Experiment 1B

Experiment 1B examined how tailoring the music to each participant might affect learning and memory. In Experiment 1B, participants were tested with music chosen based on their own ratings of mood and arousal. The way that emotion in music is perceived is highly subjective (Scherer & Zentner, 2001). The emotional perception of music varies between participants and situations (McNamara & Ballard, 1999). As such, tailoring the music to each participant should increase the strength of the mood and arousal manipulation (Greene et al., 2010). Experiment 1B was a direct replication of Experiment 1A. Participants performed the same paired-association task that measured recognition performance for faces paired with names. Musical mood, musical arousal, and context were operationalized the same way as in Experiment 1A. The aim of Experiment 1B was to determine whether participant-selected music would produce a more consistent effect on performance compared to experimenter-selected music used in Experiment 1A.

Again, HAP and LAN music should elicit better recognition performance than HAN and LAP music (Greene et al., 2010), and this pattern should be observed across all three contexts (when music was played at study only, at test only, and at both study and test). However, when music is played at study and test, recognition performance should be significantly better compared to when music is played at study only or test only. The encoding-retrieval specificity effect should be observed in all four music conditions because the music selection was personalized to the participant, thus ensuring that the mood and arousal manipulation was standardized across the four music conditions (Smith, 1985). Alternatively, if performance in Experiment 1B is similar to Experiment 1A, the effect of musical mood, musical arousal, and context on learning and memory will be replicated. Moreover, it would suggest that the emotional perception of music does not necessarily vary between individuals.

Method

Participants

Participants were 35 undergraduate students (25 females and 10 males) from the University of Western Ontario (M_{age} = 20.23 years, SD = 2.97 years). They were recruited from the Psychology Research Participation Pool and were compensated one and a half research credits for one and a half hour of participation. None had participated in the pilot experiment or Experiment 1A. The experiment was approved by the Psychology Ethics Review Board at the University of Western Ontario.

Materials

Musical stimuli. A total of 50 musical excerpts were used. The excerpts were 90-second instrumental clips drawn from a variety of different genres (e.g., blues, classical, jazz, metal, and rock). All musical excerpts were cut so only the first ten seconds of the clip were used in the rating portion of the experiment. Based on the participant's ratings of mood and arousal, 12 excerpts (three per condition) were chosen for the experimental task. The 12 chosen excerpts were standardized to ensure that no music condition was more representative than any other. The difference in ratings between any two given excerpt was no more or less than 0.25 points.

Visual stimuli. The stimuli were identical to those described in Experiment 1A.

Procedure

The music rating procedure was similar to the pilot experiment and the experimental procedure was identical to Experiment 1A. Recognition performance was analyzed the same way as was described in Experiment 1A.

Results

The analysis for recognition performance using percent correct and corrected hit rate showed comparable results; therefore, only the analysis using corrected hit rate is reported. Data from five participants was removed from the analysis. Two data sets were removed because of response bias. In these data sets, the participants had the same response for all items. The other three data sets were removed due to a large number of missing responses. Any data set with half or more of the responses missing from any of the blocks was removed.

Mauchly's Test of Sphericity indicated that the assumption of sphericity had not been violated, $\chi^2(2) = 0.289$, $p = 0.865$, and therefore, all statistics are reported with sphericity assumed. There was no main effect of musical mood, $F(1, 29) = 0.069$, $p = 0.794$, musical arousal, $F(1, 29) = 0.006$, $p = 0.938$, or context, $F(2, 58) = 1.046$, $p = 0.358$. There were also no significant interactions between musical arousal and context, $F(2, 58) = 0.063$, $p = 0.939$, $\eta^2 = 0.002$, and musical mood and context, $F(2, 58) = 0.629$, $p = 0.537$, $\eta^2 = 0.021$. However, the two-way interaction between musical mood and musical arousal was significant, $F(1, 29) = 9.449$, $p = 0.005$, $\eta^2 = 0.246$. Recognition performance was better when participants listened to HAP music compared to LAP music, $t(89) = 1.912$, $p = 0.059$, and when participants listened to LAN music compared to HAN music, $t(89) = 1.977$, $p < 0.051$ (Figure 6). In both comparisons, the effect was approaching significance. Regardless, the two-way interaction should be interpreted in light of a significant three-way interaction.

There was a significant three-way interaction between musical mood, musical arousal, and context, $F(2, 58) = 5.615$, $p = 0.006$, $\eta^2 = 0.162$. When music was played at

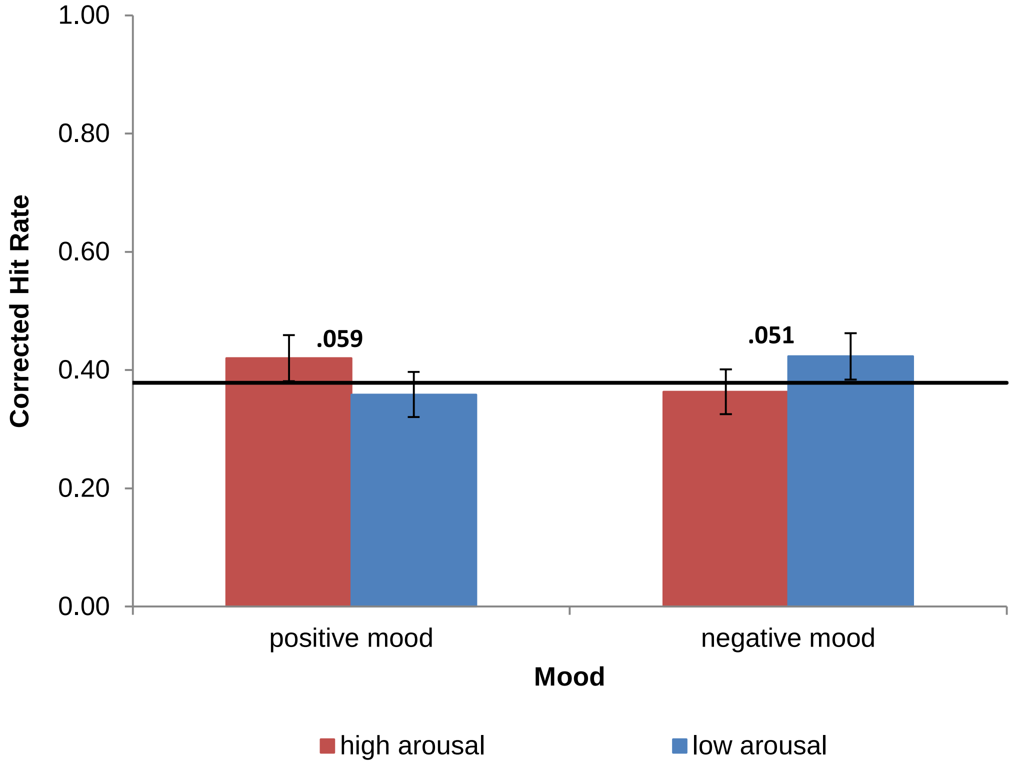

Figure 6. The significant two-way interaction between musical mood and musical arousal for Experiment 1B. Recognition performance was better when participants listened to HAP music compared to LAP music and when participants listened to LAN music compared to HAN music. In both comparisons, the effects were approaching significance. The solid black line represents performance in the silent condition. Error bars indicate standard error of the mean.

study only, there were no significant differences in recognition performance across the different musical mood and musical arousal conditions. When music was played at test only, recognition performance was significantly better with LAN music compared to LAP music, $t(29) = 2.298$, $p = 0.029$. When music was played at both study and test, performance was better with HAP and LAN music compared to HAN and LAP music. That is, recognition performance was better when participants listened to HAP music compared to when participants listened to HAN music, $t(29) = 2.916$, $p = 0.007$, and LAP music, $t(29) = 2.571$, $p = 0.016$, at both study and test. Participants also performed better on the task when they listened to LAN music compared to when they listened to HAN music, $t(29) = 3.110$, $p = 0.004$, and LAP music, $t(29) = 2.260$, $p = 0.031$, at both study and test. In summary, the three-way interaction was driven by significant differences in performance for the HAP and the LAN conditions compared to the HAN and the LAP conditions when music was played at both study and test, but no such differences were observed when music was played at study only or test only (Figure 7).

To examine the effect of music selection on performance, recognition performance for Experiments 1A and 1B was analyzed with a 2 (*music selection*: experimenter-selected or participant-selected) x 2 (*musical mood*: positive and negative) x 2 (*musical arousal*: high and low) x 3 (*context*: music played at study only, music played at test only, and music played at both study and test) split plot ANOVA, in which music selection was a between-groups variable and the rest of the factors were within-subjects variables.

There was no significant main effect of music selection on recognition performance, $F(1, 58) = 0.040$, $p = 0.843$, $\eta^2 = 0.001$. Therefore, music selection did not

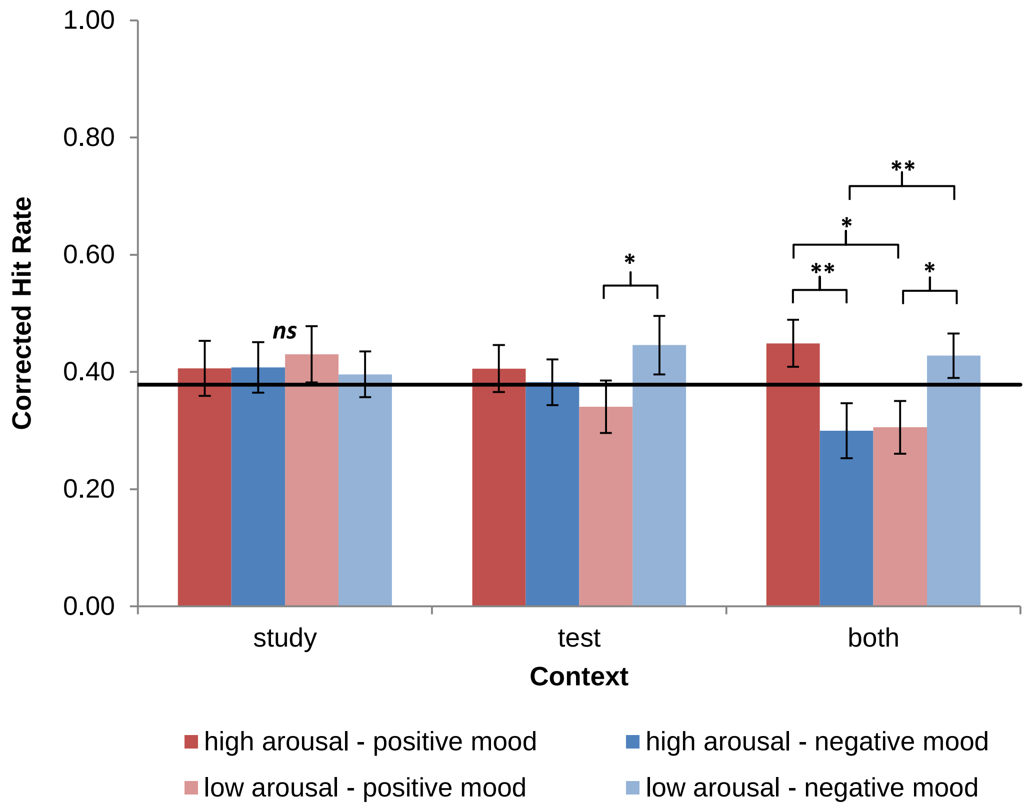

Figure 7. The significant three-way interaction between musical mood, musical arousal, and context for Experiment 1B. When music was played at study only, there were no significant differences in recognition performance across the different musical mood and musical arousal conditions. When music was played at test only, recognition performance was significantly better with LAN music compared to LAP music. When music was played at both study and test, performance was significantly better with HAP and LAN music compared to HAN and LAP music. The solid black line represents performance in the silent condition. Error bars indicate standard error of the mean. * $p < .05$. ** $p < .01$.

significantly affect memory performance and the results in Experiments 1A and 1B are comparable. There were also no significant interactions between musical mood and music selection, $F(1, 58) = 0.143$, $p = 0.706$, $\eta^2 = 0.002$, musical arousal and music selection, $F(1, 58) = 3.615$, $p = 0.062$, $\eta^2 = 0.059$, and context and music selection, $F(2, 116) = 0.030$, $p = 0.970$, $\eta^2 = 0.001$. There were no significant three-way interactions: musical mood, musical arousal, and music selection, $F(1, 58) = 0.135$, $p = 0.714$, $\eta^2 = 0.002$; musical mood, context, and music selection, $F(2, 116) = 0.081$, $p = 0.922$, $\eta^2 = 0.001$; musical arousal, context, and music selection, $F(2, 116) = 1.343$, $p = 0.265$, η2 = 0.023. Finally, the four-way interaction between musical mood, musical arousal, context, and music selection was also not significant, $F(2, 116) = 0.401$, $p = 0.670$, η2 = 0.007. Therefore, performance in Experiments 1A and 1B was not significantly different from each other.

