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Mind Your Music: The Effects of Music-Induced Mood and Arousal Across Different Memory Tasks

Tram Nguyen and Jessica A. Grahn
University of Western Ontario

The current study examined the effect of background music on different types of memory. One hypothesis is that background music modulates the listener's internal mood and arousal, putting them at optimal levels to enhance memory performance. Another hypothesis is that background music establishes a "context" that, when reinstated, aids memory performance. To investigate the role of music-induced mood, arousal, and context on memory, we used background music that varied in mood and arousal to create different memory contexts: music present at study only, test only, and both study and test. We assessed how mood, arousal, and context affected performance on recall, recognition, and associative memory tasks. Participants recalled more words when they listened to low arousal music than high arousal music, regardless of mood or whether context was consistent between study and test. For recognition memory, participants also recognized more words when they listened to low arousal music than high arousal music, but only when the music was negative. For associative memory, no significant effects of mood, arousal, or context were found on recognition of previously studied word pairs. Finally, across all experiments, background music, compared with silence, did not significantly improve verbal memory performance. Thus, mood and arousal affected recall and recognition memory, but overall background music did not enhance memory.

Keywords: arousal, background music, mood, memory, musical context

Music is prevalent in our daily lives. Many of us listen to music to help improve focus, to block out distractions, or to make a tedious task more enjoyable. However, it is unclear how this daily soundtrack affects our cognitive performance, particularly learning and memory. Although many studies support the idea that listening to music can aid learning and facilitate memory (de Groot, 2006; Foster & Valentine, 2001; Lord & Garner, 1993), other studies have shown that listening to music can interfere with important processes required for learning and memory (Iwanaga & Ito, 2002; Jäncke & Sandmann, 2010; Salamé & Baddeley, 1989). Some of the discrepancies in the literature may have arisen from the use of different memory paradigms across studies (e.g., recall vs. recognition). Therefore, the current study examined the effect of background music on different types of memory. Two potential mechanisms have been proposed to explain how background music influences memory, and these factors form the foundation of the current study. The first possibility is that background music modulates the listener's internal mood and arousal levels, which may then enhance memory performance (Greene, Bahri, & Soto, 2010; Husain, Thompson, & Schellenberg, 2002; Thompson, Schellenberg, & Husain, 2001). For example, negative moods can worsen memory, whereas positive moods can improve memory (Aubé, Peretz, & Armony, 2013; Eschrich, Münte, & Altenmüller, 2008; Rowe, Hirsh, & Anderson, 2007). Furthermore, extremely high and low levels of arousal can impair memory performance, whereas moderate levels can enhance memory performance (Berlyne, 1971; Diamond, Campbell, Park, Halonen, & Zoladz, 2007; Dutton & Carroll, 2001). The second possibility is that background music operates through associative mechanisms, establishing a "context" that, when reinstated, cues memory recall (Balch & Lewis, 1996; Balch, Myers, & Papotto, 1999; Mead & Ball, 2007; Smith, 1985; Standing, Bobbitt, Boisvert, Dayholos, & Gagnon, 2008). Thus, hearing a piece of music might bring to mind the information that was previously encoded when the music was present. Both of these possibilities have experimental support; however, to our knowledge their influences on memory have not been compared in the same study. Therefore, the current study examined whether background music affects verbal memory and

Tram Nguyen and Jessica A. Grahn, Brain and Mind Institute, Department of Psychology, University of Western Ontario.

TRAM NGUYEN is currently a doctoral-level student in the Music and Neuroscience Lab at the Brain and Mind Institute. Tram completed her Bachelor of Science and Master of Science degrees in Psychology at the University of Western Ontario (Western). Her doctoral research examines individual differences in beat perception and production, particularly between musicians and dancers.

JESSICA A. GRAHN is an Associate Professor at the Brain and Mind Institute and Department of Psychology at the University of Western Ontario (Western). She has degrees in Neuroscience and Piano Performance from Northwestern University and a PhD from Cambridge, England, in the Neuroscience of Music. She specializes in music and cognition.

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Correspondence concerning this article should be addressed to Tram Nguyen, Brain and Mind Institute, Department of Psychology, University of Western Ontario, London, ON, Canada, N6A 5B7. E-mail: tnguye95@uwo.ca

whether that effect can be attributed to mood, arousal, context, or some combination of all these factors.

Background Music and Memory

The benefit of music on memory often requires the integration of the music with the to-be-remembered items of the task (Rubin, 1977; Serafine, Crowder, & Repp, 1984; Wallace, 1994). For example, there is evidence that text is better recalled when it is heard as a song rather than as speech (Wallace, 1994). In the current study, however, the focus was to examine the effect of background music on memory, which is different from music that might be integrated with the to-be-remembered items. Here, the background music was arbitrarily paired rather than intentionally paired with the to-be-remembered items because the background music that we experience in our daily lives is not typically integrated with the task we are performing.

Whether background music enhances learning and memory has yet to be fully elucidated because the effects are inconsistent. Some studies have found that background music has either no effect on memory (Hirokawa, 2004; Jäncke & Sandmann, 2010; Miller & Schyb, 1989), worsens memory (Hallam, Price, & Katsarou, 2002; Iwanaga & Ito, 2002; Reaves, Graham, Grahn, Rabannifard, & Duarte, 2016), or improves memory (de Groot, 2006; Eschrich et al., 2008; Richards, Fassbender, Bilgin, & Thompson, 2008). Although the findings of the aforementioned studies are mixed, one meta-analysis has identified several studies where background music had a detrimental effect on memory compared with silence (Kämpfe, Sedlmeier, & Renkewitz, 2011). The researchers reviewed eight studies where participants performed a memory task with and without background music, and found that the weighted average effect size was negative, indicating that background music slightly hindered memory performance compared with silence (Kämpfe et al., 2011). The current study was designed to readdress the question of whether background music compared with silence has an effect on different types of memory.

The Arousal-Mood Hypothesis