Discussion

In Experiment 1B, participant-selected music was used to increase the strength of the mood and arousal manipulation, but participant-selected and experimenter-selected music did not differ in their effect on recognition performance. Perhaps the emotional perception of music does not vary greatly between individuals, as was previously demonstrated (Scherer & Zentner, 2001). Experiment 1B replicated the results in Experiment 1A. Performance on the paired-association task was significantly better when participants listened to HAP and LAN music compared to HAN and LAP music, but only when the music was played at both study and test. Again, the results were consistent with the prediction that HAP and LAN music would enhance recognition performance and that HAN and LAP music would lower recognition performance (Greene et al., 2010), but the pattern was not observed when music was played at study only or at test only. One explanation is that musical mood and musical arousal acted simultaneously with context to produce the effect observed in Experiment 1. It is possible that performance was hindered by HAN and LAP music and that the effects were too detrimental for participants to benefit from having a similar context generated by the music played at both study and test. Another possibility as to why the detrimental effects of HAN and LAP music were only observed when music was played at both study and test could be due to length of music exposure. When music was played at study only and at test only, participants were exposed to 72 seconds of music, but that length was doubled when music was played at both study and test. Therefore, it is possible that the effect of HAN and LAP music was more detrimental with increased music exposure. Nonetheless, Experiment 1B, in combination with Experiment 1A, provided evidence that musical mood, musical arousal, and context act simultaneously to affect memory performance. The results of Experiment 1 suggested that there is something distinctive about the presentation of the music at both study and test that yielded the mood and arousal interaction.

Chapter 3

Experiment 2

Experiment 1 provided evidence that musical mood, musical arousal, and context act concurrently to affect recognition performance. When music was played at both study and test, HAP and LAN music facilitated recognition performance while HAN and LAP music inhibited recognition performance. The presentation of music at both study and test seemed to produce the mood and arousal interaction that influenced memory performance and this effect could be due to context. When music is played at both study and test, there are potentially two ways that context can enhance memory: (1) the specific musical piece can serve as the contextual cue or (2) the mood and arousal states induced by the music can serve as the contextual cue (Balch & Lewis, 1996; Mead & Ball, 2007; Smith, 1985). It is difficult to distinguish between these two possibilities in Experiment 1 because when music was played at both study and test, the same musical piece with the same emotional states (mood and arousal) were reinstated. Therefore, both types of context were present. The motivation for Experiment 2 was to distinguish whether congruent musical pieces or congruent emotional states were driving better recognition performance, especially with HAP and LAN music. Experiment 2A examined whether the perceptual context of a specific musical piece was needed to enhance memory, while Experiment 2B examined whether the emotional context of musical mood and musical arousal was needed to enhance memory. Experiment 2 also addressed the possibility that the effects observed in Experiment 1 occurred because of increased music exposure when music was played at both study and test. To control for length of exposure, in Experiment 2, music was always played at both study and test, but the context at encoding and at retrieval was not always the same. The aim of Experiment 2 was to investigate the two ways that context can have on memory.

Experiment 2A

Experiment 2A examined whether music can establish a context that, when reinstated, enhances memory performance. Participants performed the same paired-association task used in Experiment 1. While participants performed the task, music was playing in the background. The four music conditions were created by combining the two levels of mood and arousal: (1) HAP music, (2) HAN music, (3) LAP music, and (4) LAN music. To study the encoding-retrieval specificity effect of music, there were two different contexts: (1) the same piece of music was played at study and test and (2) a different piece of music was played at study and test. That is, participants either heard the same piece of music at study and at test, or two different pieces of music with similar mood and arousal levels. Keeping the emotional states consistent ensures that any effect on recognition performance was attributed to the perceptual context of the specific music piece and not the change in the emotional context of musical mood and musical arousal. If music does establish a contextual cue that when reinstated provides a memory cue, then hearing the same piece of music at study and at test should improve recognition performance (Smith, 1985). Moreover, HAP and LAN music should elicit better recognition performance compared to HAN and LAP music (Greene et al., 2010), as was observed in Experiment 1.

Method

Participants

The participants in the experiment were 32 undergraduate students (24 females and 8 males) from the University of Western Ontario (M_{age} = 19.25 years, *SD* = 4.40 years). They were recruited from the Psychology Research Participation Pool and were compensated half a research credit for half an hour of participation. All participants were naïve to the purpose of the experiment. The experiment was approved by the Psychology Ethics Review Board at the University of Western Ontario.

Materials

Musical stimuli. A total of 12 musical excerpts were used (Table 2 in Appendix A). The excerpts were 90-second instrumental clips chosen based on ratings of mood and arousal in the pilot experiment with the sole restriction that the two excerpts in the different music conditions have similar mood and arousal ratings. Three excerpts were chosen for each of the four music conditions (HAP, HAN, LAN, and LAP).

Visual stimuli. The visual stimuli were similar to those described in Experiment 1A, except that a total of 228 face-name pairs were used.

Procedure

The experimental procedure was similar to Experiment 1A. However, Experiment 2A consisted of 9 blocks of studying and testing: 8 experimental blocks and one silent block. Each participant was exposed to all 9 blocks that were randomly ordered by the E-Prime (2.0) program (Psychology Software Tools, 2002).

Statistical Analysis

Recognition performance was analyzed the same way as was described in Experiment 1A. However, in Experiment 2A, a 2 (*musical mood*: positive and negative) x 2 (*musical arousal*: high and low) x 2 (*context*: same music and different music) repeated measures ANOVA for the percent correct and corrected hit rate scores was performed.

Results

The analyses for recognition performance using percent correct and corrected hit rate showed comparable results; therefore, only the analysis using corrected hit rate is reported. Data from two participants were removed from the analysis due to a large number of missing responses. Any data set with half or more of the responses missing from any of the blocks was removed. The results showed no main effect of musical mood, $F(1, 29) = 0.044$, $p = 0.835$, musical arousal, $F(1, 29) = 0.684$, $p = 0.415$, or context, $F(1, 29) = 0.210$, $p = 0.650$. There were also no significant interactions between musical mood and musical arousal, $F(1, 29) = 0.803$, $p = 0.378$, $\eta^2 = 0.027$, musical mood and context, $F(1, 29) = 0.949$, $p = 0.338$, $\eta^2 = 0.032$, and musical arousal and context, $F(1, 29) = 3.891$, $p = 0.058$, $\eta^2 = 0.118$. Finally, there was also no significant interaction between musical mood, musical arousal, and context, $F(1, 29) = 3.891$, $p = 0.058$, $\eta^2 = 0.118$. Thus, there were no significant differences in recognition performance across all eight conditions (Figure 8).

Discussion

In Experiment 2A, participants performed a paired-association task while listening to perceptually congruent or incongruent music in the background. There were no enhancing effects for playing the same musical piece at study and test. Recognition performance in all four music conditions was similar regardless of context. This finding was inconsistent with the encoding-retrieval specificity hypothesis that states that memory is facilitated when the retrieval contexts are consistent with the encoding contexts. One explanation is that participants might have tuned out the music while performing the task so the contextual cues were not well established. Participants were

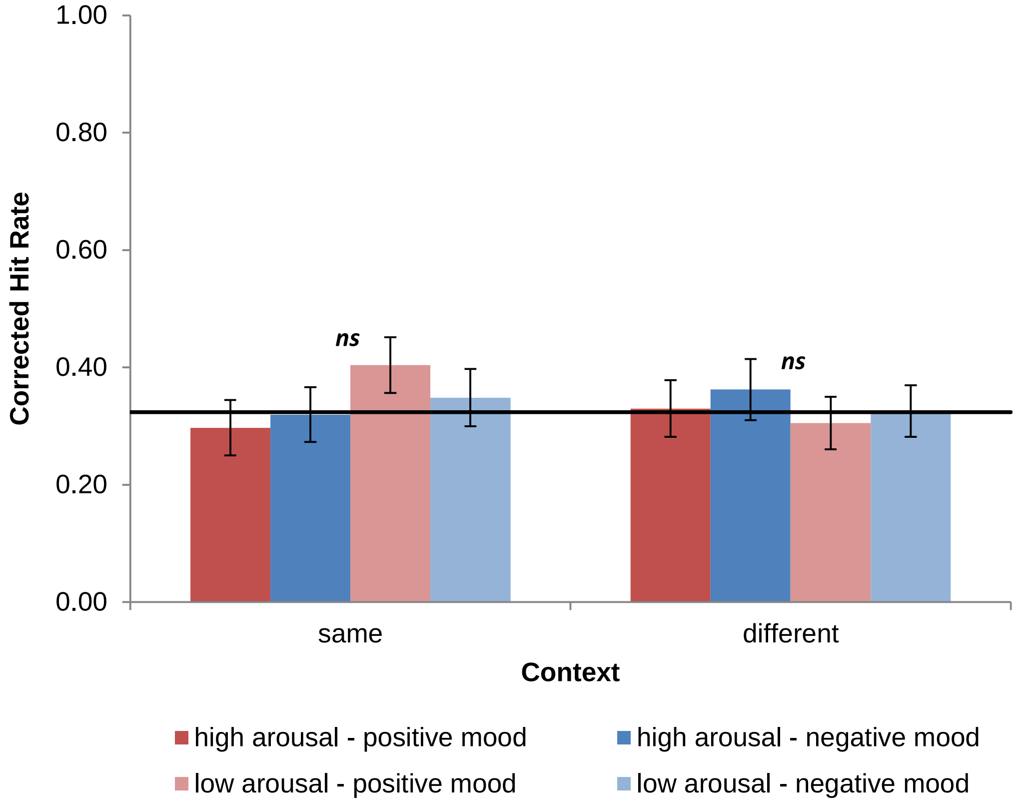

Figure 8. The three-way interaction between musical mood, musical arousal, and context for Experiment 2A. There were no significant differences in recognition performance across all eight conditions. The solid black line represents performance in the silent condition. Error bars indicate standard error of the mean.

instructed that the music would be playing in the background as they performed the task but they were not specifically instructed that they had to pay attention to it. Thus, music would not have any beneficial effects on memory if participants were not attending to it. Perhaps the emotional contexts of music are better cues than the perceptual contexts of music because emotional contexts are automatically induced, even when the music is not actively attended to (Eschrich et al., 2008). For that reason, musical mood and musical arousal might be better contextual cues than the specific musical piece.

Experiment 2B

Experiment 2B examined whether the emotional context of musical mood and musical arousal can enhance recognition performance when reinstated. The emotional contexts in Experiment 2B should be more effective at aiding memory retrieval than the perceptual contexts in Experiment 2A because mood and arousal are automatically induced even when the music is just playing in the background (Eschrich et al., 2008). In Experiment 2B, participants performed the same paired-association task that was used in Experiments 1 and 2A. Musical mood and musical arousal were also operationalized the same way as in Experiments 1 and 2A. The four music conditions were created by combining the two levels of mood and arousal: (1) HAP music, (2) HAN music, (3) LAP music, and (4) LAN music. Context was operationalized differently. There were four different contexts: (1) the same mood and arousal states at study and at test, (2) only the same mood state at study and at test, (3) only the same arousal state at study and at test, and (4) different mood and arousal states at study and at test. Therefore, participants always heard two different pieces of music with either the same or different levels of mood and arousal. Playing two different pieces of music at study and test ensures that any effect on recognition performance was attributed to the emotional context of mood and arousal and not the change in perceptual context of the specific music piece.

If the emotional state induced by the music does establish a contextual cue then reinstating the same mood and arousal should improve memory performance (Balch & Lewis, 1996; Mead & Ball, 2007; Tulving & Thomson, 1973). Moreover, when only mood or only arousal is reinstated then memory should also be improved, but not to the same extent as reinstating both mood and arousal at test. Furthermore, the context effect of musical mood and musical arousal should be better with HAP and LAN music compared to HAN and LAP music based on the findings of Experiment 1.

Method

Participants

Participants were 33 undergraduate students (21 females and 12 males) from the University of Western Ontario (M_{age} = 20.18 years, *SD* = 3.88 years). They were recruited from the Psychology Research Participation Pool and were compensated one research credit for one hour of participation. All participants were naïve to the purpose of the experiment. The experiment was approved by the Psychology Ethics Review Board at the University of Western Ontario.

Materials

Musical stimuli. A total of 20 musical excerpts were used (Table 3 in Appendix A). The excerpts were 90-second instrumental clips chosen based on ratings of mood and arousal in the pilot experiment. Five excerpts were chosen for each of the four music conditions (HAP, HAN, LAN, and LAP).

Visual stimuli. The visual stimuli were similar to those described in Experiment

1A, except that a total of 318 face-name pairs were used.

Procedure

The experimental procedure was similar to Experiment 1A. However, Experiment 2B consisted of 17 blocks of studying and testing: 16 experimental blocks and one silent block. Each participant was exposed to all 17 blocks that were randomly ordered by the E-Prime (2.0) program (Psychology Software Tools, 2002). During the study phase of each block, participants were presented with a series of 18 randomly ordered face-name pairs (instead of 24 face-name pairs as in Experiments 1 and 2A). Of the 18 face-name pairs, 12 pairs were kept the same between the study phase and the test phase and six pairs were swapped.

Statistical Analysis

Recognition performance was analyzed the same way as was described in Experiment 1A. However, in Experiment 2B, a 2 (*musical mood*: positive and negative) x 2 (*musical arousal*: high and low) x 4 (*context*: same mood and arousal at study and at test, same mood only at study and at test, same arousal only at study and at test, and different mood and arousal at study and at test) repeated measures ANOVA for the percent correct and corrected hit rate scores was performed.

Results

Only the analysis for the corrected hit rate scores is reported because the analyses using the percent correct and corrected hit rate scores showed comparable results. Data from three participants were removed from the analysis. One data set was removed because of response bias: the participant had the same response for all items. The other two data sets were removed due to a large number of missing responses. Any data set with half of the responses missing from any of the blocks was removed.

Mauchly's Test of Sphericity indicated that the assumption of sphericity had not been violated, $\chi^2(5) = 3.306$, $p = 0.653$, and therefore, all statistics are reported with sphericity assumed. The results showed no main effect of musical mood, $F(1, 29) = 0.078$, $p = 0.782$, musical arousal, $F(1, 29) = 3.344$, $p = 0.078$, or context, $F(3, 87) = 0.539$, $p = 0.657$. There were also no significant interactions between musical mood and musical arousal, $F(1, 29) = 0.121$, $p = 0.730$, $\eta^2 = 0.004$, and musical mood and context, $F(3, 87) = 0.724$, $p = 0.540$, $\eta^2 = 0.024$. However, there was a significant two-way interaction between musical arousal and context, $F(3, 87) = 2.707$, $p = 0.050$, $\eta^2 = 0.085$. Further analysis of the two-way interaction showed that it was driven by significant differences in performance for low arousal music at each level of context. When mood and arousal were the same at study and at test, recognition performance was significantly better with low arousal music compared to high arousal music, $t(59) = 3.343$, $p = 0.001$. Although reinstatement of mood an arousal at study and at test was necessary to facilitate recognition performance, neither context (same mood or same arousal) alone was sufficient to facilitate the same effect in the low arousal conditions. When studying with low arousal music, recognition performance was significantly worse when only the same mood state was reinstated at test compared to when both mood and arousal was reinstated, $t(59) = -2.834$, $p = 0.006$. Furthermore, for low arousal music, performance was better when mood and arousal were the same at study and at test compared to when both were different, $t(59) = 2.126$, $p = 0.038$ (Figure 9). Finally, there was no significant interaction between musical mood, musical arousal, and context, $F(3, 87) = 2.049$, $p = 0.113$, $\eta^2 = 0.066$. However, when music with the same mood and arousal was played at

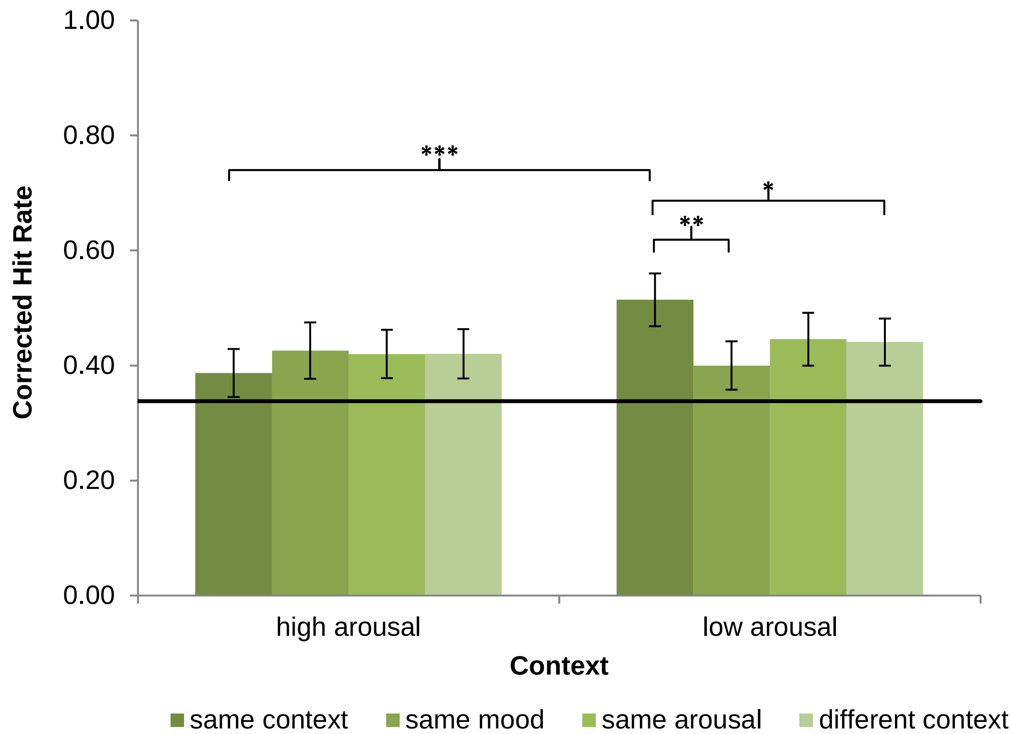

Figure 9. The significant two-way interaction between musical arousal and context for Experiment 2B. When mood and arousal were the same at study and at test, recognition performance was significantly better with low arousal music compared to high arousal music. When studying with low arousal music, recognition performance was significantly worse when only the same mood was reinstated at test compared to when both mood and arousal was reinstated. Furthermore, for low arousal music, performance was better when mood and arousal were the same at study and at test compared to when both were different. The solid black line represents performance in the silent condition. Error bars indicate standard error of the mean. * $p < .05$. ** $p < .01$. *** $p < .001$.

study and test, recognition performance was significantly worse for HAN music compared to the two low arousal music conditions: LAP music, $t(29) = -3.033$, $p = 0.005$, and LAN music, $t(29) = -2.740$, $p = 0.010$. These significant differences were most likely because the significant two-way interaction between musical arousal and context was encompassed within the non-significant three-way interaction between musical mood, musical arousal, and context (Figure 10).

Discussion

Experiment 2B examined whether the emotional aspects (mood and arousal) of music were needed to establish contextual cues that would enhance recognition performance. Participants performed a paired-association task that measured recognition performance for faces paired with names while emotionally congruent or incongruent music was playing in the background. Performance was significantly better when the same mood and arousal were reinstated at study and test, but only for low arousal music. The results were somewhat consistent with the prediction that musical mood and musical arousal would serve as contextual cues that enhance memory performance when presented at study and at test (Balch & Lewis, 1996; Mead & Ball, 2007; Tulving & Thomson, 1973). However, it was not predicted that the effect would be limited to low arousal music. The results showed that performance with LAP and LAN music was significantly better compared to HAN music. There may be something distinctive about HAN music that was detrimental to memory performance because it also had a negative effect on memory in Experiment 1. It is possible that the effect of HAN music is so adverse that the participants did not benefit from having it repeated. Alternatively, there could be something distinctive about low arousal music that, when reinstated, may have

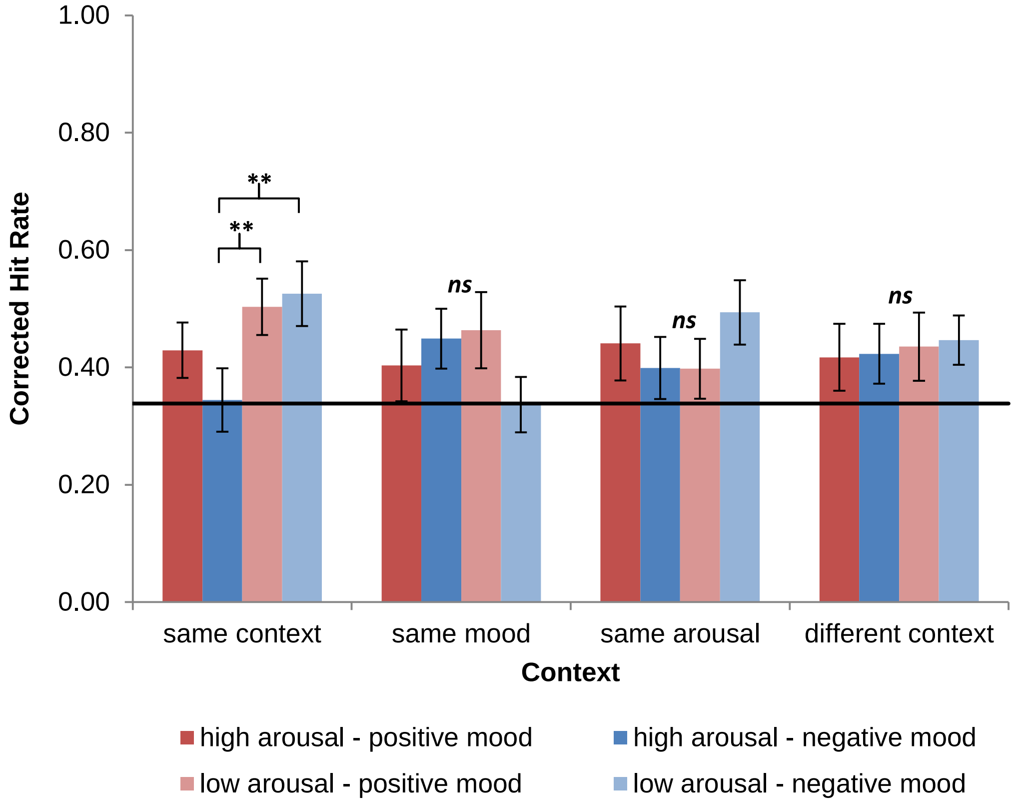

Figure 10. The three-way interaction between musical mood, musical arousal, and context for Experiment 2B. The significant differences between HAN and the two low arousal music conditions when music with the same mood and arousal was played at study and test were most likely because the significant two-way interaction between musical arousal and context was encompassed within the non-significant three-way interaction between musical mood, musical arousal, and context. The solid black line represents performance in the silent condition. Error bars indicate standard error of the mean. ** $p < .01$.

prompted the recall of associated memories. The results of Experiment 2B suggested that arousal was a more effective contextual cue than mood. In the low arousal conditions, when the same mood—but not the same arousal—was reinstated at test, recognition performance was significantly reduced compared to when both mood and arousal were reinstated. Such effects were not seen when the same arousal, but not the same mood, was reinstated at test. Previous literature has shown that changing factors that influence ratings of arousal, such as tempo, lead to worse performance than changing factors that do not influence arousal (Balch, Bowman, & Mohler, 1992; Balch & Lewis, 1996; Balch et al., 1999). Therefore, the results of Experiment 2B were consistent with previous literature. However, in the previous literature, the encoding-retrieval specificity effect of musical arousal on memory was consistently shown at all levels of arousal. One explanation why the effect in Experiment 2B was not consistent with previous literature could be the choice of task. Perhaps the paired-association task used in Experiment 2B was too difficult because it incorporated elements of both recognition and association memory. Therefore, participants may not have benefitted from having the music in the background. It is possible that the emotional context effect of music does not occur in the paired-association task used in Experiment 2.

Chapter 4

Experiment 3

As previously mentioned, successful retrieval of learned information occurs because the associated context can prompt the recall or recognition of the learned information (Park, Puglisi, Smith, & Dudley, 1987). In the literature, the context effect of music is often assessed using a recall or recognition memory task and the effects are consistent with the encoding-retrieval specificity hypothesis (Balch & Lewis, 1996; Balch et al., 1992; Mead & Ball, 2007). To date, no studies have used a paired-association task to study the context effect of music. The paired-association task is the most popular paradigm to assess memory deficits in older individuals (Naveh-Benjamin, Guez, Kilb, & Reedy, 2004; Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003; Old & Naveh-Benjamin, 2008), but has not been used to investigate how music might influence association memory. Therefore, it is possible that the context effects of music were not observed in Experiment 2A and were weak in Experiment 2B because the effects do not apply to association memory. Experiment 3 examined whether the context effect of musical mood and musical arousal occurs across (1) a recall task (Experiment 3A), (2) a recognition task (Experiment 3B), and (3) an association task (Experiment 3C). Instead of using faces and names, words were used in all three experiments to keep the stimuli as comparable as possible. Musical mood, musical arousal, and context were operationalized the same way as in Experiment 1. The four music conditions were created by combining mood and arousal: (1) HAP music, (2) HAN music, (3) LAP music, and (4) LAN music. The presence of music at the study and test phases was used to manipulate context: (1) music played at study only, (2) music played at test only, and (3) music played at both study and test. The aim of Experiment 3 was to determine how musical mood, musical arousal, and context might influence recall, recognition, and association memory.

Experiment 3A

Experiment 3A investigated how musical mood, musical arousal, context, or some combination of those factors might influence recall memory. Participants performed a free recall task that required learning and recalling words. The task consisted of multiple blocks of studying and testing. In each block, participants learned words during the study phase and recalled as many words as possible during the test phase. While participants performed the task, silence or music was present in the background. Musical mood, musical arousal, and context were operationalized the same way as in Experiment 1. The aim of this experiment was to determine whether the effects observed in Experiment 1 would occur in recall memory. If so, then musical mood, musical arousal, and context should act concurrently to affect recall performance. Recall performance with HAP and LAN music should be better than recall performance with HAN and LAP music, especially when the music is played at both study and test. HAP and LAN music should enhance recall performance because HAP and LAN music elicited better memory performance than HAN and LAP music (Greene et al., 2010). Music may also serve as a contextual cue that can also influence memory (Smith, 1985). Therefore, when the same music is played at both study and test, it should serve as a contextual cue that can enhance memory performance compared to when music is played at study only or at test only.

Method

Participants

Thirty undergraduate students (15 females and 15 males) from the University of Western Ontario (M_{age} = 20.00 years, *SD* = 2.32 years) participated in this experiment. They were recruited from the Psychology Research Participation Pool and were compensated one research credit for an hour of participation. None had participated in any of the other experiments in this thesis. The experiment was approved by the Psychology Ethics Review Board at the University of Western Ontario.

Materials

Musical stimuli. The musical stimuli were identical to those described in Experiment 1A (Table 1 in Appendix A).

Visual stimuli. A total of 270 English words were used (Table 1 in Appendix B). The words were all nouns approximately five to nine letters in length (*M* = 6.66 letters ± 1.26 letters), with a written mean frequency of 2.54 per million words (*SD* = 3.60 per million words) according to the CELEX database (Baayen, Piepenbrock, & Gulikers, 1995). Word frequency was equivalent across the 13 word lists.

Procedure

The experiment consisted of 13 blocks of studying and testing: 12 experimental blocks and one silent block. Each participant was exposed to all 13 blocks that were randomly ordered by the E-Prime (2.0) program (Psychology Software Tools, 2002). During the study phase of each block, participants learned a list of 20 randomly ordered words. The words were presented in black lowercase letters in the center of a white screen at the rate of three seconds per word with an inter-stimulus interval of zero seconds. Following the study phase, a red screen appeared for three seconds to indicate that the study phase for that block was over and the test phase for that block would begin. During the test phase of each block, participants were given three minutes to recall as many of the 20 words as possible in any order. Between each block of study and test, a white screen with the word 'break' in capital letters appeared for five seconds to indicate that the participant was moving on to a new block. Participants were told that sometimes music would be playing in the background as they performed the task but they did not need to pay any attention to it because they would not be asked to make any decisions about it. Before beginning the actual task, participants performed a practice block that consisted of 10 words to ensure comprehension of the task. All participants provided written informed consent and were fully debriefed after the experiment.

Statistical Analysis

Recall performance was analyzed using percent correct. Percent correct was calculated as the number of correctly recalled words divided by 20, multiplied by 100. The score for each block was expressed as a difference score, relative to the silent block (experimental score – silent score). The 12 difference scores (one for each block relative to silence) were analyzed statistically. Recall performance was analyzed with a 2 (*musical mood*: positive and negative) x 2 (*musical arousal*: high and low) x 3 (*context*: music played at study only, music played at test only, and music played at both study and test) repeated measures ANOVA. All hypothesis tests used $\alpha = 0.05$ for significance. Data were analyzed using SPSS (20.0) software.

Results

All data sets were included in the analysis. Mauchly's Test of Sphericity indicated that the assumption of sphericity had not been violated, $\chi^2(2) = 2.287$, $p = 0.319$, and therefore, all statistics are reported with sphericity assumed. The results showed no main effect of musical mood, $F(1, 29) = 0.378$, $p = 0.543$. There was also no main effect of context, $F(2, 58) = 1.416$, $p = 0.251$. However, there was a significant main effect of musical arousal, $F(1, 29) = 6.330$, $p = 0.018$. Participants recalled more words correctly with low arousal music ($M = 0.003$, $SE = 0.020$) compared to high arousal music ($M = -0.015$, $SE = 0.020$). There were no significant interactions between musical mood and musical arousal, $F(1, 29) = 0.028$, $p = 0.869$, $\eta^2 = 0.001$, musical mood and context, $F(2, 58) = 1.371$, $p = 0.262$, $\eta^2 = 0.045$, and musical arousal and context, $F(2, 58) = 0.256$, $p = 0.775$, $\eta^2 = 0.009$. Finally, there was no significant interaction between musical mood, musical arousal, and context, $F(2, 58) = 0.296$, $p = 0.745$, $\eta^2 = 0.010$ (Figure 11).

Discussion

In Experiment 3A, participants performed a recall task that required learning and recalling words while silence or music was present in the background. The results showed that participants correctly recalled more words when they listened to low arousal music compared to high arousal music. The finding that low arousal music enhanced recall memory was consistent with the finding in Experiment 2B. In Experiment 2B, the context effect of mood and arousal was also only observed in the low arousal music conditions. There may be something unique about low arousal music that improved memory performance. One explanation is that low arousal music elicited the optimal amount of arousal, which positively affected performance (Yerkes & Dodson, 1908). However, in Experiment 1A, when music was played at test only, recognition performance was worse when participants listened to low arousal music compared to high

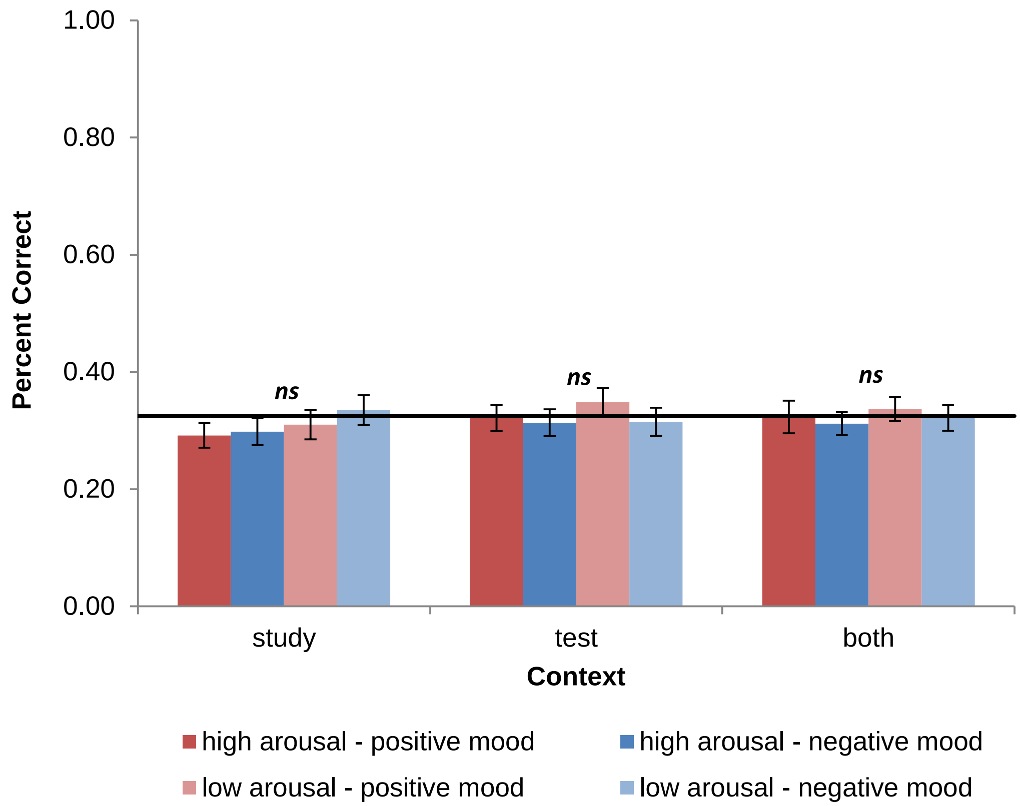

Figure 11. The three-way interaction between musical mood, musical arousal, and context for Experiment 3A. There were no significant differences in recall performance across all twelve conditions. The solid black line represents performance in the silent condition. Error bars indicate standard error of the mean.

arousal music. Perhaps arousal has different effects at different stages of learning and memory, such that high arousal was needed for effective memory retrieval but low arousal was needed for effective encoding.

In addition, musical mood, musical arousal, and context did not interact. The lack of interaction was inconsistent with the prediction that all three variables would act concurrently to affect memory recall. The results also suggested a lack of replication with previous literature because musical mood and musical arousal have been shown to improve memory performance, especially when the context at encoding was the similar to the context at retrieval (Balch & Lewis, 1996; Balch et al., 1992; Mead & Ball, 2007). Perhaps no significant effects of musical mood, musical arousal, and context were observed because the task was too difficult. On average, performance on the recall task was worse compared to the other studies from which the paradigm was adapted (Balch & Lewis, 1996; Balch et al., 1992; Mead & Ball, 2007). Previous literature demonstrated that music and task difficulty can influence learning and memory. For example, memory performance on an easy task was improved with the presence of background music while memory performance on a hard task was reduced (Angel, Polzella, & Elvers, 2010). Therefore, it is possible that the recall task was too difficult and therefore performance was reduced with the presence of background music. Perhaps the enhancing effects of music will be more robust with recognition memory than recall memory.

Experiment 3B

According the two-stage theory of memory, memory retrieval is easier for recognition memory than recall memory (Watkins & Gardiner, 1979). Successful recall involves two processes: (1) a search and retrieval process of the to-be-remembered information and (2) a recognition process in which the correct information is chosen from the retrieved information (Bahrick, 1970). However, successful recognition memory requires only the second of the two processes. It is possible that the enhancing effect of music is more likely to occur in an easier recognition task than in the harder recall task. Therefore, Experiment 3B examined how recognition memory might be influenced by musical mood, musical arousal, and context. Participants performed a recognition task that required learning and distinguishing learned words from new words. Musical mood, musical arousal, and context were operationalized the same way as in Experiment 3A. The aim of Experiment 3B was to determine how musical mood, musical arousal, and context might affect recognition memory. If memory retrieval for recognition memory is easier than recall memory (Watkins & Gardiner, 1979), then recognition performance should be better in all conditions compared to recall performance in Experiment 3A. Moreover, musical mood, musical arousal, and context should act concurrently to affect recognition memory. That is, recognition performance with HAP and LAN music should be better than recognition performance with HAN and LAP music, especially when the music is played at both study and test (Greene et al., 2010; Smith, 1985; Tulving & Thomson, 1973).

Method

Participants

Participants were 30 undergraduate students (15 females and 15 males) from the University of Western Ontario (M_{age} = 21.07 years, SD = 2.89 years). They were recruited from the Psychology Research Participation Pool and were compensated one research credit for one hour of participation. None had participated in any other experiments in this thesis. This experiment was approved by the Psychology Ethics Review Board at the University of Western Ontario.

Materials

Musical stimuli. The musical stimuli were identical to those described in Experiment 1A (Table 1 in Appendix A).

Visual stimuli. A total of 405 English words were used (Table 2 in Appendix B). The words were all nouns approximately five to nine letters in length (*M* = 6.62 letters ± 1.25 letters), with a written mean frequency of 3.05 per million words (*SD* = 2.54 per million words) according to the CELEX database (Baayen et al., 1995). Word frequency was equivalent across the 13 word lists.

Procedure

The experiment consisted of 13 blocks of studying and testing: 12 experimental blocks and one silent block. Each participant was exposed to all 13 blocks that were randomly ordered by the E-Prime (2.0) program (Psychology Software Tools, 2002). During the study phase of each block, participants learned a list of 20 randomly ordered words. The words were presented in black lowercase letters in the center of a white screen at the rate of three seconds per word with an inter-stimulus interval of zero seconds. Following the study phase, a red screen appeared for three seconds to indicate that the study phase for that block was over and the test phase for that block would begin.

During the test phase of each block, participants were presented with ten old words taken from the study list and ten new words. Participants were asked to indicate, using the keyboard, if the test phase words were new or old relative to the study phase words. Participants pressed the key labeled ‘yes’ if the word at testing had been presented during studying and pressed the key labeled ‘no’ if the word was at testing had not been presented during studying. Again, the words in the test phase were presented in black lowercase letters in the center of a white screen at the rate of three seconds per word with an inter-stimulus interval of zero seconds. Between each block of study and test, a white screen with the word ‘break’ in capital letters appeared for five seconds to indicate that the participants was moving on to a new block. Participants were told that sometimes music would be playing in the background as they performed the task but they did not need to pay any attention to it because they would not be asked to make any decisions about it. Before beginning the actual task, participants performed a practice block that consisted of 10 words to ensure comprehension of the task. All participants provided written informed consent and were fully debriefed after the experiment.

Statistical Analysis

Performance was analyzed the same way as was described in Experiment 1A.

Results

Analyses of recognition performance using percent correct and corrected hit rate showed comparable results; therefore, only the analysis of corrected hit rate is reported. All data sets were included in the analysis. Mauchly’s Test of Sphericity indicated that the assumption of sphericity had not been violated, $\chi^2(2) = 3.270$, $p = 0.195$, and therefore, all statistics are reported with sphericity assumed. There were no main effects of musical mood, $F(1, 29) = 0.355$, $p = 0.556$, musical arousal, $F(1, 29) = 3.172$, $p = 0.085$, or context, $F(2, 58) = 2.506$, $p = 0.090$.

There were significant interactions between musical mood and musical arousal, $F(1, 29) = 4.608$, $p = 0.040$, $\eta^2 = 0.137$, and musical arousal and context, $F(2, 58) =$

3.489, $p = 0.037$, $\eta^2 = 0.107$. The two-way interaction between musical mood and musical arousal occurred because participants recognized more words correctly with LAN music compared to HAN music, $t(89) = 2.805$, $p = 0.006$. However, there were no significant differences in recognition performance between HAP and LAP music, $t(89) = 0.124$, $p = 0.901$ (Figure 12). The two-way interaction between musical arousal and context was driven by poor recognition performance for high arousal music when it was played at both study and test. Participants recognized more words correctly with low arousal music compared to high arousal music when music was played at study and at test, $t(59) = 2.796$, $p = 0.007$. However, musical arousal did not significantly affect recognition performance when music was played at study only, $t(59) = 0.910$, $p = 0.366$, or at test only, $t(59) = 1.642$, $p = 0.106$ (Figure 13). The two-way interaction between musical mood and context was not significant, $F(2, 58) = 0.059$, $p = 0.942$, $\eta^2 = 0.002$. There was also no significant interaction between musical mood, musical arousal, and context, $F(2, 58) = 1.266$, $p = 0.290$, $\eta^2 = 0.042$ (Figure 14).

Discussion

In Experiment 3B, participants performed a recognition task that required learning and recognizing learned words from new words while silence or music was present in the background. When the music was played at both study and test, better recognition performance was observed when participants listened to low arousal music compared to high arousal music. The finding that performance was better with low arousal music was consistent with the findings in Experiments 2B and 3A. In Experiments 2B, low arousal music also had a beneficial effect on recognition performance, particularly when the context at study was similar to the context at test. However, in Experiment 3A, the

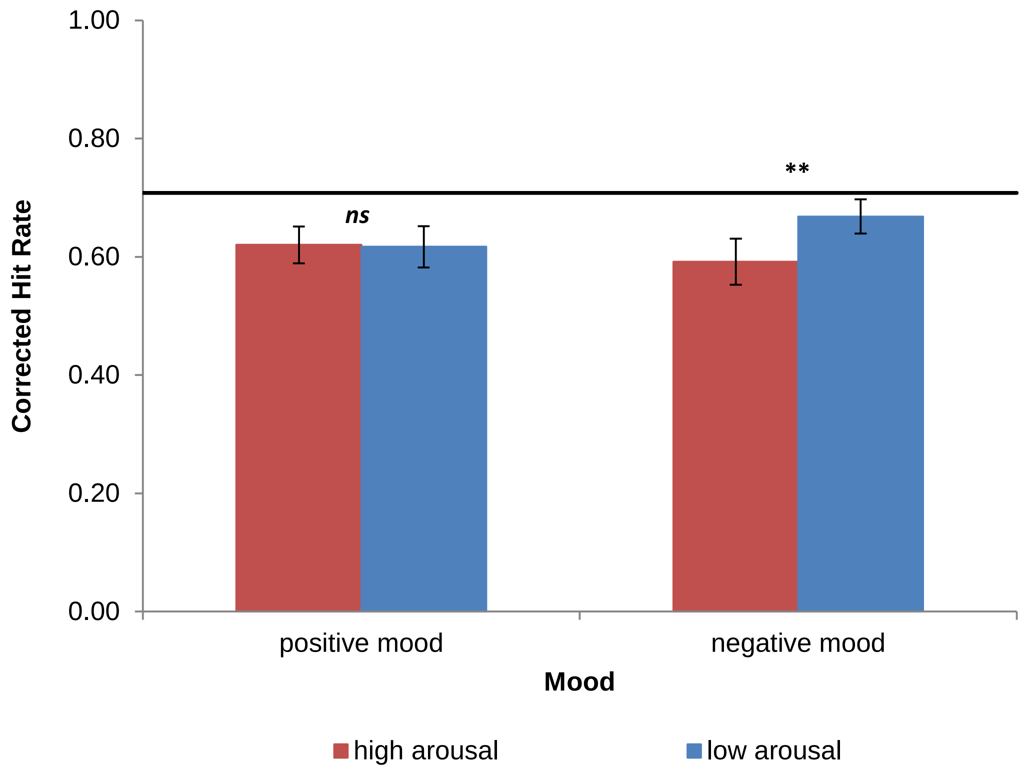

Figure 12. The significant two-way interaction between musical mood and musical arousal for Experiment 3B. Participants recognized more words correctly with LAN music compared to HAN music, but there was no significant difference in performance between HAP and LAP music. The solid black line represents performance in the silent condition. Error bars indicate standard error of the mean. ** $p < .01$.

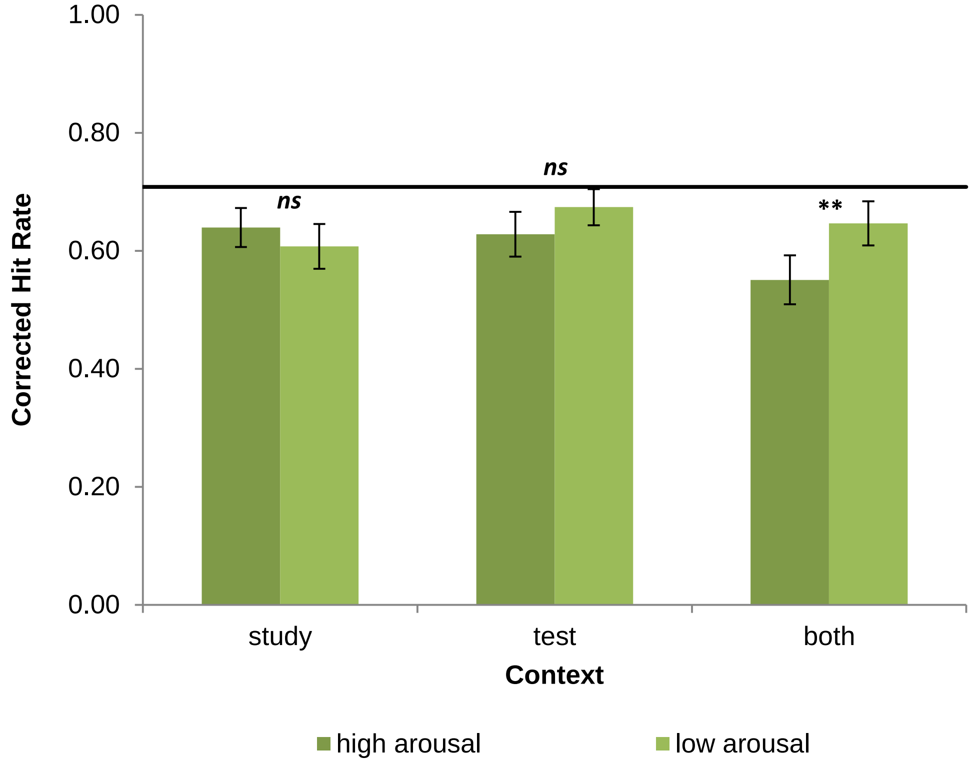

Figure 13. The significant two-way interaction between musical arousal and context for Experiment 3B. Participants recognized more words correctly with low arousal music compared to high arousal music when music was played at study and at test. However, arousal did not significantly affect recognition performance when music was played at study only or at test only. The solid black line represents performance in the silent condition. Error bars indicate standard error of the mean. ** p < .01.

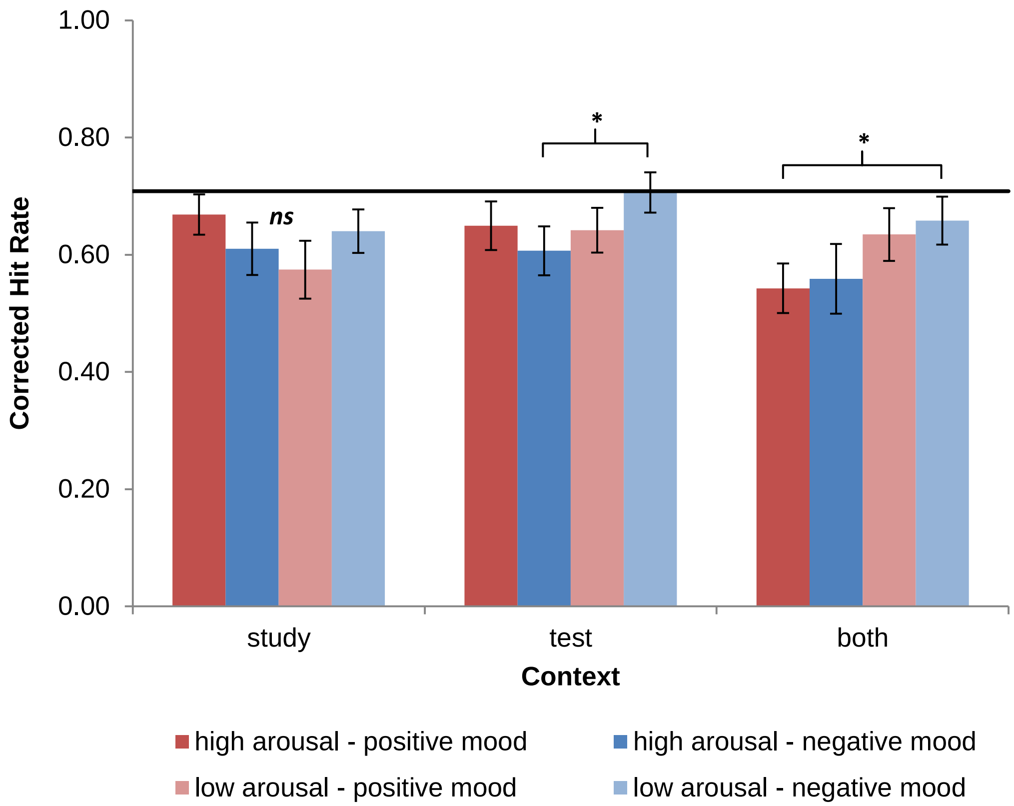

Figure 14. The three-way interaction between musical mood, musical arousal, and context for Experiment 3B. The significant differences between LAN and HAN (when music was played at test only) and LAN and HAP (when music was played at study and at test) were most likely because the significant two-way interactions were encompassed within the non-significant three-way interaction between musical mood, musical arousal, and context. The solid black line represents performance in the silent condition. Error bars indicate standard error of the mean. * p < .05.

beneficial effect of low arousal music was not limited to whether the music was played at study only, at test only, or at both study and test. One explanation is that high arousal music may have elicited too much arousal, which adversely affected performance (Yerkes & Dodson, 1908), and by having it presented at study and at test, high arousal music had a detrimental effect on memory performance. Meanwhile, low arousal music had a positive effect on memory because an optimal level of arousal was elicited. In addition, recognition performance was equally poor when participants listened to HAP and HAN music compared to LAN music. This finding was consistent with the prediction that LAN music would improve recognition performance, but not consistent with the prediction that HAP music would also improve performance (Greene et al., 2010). The effects in Experiment 1 should have been observed here, as the experimental design was similar, except for the memory task. However, the lack of interaction between mood and arousal when music was presented at study and at test suggested that the effects observed in Experiment 1 do not occur in recognition memory. Therefore, it is possible that the interaction of musical mood, musical arousal, and context is limited to association memory.

Experiment 3C

Experiment 3C compared the effects of musical mood, musical arousal, and context on an association task relative to the recall task in Experiment 3A and the recognition task in Experiment 3B. The task that participants performed in Experiment 3C was similar to the paired-association task used in Experiments 1 and 2. However, instead of using faces and names, pairs of words were used to keep Experiment 3C standardized with Experiments 3A and 3B. After studying 20 word pairs in the study phase, participants immediately completed the test phase, in which they determined whether the word pairings in the test phase matched the study phase. Musical mood, musical arousal, and context were operationalized the same way as in Experiments 3A and 3B. The aim of Experiment 3C was to examine whether the lack of replication between Experiment 2 and previous literature was related to the type of memory tested. If the interaction of musical mood, musical arousal, and context is limited to association memory then the effects observed in Experiment 1 should be replicated here because the experimental paradigm was identical across the two experiments, except that words are used instead of faces and names. HAP and LAN music should elicit better recognition performance than HAN and LAP music, especially when the music is played at both study and test (Greene et al., 2010; Smith, 1985; Tulving & Thomson, 1973). Alternatively, if the results of Experiment 3C do not replicate the results of Experiment 1 then it is possible that the effects of musical mood, musical arousal, and context vary with different stimuli and different memory tasks.

Method

Participants

Participants were 33 undergraduate students (16 females and 17 males) from the University of Western Ontario (M_{age} = 19.27 years, *SD* = 2.81 years). They were recruited from the Psychology Research Participation Pool and were compensated one research credit for one hour of participation. None had participated in any other experiments in this thesis. This experiment was approved by the Psychology Ethics Review Board at the University of Western Ontario.

Materials

Musical stimuli. The musical stimuli were identical to those described in Experiment 1A (Table 1 in Appendix A).

Visual stimuli. A total of 540 English words were used (Table 3 in Appendix B). The words were all nouns approximately five to nine letters in length (*M* = 6.61 letters ± 1.22 letters), with a written mean frequency of 2.50 per million words (*SD* = 3.05 per million words) according to the CELEX database (Baayen et al., 1995). Word frequency was equivalent across the 13 word lists.

Procedure

The experiment consisted of 13 blocks of studying and testing: 12 experimental blocks and one silent block. Each participant was exposed to all 13 blocks that were randomly ordered by the E-Prime (2.0) program (Psychology Software Tools, 2002). During the study phase of each block, participants learned a list of 20 randomly ordered word pairs. The words were presented in black lowercase letters that was separated by a '+' in the center of a white screen at the rate of three seconds per pair with an inter-stimulus interval of zero seconds. Following the study phase, a red screen appeared for three seconds to indicate that the study phase for that block was over and the test phase for that block would begin.

During the test phase of each block, participants were presented with the same 20 word pairs, but some of the pairings were swapped. Of the 20 word pairs, ten pairs were kept the same between the study phase and the test phase and ten pairs were swapped. For example, the word "patio", which was originally paired with the word "eraser" in the study phase, could be paired with the word "jaguar" in the test phase and the word originally paired with “jaguar” could be paired with the word “eraser”. Participants were asked to indicate, using the keyboard, if the test pairings were the same as the study pairings. Participants pressed the key labeled ‘yes’ if the pairing at testing was the same as the pairing at studying and pressed the key labeled ‘no’ if the pairing was different. Again, the words in the test phase were presented in black lowercase letters, separated by a ‘+’ in the center of a white screen at the rate of three seconds per pair with an inter-stimulus interval of zero seconds. Between each block of study and test, a white screen with the word ‘break’ in capital letters appeared for five seconds to indicate that the participants was moving on to a new block. Participants were told that sometimes music would be playing in the background as they performed the task but they did not need to pay any attention to it because they would not be asked to make any decisions about it. Before beginning the actual task, participants performed a practice block that consisted of 10 word pairs to ensure comprehension of the task. All participants provided written informed consent and were fully debriefed after the experiment.

Statistical Analysis

Performance was analyzed the same way as was described in Experiment 1A.

Results

Only the analysis for the corrected hit rate scores is reported because the analyses using the percent correct and corrected hit rate scores showed comparable results. Data from three participants were removed from the analysis due to a large number of missing responses. Any data set with half of the responses missing from any of the blocks was removed. Mauchly’s Test of Sphericity indicated that the assumption of sphericity had not been violated, $\chi^2(2) = 3.162$, $p = 0.206$, and therefore, all statistics are reported with sphericity assumed. There were no main effects of musical mood, $F(1, 29) = 0.004$, $p = 0.951$, musical arousal, $F(1, 29) = 0.001$, $p = 0.975$, or context, $F(2, 58) = 0.775$, $p = 0.465$. There were no significant interactions between musical mood and musical arousal, $F(1, 29) = 1.702$, $p = 0.202$, $\eta^2 = 0.055$, musical mood and context, $F(2, 58) = 0.260$, $p = 0.772$, $\eta^2 = 0.009$, and musical arousal and context, $F(2, 58) = 0.431$, $p = 0.625$, $\eta^2 = 0.015$. Finally, there was also no significant interaction between musical mood, musical arousal, and context, $F(2, 58) = 0.068$, $p = 0.934$, $\eta^2 = 0.002$. Thus, there were no significant differences in performance across all 12 conditions (Figure 15).

Discussion

In Experiment 3C, participants performed a paired-association task that required learning and recognizing word pairs while silence or music was present in the background. There were no significant effects of musical mood, musical arousal, or context on performance. In fact, performance was similar across all 12 conditions. The findings in Experiment 3C were inconsistent with the findings in Experiment 1, which showed that musical mood, musical arousal, and context acted simultaneously to affect memory performance. The non-significant effects were also inconsistent with previous literature that has suggested that specific combinations of mood and arousal, particularly HAP and LAN music, were critical for enhanced memory performance (Greene et al., 2010). Perhaps the interactive effect of musical mood and musical arousal does not occur with word stimuli as the to-be-remembered items, as previous work used abstract shapes and Experiments 1 and 2 used face-name pairs. Musical mood and musical arousal may have differential effects on different types of stimuli (Biss et al., 2010). In fact, previous literature suggested that mood and arousal have opposite effects on spatial information,

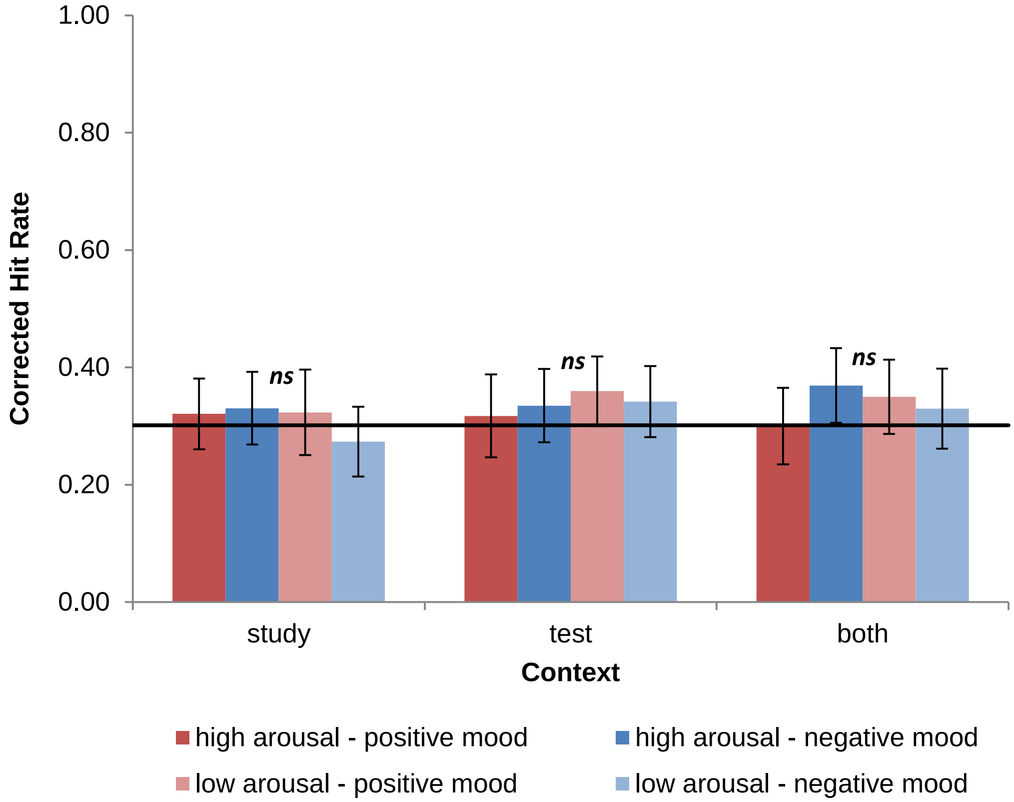

Figure 15. The three-way interaction between musical mood, musical arousal, and context for Experiment 3C. There were no significant differences in performance across all twelve conditions. The solid black line represents performance in the silent condition. Error bars indicate standard error of the mean.

such as faces and shapes, and verbal information, such as words (Gray et al., 2002). Music may also have different effects on different types of learning (Ho, Cheung, & Chan, 2003). For example, music can enhance spatial learning (Rauscher, Shaw, & Ky, 1993), but can have no effect on, or even interfere with, verbal learning (Salamé & Baddeley, 1989). It is possible that the interactive effect of musical mood and musical arousal was specific to spatial learning and spatial stimuli because the interaction was not seen with word stimuli in Experiment 3. Taken together, musical mood and musical arousal seemed to have varying effects at different stages of learning and memory performance, as well as for different types of learning.

Chapter 5

General Discussion

The purpose of this thesis was to examine how musical mood, musical arousal, context, or some combination of these factors affects memory for previously learned items. Past literature has examined the interaction between musical mood and musical arousal on recognition memory (Greene et al., 2010), as well as the context effect of music on recall and recognition memory (Smith, 1985), but has never looked at the effect of all three factors together or tested association memory. This thesis built upon the literature by investigating how the combination of all these factors affects association memory. Participants were tested with a paired-association task that required learning and recognizing face-name pairs while music was played in the background. Differences in performance were predicted based on two primary hypotheses: (1) HAP and LAN music would enhance memory compared to HAN and LAP music (Greene et al., 2010), and (2) music would establish a context at study that, when reinstated at test, would enhance memory (Smith, 1985).

Experiment 1 revealed that musical mood, musical arousal, and context act concurrently to affect memory. In Experiment 1A, participants were tested with music chosen based on other participants' ratings of mood and arousal in a pilot experiment, while in Experiment 1B, the music was chosen based on each participant's own ratings of mood and arousal. The results showed that experimenter-selected (Experiment 1A) and participant-selected music (Experiment 1B) did not differ in their effect on memory. In both experiments, recognition performance was better when participants listened to HAP music compared to HAN music, and LAN music compared to LAP music. However, this interactive effect of mood and arousal was only observed when music was played at both study and test. It is possible that in the absence of the beneficial effect produced by positive mood, high arousal music lowered memory performance (Greene et al., 2010). Therefore, HAN music reduced memory performance, whereas HAP music improved memory performance. However, positive mood alone did not improve memory, as LAP music did not improve performance. The 'plaintive' state produced by the combination of low arousal and negative mood may have led to more detailed processing, which in turn lead to more detailed representation of the to-be-remembered items, and thus facilitated memory (Jefferies, Smilek, Eich, & Enns, 2008). The enhancement produced by HAP and LAN music and the detraction produced by HAN and LAP music on memory performance when the same music was played at study and at test suggested that having a similar context at study and at test made have yielded the mood and arousal interaction. However, it is uncertain whether the facilitation effect of some types of music on memory can be attributed to the presence of the same musical piece, or the presence of the same mood and same arousal properties at both study and test.

Experiment 2 examined whether better recognition performance was driven by the reinstatement of congruent musical pieces (Experiment 2A) or congruent emotional states (Experiment 2B) when music was played at both study and test. Experiment 2A examined whether repeating a specific musical piece would establish a perceptual context that could improve recognition performance. Consequently, participants either heard the same piece of music at study and at test, or two different pieces of music but with matched mood and arousal levels. In Experiment 2A, recognition performance was not significantly different across conditions, suggesting that reinstating the same musical piece at study and at test did not improve performance. However, there was a notable trend that low arousal music facilitated better recognition performance than high arousal music, specifically when the same musical piece was played at study and at test. Experiment 2B examined whether the mood and arousal of the music were able to establish emotional contexts that could improve recognition performance, without reinstating the same musical piece. In Experiment 2B, participants always heard different pieces of music between study and test, but the pieces were matched or mismatched on levels of mood and arousal. For low arousal music, recognition performance was significantly better when the same mood and arousal was reinstated at study and at test. Therefore, low arousal music facilitated better recognition performance than high arousal. The findings of Experiment 2B were similar to Experiment 1, in that LAN music improved recognition performance while HAN music reduced recognition performance. However, unlike Experiment 1, HAP music did not improved performance and LAP music did not reduced performance. Experiment 2 indicated that low arousal music enhanced memory performance more than high arousal music, especially when the musical mood was negative. It seems that arousal paired with negative mood might contribute more to the enhancement of memory than context. In the literature, the context effect of music were often assessed using a recall or recognition task and these effects were consistent with the encoding-retrieval specificity hypothesis (Balch & Lewis, 1996; Balch et al., 1992; Mead & Ball, 2007). However, the results of Experiment 2 were not consistent with past literature. It is possible that the context effects of music were not observed because the effects do not apply to association memory.

Experiment 3 compared the effects of musical mood, musical arousal, and context on association (Experiment 3C) memory relative to recall (Experiment 3A) and recognition (Experiment 3B) memory. Across the three experiments, words were used as the to-be-remembered items rather than faces and names to keep the stimuli standardized between the three memory tasks. In Experiment 3A, participants were tested with a recall task. Participants recalled more words with low arousal music than high arousal music. In Experiment 3B, participants were tested with a recognition task. Again, participants also recognized more words correctly with low arousal music than high arousal music. Specifically, LAN music was more beneficial to recognition performance than HAN music. The results of Experiments 3A and 3B showed a similar trend for arousal that was observed in Experiment 2B. In Experiment 3C, participants were tested with a paired-association task that required learning and recognizing word pairs. Unlike Experiments 3A and 3B, memory performance was similar across all conditions in Experiment 3C. There were no significant effects of musical mood, musical arousal, or context on association performance. Perhaps the added level of association to the recognition task made the task more difficult; especially because the word pairings were designed to be unrelated, therefore no significant effects emerged in Experiment 3C. Also, the lack of replication between Experiments 1 and 3C suggested that the music has different effects on memory for different stimuli because the only difference between the two experiments was the to-be-remembered items. It is possible that the effects observed in Experiment 1 were specific to faces and names because such effects were not consistent with words in Experiment 3C.

Theoretical Explanations

Across all the experiments in this thesis, the most consistent effect was that low arousal music improved memory performance while high arousal music reduced memory performance. This finding was consistent with the Yerkes-Dodson law of arousal and task performance. Specifically, too little or too much arousal is associated with poor performance, but at moderate level, arousal is associated with improved performance (Yerkes & Dodson, 1908). Low arousal music may have elicited the optimal level of arousal in the participants, and thus memory was enhanced. Alternatively, there could be something about high arousal music that was detrimental to memory performance. One explanation is that high arousal music elicited too much arousal, and therefore performance was negatively affected (Yerkes-Dodson, 1908). Instead of energizing participants, high arousal music may have taxed them, and therefore performance was decreased. Also, when arousal is too high then attention is easily diverted (Dutton & Carroll, 2001). High arousal music might have been too distracting; therefore, attention was allocated to processing the music rather than the memory task, and performance was decreased. However, it is unclear why the effect of arousal was more consistent when the musical mood was negative rather than positive.

In four of the seven experiments in this thesis, LAN music had a beneficial effect on memory performance while HAN music had a detrimental effect. There may be something about negative music that when paired with arousal affected memory performance. This view is consistent with the arousal and mood hypothesis that posits that cognition is likely mediated by changes in the listener's mood and arousal states (Thompson et al., 2001). In past literature, the plaintive state of low arousal and negative mood has been associated with more detailed representations of the to-be-remembered items and improved attention, which resulted in better memory performance (Basso et al., 1996; Gasper & Clore, 2002; Jefferies et al., 2008). Therefore, when negative mood was paired with low arousal, it is possible that the optimal emotional state for enhanced memory performance was reached. However, when negative mood was paired with high arousal, the beneficial effect of negative mood may have been counteracted by the detrimental effect of high arousal and thus performance was hampered. An alternative view would be that positive mood had a variable effect on memory performance, explaining why a consistent effect of positive mood on memory was not observed. Some studies have shown that positive mood facilitated memory by broadening attention, and thus making task-relevant information more accessible (Rowe et al., 2007). However, other studies showed that positive mood reduced memory by also broadening attention for task-irrelevant information, and thus reduced memory storage capacity for task-relevant information (Martin & Kerns, 2011). The variable effect of positive mood on memory explains why the results of this thesis indicated that arousal when paired with negative mood has the most prominent effect on memory.

Although the musical mood and musical arousal effects were most prominent when the context at study and at test was similar, the effects were inconsistent with the encoding-retrieval specificity hypothesis. According to the encoding-retrieval specificity hypothesis, memory is facilitated when the retrieval contexts are consistent with the encoding contexts (Tulving & Thomson, 1973). Therefore, the encoding-retrieval specificity effect should have been observed in all four music conditions in Experiment 1. Furthermore, presenting the same musical piece (Experiment 2A) or the same mood and arousal states (Experiment 2B) at study and at test should have enhanced memory performance. However, no such effects were observed in Experiments 1 or 2. Under a wide range of conditions, many studies have demonstrated that the encoding-retrieval specificity hypothesis is not always supported (Fernandez & Glenberg, 1985; Newman et al., 1982; Saufley, Otaka, & Bavaresco, 1985). For example, the encoding-retrieval specificity effect fails to emerge when the encoding task involves imagery or self-referencing (McDaniel, Anderson, Einstein, & O'Halloran, 1989). Although there are no ways of confirming (without future research) if participants used imagery or self-referent processes to encode the to-be-remembered items, it is important to note that the encoding-retrieval specificity effect may not always be predictable without considering all the limitations of the theory.

Even though the results of this thesis did not support the encoding-retrieval specificity hypothesis, they do suggest that mood, arousal, and context act simultaneously to affect memory. For example, in Experiment 1, the interactive effect of mood and arousal was only observed when the music was played at both study and test. That is, HAP and LAN music enhanced recognition performance, while HAN and LAP music reduced recognition performance, when the context was kept the same. Similarly, in Experiments 2B and 3B, when the context at study and at test was the same, low arousal music enhanced performance compared to high arousal music. Specifically, LAN music was more beneficial to performance than HAN music. A similar trend for arousal was also seen in Experiment 2A; however, the effect was not statistically significant. The results seem to indicate that increasing the amount of music exposure resulted in a strengthening of the effects produced by mood and arousal. It is possible that the effect of HAN music was so adverse that participants did not benefit from having the music presented at study and then repeated at test. The same could be said about the enhancing effect of LAP music. LAP music enhances performance; therefore, participants benefitted by having the same context at study and at test.

Although certain trends did emerge in this thesis, taken together, there was still a great deal of variability between the experiments. The results of Experiment 1A was replicated in Experiment 1B, but the effect was only replicated when music was played at both study and test. When music was played at study only or at test only, musical mood and musical arousal produced different results in Experiment 1A (experimenter-selected music) and Experiment 1B (participant-selected music), even though those effects were not statistically different. In Experiment 2, the manipulation of context also produced different results. No significant effects were observed when the perceptual context of a musical piece was reinstated (Experiment 2A). Meanwhile, in Experiment 2B, low arousal music enhanced recognition performance when the same emotional context was present at study and at test. Finally, the manipulation of memory task in Experiment 3 also yielded variable results. Performance on the recall (Experiment 3A) and the recognition task (Experiment 3B) yielded similar results, but performance on the association task (Experiment 3C) yielded no significant effects. Some of these inconsistences between experiments could be the choice of task, the choice of stimuli, the music manipulation, or individual differences between participants.

Implications and Limitations

The results of this thesis have provided valuable insights on how music might affect learning and memory. In particular, this thesis demonstrated that together musical mood, musical arousal, and context can have a significant effect on memory performance. The results showed that low arousal music is associated with enhanced memory performance while high arousal music is associated with lowered memory performance, particularly when arousal is paired with negative mood. Furthermore, the effects of mood and arousal are most robust when the context at study is similar to the context at test. Although this thesis has added to our understanding of how musical mood and musical arousal, presented under different contexts, affect memory performance, it does not fully resolve the contradictions found in the literature and the inconsistencies between the experiments presented in this thesis. In order for future research to resolve some of these contradictions and inconsistences, limitations for this thesis should be discussed.

In this thesis, music was used as a method of inducing changes to the participant's internal mood and arousal levels. However, no physiological measures of mood and arousal were obtained. Without physiological measures, there are no ways of confirming that the music elicited the expected levels of mood and arousal and whether those changes were equally successful for both dimensions. It is possible that the effect of arousal was more prominent than mood in this thesis because the music was more effective at inducing changes in arousal than changes in mood. Previous studies have demonstrated that changes in mood and arousal can be successfully quantified by psychophysiological measures of cardiac, vascular, and respiratory function (Krumhansl, 1997; Rickard, 2004; Salimpoor et al., 2009). Therefore, future research will benefit by obtaining more objective measures of mood and arousal and examining their effects on memory.

Another limitation of this thesis was that certain individual differences were not accounted for. Differences in study habits, musical training, musical preferences, as well as a myriad of other factors could all influence how a participant performed on the memory task (Chan, Ho, & Cheung, 1998; Ho et al., 2003; Nantais & Schellenberg, 1999). For example, a participant who seldom studies with music would probably perform differently on a memory task compared to a participant who frequently studies to music. In fact, one study demonstrated that participants who often study with background music perform better on a memory task in the presence of music, while those who do not study with music perform better in silence (Etaugh & Ptasnik, 1982). These individual differences were not addressed in this thesis. Therefore, future research should consider administering a background questionnaire to account for some of these individual differences.

One final limitation was that all the factors in this thesis were designed to be within-subjects variables. One advantage of a within-subjects design is the reduction in variance associated with individual differences. Another advantage of a within-subjects design is that statistical power is increased, especially given a smaller sample size. However, the use of a within-subjects design required participants to learn and remember multiple lists of items in a short period of time. Other studies that have examined the effects of music on memory were often between-subjects design; therefore participants were required to commit only a few items to memory (Balch & Lewis, 1996; Balch et al., 1992; Mead & Ball, 2007). For that reason, the participants, in this thesis, may not have been given the best opportunity to learn and any effects that music might have had on memory were too small to be significant. Therefore, future research might benefit from a different experimental design. Perhaps if musical mood and musical arousal were between-subject variables then participants would not be required to commit hundreds of items to memory. Meanwhile, context could be kept as a within-subjects variable to retain some of the advantages of a within-subjects design. Future research would also benefit with more trials per conditions to reduce some of the variability in the data.

Conclusion

The main purpose of this thesis was to distinguish whether the effect of music on memory was attributable to musical mood, musical arousal, context, or a combination of these factors. The results indicated that the most consistent contrast between conditions was between low arousal and high arousal music. That is, low arousal music enhanced memory performance while high arousal music reduced memory performance, particularly when arousal was paired with negative mood and when the context at study and at test was similar. However, this effect was not consistently shown across all seven experiments. The variability between the experiments in this thesis is mirrored by the variability that currently exists in the literature. Therefore, the effects of musical mood, musical arousal, and context on learning and memory need further examination.

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Appendix A – Music Stimuli

Table 1. *Mean ratings of arousal and mood for the music used in Experiment 1A and Experiment 3.*

Music	Condition	Arousal Rating		Mood Rating	
		M	*SD*	*M*	*SD*
01. Montenegro.wav	HAPS	2.333	0.617	1.667	1.047
02. SatchBoogie.wav	HAPT	2.267	1.280	1.733	1.335
03. Ghosts.wav	HAPB	2.467	1.125	2.133	0.990
04. Burn1.wav	HANS	1.933	1.486	-1.267	1.534
05. SFX.wav	HANT	1.533	2.042	-1.200	1.506
06. TemptingTime.wav	HANB	1.667	1.356	-1.533	2.093
07. ComeHomeTo.wav	LAPS	-1.000	1.580	1.067	1.414
08. KillerJoe.wav	LAPT	-1.133	0.990	0.867	1.407
09. HelloMyLovely.wav	LAPB	-1.267	1.521	0.800	1.486
10. PoliceFire.wav	LANS	-2.467	0.900	-1.333	0.743
11. SadPiano.wav	LANT	-2.200	1.767	-1.133	0.862
12. ChopinPreludeE.wav	LANB	-1.733	0.704	-1.933	1.335

01. Montenegro – David Guetta
02. Satch Boogie – Joe Satriani
03. Ghost N Stuff – Deadmau5
04. Burn – Apocalyptica
05. SFX – The Upbeats
06. Tempting Time – Animals as Leaders
07. You’d be So Nice to Come Home to – Cole Porter
08. Killer Joe – Benny Golson
09. Hello My Lovely – Charlie Haden Quartet West
10. Static – Godspeed You Black Emperor!
11. Hear Me Cry – Thomas C. Sanchez
12. Prelude in E-Minor (Op. 28: No. 4) – Frédéric Chopin

Table 2. *Mean ratings of arousal and mood for the music used in Experiment 2A.*

Music	**Condition**	**Arousal Rating**		**Mood Rating**	
		M	*SD*	*M*	*SD*
01. Ghosts.wav	HAPS	2.467	1.125	2.133	0.990
02. Escape.wav	HAPD	2.067	1.163	1.733	1.335
03. SurfingAlien.wav	HAPD	2.067	1.685	1.533	1.534
04. TemptingTime.wav	HANS	1.667	1.356	-1.533	2.093
05. Kellot.wav	HAND	1.333	1.100	-1.267	1.877
06. TarzanFight.wav	HAND	1.333	1.335	-1.733	0.900
07. ComeHomeTo.wav	LAPS	-1.000	1.580	1.067	1.414
08. HelloMyLovely.wav	LAPD	-1.267	1.521	0.800	1.486
09. KillerJoe.wav	LAPD	-1.133	0.990	0.867	1.407
10. ChopinPreludeE.wav	LANS	-1.733	0.704	-1.933	1.335
11. SadPiano.wav	LAND	-2.200	1.767	-1.133	0.862
12. TigerDragon.wav	LAND	-2.333	1.302	-1.133	0.488

01. Ghost N Stuff – Deadmau5
02. Escape – Fictivision
03. Surfing with the Alien – Joe Satriani
04. Tempting Time – Animals as Leaders
05. Kellot – Apocalyptica
06. Die Gorillas – Various Artists
07. You’d be So Nice to Come Home to – Cole Porter
08. Hello My Lovely – Charlie Haden Quartet West
09. Killer Joe – Benny Golson
10. Prelude in E-Minor (Op. 28: No. 4) – Frédéric Chopin
11. Hear Me Cry – Thomas C. Sanchez
12. Crouching Tiger, Hidden Dragon – Tan Dun with Yo-Yo Ma

Table 3. *Mean ratings of arousal and mood for the music used in Experiment 2B.*

Music	**Condition**	**Arousal Rating**		**Mood Rating**	
		M	*SD*	*M*	*SD*
01. Carnival.wav	HAP	1.867	1.187	1.733	1.438
02. DieToLive.wav	HAP	1.000	0.834	1.133	1.852
03. Escape.wav	HAP	2.067	1.163	1.733	1.335
04. NotAPressure.wav	HAP	1.667	1.242	1.600	1.047
05. SatchBoogie.wav	HAP	2.267	1.280	1.733	1.335
06. Burn1.wav	HAN	1.933	1.486	-1.267	1.534
07. Kellot.wav	HAN	1.333	1.100	-1.267	1.877
08. LionelRichie1.wav	HAN	1.267	1.163	-0.867	1.598
09. TarzanFight.wav	HAN	1.333	1.335	-1.733	0.900
10. TemptingTime.wav	HAN	1.667	1.356	-1.533	2.093
11. Akiko.wav	LAP	-0.533	1.033	0.733	1.187
12. ComeHomeTo.wav	LAP	-1.000	1.580	1.067	1.414
13. GiveYouAway.wav	LAP	-0.533	0.845	1.000	1.506
14. HelloMyLovely.wav	LAP	-1.267	1.521	0.800	1.486
15. KillerJoe.wav	LAP	-1.133	0.990	0.867	1.407
16. ChopinPreludeE.wav	LAN	-1.733	0.704	-1.933	1.335
17. ImWishing.wav	LAN	-1.733	0.961	-0.867	1.356
18. QuasiAdagio.wav	LAN	-1.400	1.699	-1.800	1.882
19. TigerDragon.wav	LAN	-2.333	1.302	-1.133	0.488
20. WhatAmI2.wav	LAN	-2.067	1.280	-1.067	1.223

01. Carnival Overture (Op. 92) – Antonín Dvořák
02. Die to Live – Steve Vai
03. Escape – Fictivision
04. Not a Pressure – Unknown
05. Satch Boogie – Joe Satriani
06. Burn – Apocalyptica
07. Kellot – Apocalyptica
08. You’re Lionel Richie – Mogwai
09. Die Gorillas – Various Artists
10. Tempting Time – Animals as Leaders
11. Akiko – Guitar
12. You’d be So Nice to Come Home to – Cole Porter
13. The Little Things Give You Away – Linkin Park
14. Hello My Lovely – Charlie Haden Quartet West
15. Killer Joe – Benny Golson
16. Prelude in E-Minor (Op. 28: No. 4) – Frédéric Chopin
17. I’m Wishing – Frank Churchill
18. Piano Concerto No. 1 in E-Flat Major – Franz Liszt
19. Crouching Tiger, Hidden Dragon – Tan Dun with Yo-Yo Ma
20. I Know You Are But What Am I? – Mogwai

Appendix B – Word Stimuli

Table 4. *Words used in Experiment 3A.*

List A	List B	List C	List D	List E	List F	List G
sardine	carpenter	cookie	acrobat	tangerine	artichoke	crocodile
glitter	lobster	bracelet	compass	pharaoh	hooligan	pasta
octagon	gasoline	quilt	jester	mitten	python	soccer
tassel	bandit	rectangle	oasis	squash	berry	ukulele
fossil	haddock	ravine	cheetah	lasagna	folder	buffalo
maiden	ballad	florist	gecko	tuxedo	cinnamon	viper
vulture	coupon	torso	nectarine	valve	blazer	goblin
repellent	tortoise	venue	fiddle	panda	magician	poodle
washer	moccasin	shovel	antelope	shampoo	footage	sculptor
cedar	ghoul	walnut	limerick	dandelion	alpaca	comedian
pylon	alfalfa	shingle	kernel	apricot	legume	errand
samurai	ignition	enigma	stencil	toucan	avalanche	thimble
niece	goblet	mirage	platypus	librarian	messenger	nemesis
acorn	gargoyle	veteran	hiccup	ladle	gladiator	parachute
gondola	alibi	hornet	mullet	juror	crumb	icicle
warden	ointment	opera	melody	barbecue	butcher	camper
rooster	chemical	drummer	salami	reptile	manicure	migraine
stroller	dresser	scallop	lotus	vaccine	mascot	pecan
generator	arcade	mafia	smoothie	sandal	roulette	disco
sensor	mixer	appetizer	entourage	scenario	giraffe	caramel

List H	List I	List J	List K	List L	List M	Practice
racket	integer	khaki	tabloid	ketchup	toddler	hyphen
plaque	tapestry	amethyst	tulip	hockey	stapler	spout
mango	porcupine	kitten	paddle	bonnet	pulley	toboggan
asteroid	thyme	mower	rudder	prune	clove	parrot
clarinet	calculus	escalator	lavender	cucumber	cafeteria	raffle
skillet	volcano	possum	yacht	pigeon	dingo	gallon
monitor	vortex	cashew	umpire	pilgrim	dessert	fleece
balloon	giggle	bunny	heiress	lasso	zucchini	itinerary
ballerina	violet	cougar	pelican	hurricane	appliance	patio
spider	cadet	mussel	wrapper	baboon	igloo	cartoon
blizzard	dormitory	ripple	diagonal	plaza	accordion	
crater	nickel	martyr	coaster	maple	banana	
garnish	tangle	broccoli	waffle	locket	beverage	
limousine	genie	trash	mascara	marmalade	eclipse	
jockey	mentor	gasket	mural	droplet	zipper	
petal	alphabet	parasite	emblem	sheriff	trumpet	
bongo	puppy	pestle	orangutan	plaintiff	ransom	
bakery	anthem	pretzel	tailor	cactus	mannequin	
weasel	stork	banquet	bristle	anvil	hydrant	
piano	incense	scorpion	cider	vinyl	feather	

Table 5. *Words used in Experiment 3B (in addition to the words listed in Table 4).*

List A	**List B**	**List C**	**List D**	**List E**	**List F**	**List G**
mackerel	plumber	biscuit	trapeze	citrus	asparagus	alligator
confetti	shrimp	anklet	navigator	mummy	scoundrel	macaroni
hexagon	propane	duvet	joker	glove	serpent	lacrosse
ruffle	robber	pentagon	utopia	badminton	cherry	banjo
dinosaur	halibut	lagoon	jaguar	casserole	portfolio	bison
damsel	sonnet	bouquet	iguana	attire	ginger	cobra
falcon	voucher	navel	peach	funnel	cardigan	gremlin
mosquito	turtle	stadium	violin	koala	wizard	beagle
dryer	slipper	hatchet	gazelle	dandruff	video	figurine
birch	phantom	almond	rhyme	daffodil	llama	clown

List H	**List I**	**List J**	**List K**	**List L**	**List M**	**Practice**
rattle	digit	trouser	celebrity	mustard	diaper	decimal
trophy	drapery	sapphire	petunia	goalie	sharpener	faucet
papaya	armadillo	whisker	canoe	toque	magnet	sleigh
meteor	oregano	sprinkler	propeller	raisin	basil	parakeet
flute	algebra	stair	jasmine	pickle	diner	lottery
spatula	magma	raccoon	anchor	quail	coyote	
printer	cyclone	pistachio	referee	pioneer	fudge	
blimp	dimple	carrot	duchess	leash	turnip	
recital	lilac	tiger	crane	tornado	freezer	
tarantula	admiral	oyster	present	gorilla	lodging	

Table 6. *Words used in Experiment 3C (in addition to the words listed in Table 4).*

List A	List B	List C	List D	List E	List F	List G
penguin	stair	caboose	citrus	stretcher	antler	duvet
rookie	gourd	streamer	salon	meteor	scoundrel	carrot
gymnasium	parakeet	pioneer	oyster	tornado	jasmine	mosquito
piccolo	casserole	cobra	lemonade	anchor	asparagus	musket
minion	chariot	podium	falcon	rattle	amphibian	dungeon
fable	mummy	gazelle	magma	warrior	lilac	sleigh
octopus	willow	boomerang	medal	toupee	spinach	ruffle
celebrity	dynamite	clown	blemish	wizard	armadillo	dimple
lantern	beaver	navigator	toque	janitor	knuckle	domino
flipper	flamingo	vault	tonsil	facet	squirrel	kidney
radiator	visor	labyrinth	musician	crate	nugget	cradle
cymbal	fondue	bayonet	thorn	fracture	lotion	torpedo
gnome	foyer	graffiti	mechanic	liquorice	bazaar	baton
tentacle	decathlon	lullaby	nostril	retainer	radish	marinade
comet	ornament	jingle	vandal	equator	kangaroo	electrode
laser	canister	orchard	hurdle	badger	mandolin	totem
cello	aquarium	muffin	grape	asphalt	nozzle	vanilla
trivia	scooter	ostrich	renegade	espresso	banister	gadget
poncho	coral	omelette	gazebo	geyser	minnow	melon
pellet	cannon	recess	magnet	trolley	walrus	wrestler

List H	List I	List J	List K	List L	List M	Practice
scalpel	oregano	panther	propane	vendor	ginger	jaguar
replica	orphan	villain	blimp	figurine	squid	freezer
harmonica	hexagon	riddle	banjo	hatchet	tiger	video
kimono	diaper	hammock	canoe	violin	decimal	peninsula
birch	vixen	relish	unicorn	dolphin	biscuit	derby
mammal	algebra	lacrosse	trouser	fungus	incisor	mulch
stadium	raisin	drought	lizard	jersey	voodoo	scavenger
siren	plumber	drapery	snail	lagoon	welder	mallet
quiver	nominee	admiral	leash	dinosaur	confetti	eraser
peach	cherry	mammoth	spouse	robot	sapphire	carousel
freight	glacier	mistletoe	scalp	toaster	toffee	
vampire	gauze	cauldron	sneaker	polka	daffodil	
grocery	antenna	activist	ozone	diploma	attire	
archer	utensil	finch	intern	quadrant	printer	
pageant	puddle	skunk	detergent	recipient	basil	
talon	pharmacy	optician	turkey	tinsel	inventory	
massage	golfer	gremlin	saucer	aroma	slipper	
souvenir	napkin	pitcher	enamel	picket	capsule	
trailer	ledger	hamster	venom	ranger	spatula	
ferret	alien	kiosk	lumber	quartz	quill	

Appendix C – Ethics

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Western

Use of Human Subjects - Ethics Approval Notice

Review Number	12 01 05	Approval Date	12 01 12
Principal Investigator	Jessica Grahn/Tram Nguyen	End Date	12 12 31
Protocol Title	Musical mood and arousal at different stages of learning and memory		
Sponsor	n/a		

This is to notify you that The University of Western Ontario Department of Psychology Research Ethics Board (PREB) has granted expedited ethics approval to the above named research study on the date noted above.

The PREB is a sub-REB of The University of Western Ontario's Research Ethics Board for Non-Medical Research Involving Human Subjects (NMREB) which is organized and operates according to the Tri-Council Policy Statement and the applicable laws and regulations of Ontario. (See Office of Research Ethics web site: http://www.uwo.ca/research/ethics/)

This approval shall remain valid until end date noted above assuming timely and acceptable responses to the University's periodic requests for surveillance and monitoring information.

During the course of the research, no deviations from, or changes to, the protocol or consent form may be initiated without prior written approval from the PREB except when necessary to eliminate immediate hazards to the subject or when the change(s) involve only logistical or administrative aspects of the study (e.g. change of research assistant, telephone number etc). Subjects must receive a copy of the information/consent documentation.

Investigators must promptly also report to the PREB:
a) changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
b) all adverse and unexpected experiences or events that are both serious and unexpected;
c) new information that may adversely affect the safety of the subjects or the conduct of the study.

If these changes/adverse events require a change to the information/consent documentation, and/or recruitment advertisement, the newly revised information/consent documentation, and/or advertisement, must be submitted to the PREB for approval.

Members of the PREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussion related to, nor vote on, such studies when they are presented to the PREB.

Clive Seligman Ph.D.

Chair, Psychology Expedited Research Ethics Board (PREB)

The other members of the 2011-2012 PREB are: Mike Atkinson (Introductory Psychology Coordinator), Rick Goffin, Riley Hinson Albert Katz (Department Chair), Steve Lupker, and Karen Dickson (Graduate Student Representative)

CC: UWO Office of Research Ethics

This is an official document. Please retain the original in your files

Curriculum Vitae

Name:	Tram Nguyen
Post-secondary Education and Degrees:	The University of Western Ontario London, Ontario, Canada 2006-2011 B.Sc. (Psychology Honors Specialization)
	The University of Western Ontario London, Ontario, Canada 2011-2013 M.Sc. (Psychology)
Honours and Awards:	Western Graduate Research Scholarship 2011-2012, 2012-2013
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Presentations:

Nguyen, T., & Grahn, J. A. (2013). Context-Dependent: The Effects of Musical Mood and Arousal on Memory Performance. Poster presented at the 42nd annual meeting of the Lake Ontario Visionary Establishment (L.O.V.E), Niagara Falls, ON, Canada, February 2013.

Nguyen, T., & Grahn, J. A. (2012). Effects of Mood and Arousal in Pre-Selected and Self-Selected Music on Learning and Memory. Talk presented at the 22nd annual meeting of the Canadian Society for Brain, Behaviour, and Cognitive Science (CSBBCS), Kingston, ON, Canada, June 2012.

Nguyen, T., Graham, B., Duarte, A., & Grahn, J. A. (2011). Musical Mood and Arousal Affect Different Stages of Learning and Memory Performance. Poster presented at the meeting of the Neurosciences and Music – IV: Learning and Memory, Edinburgh, Scotland, June 2011.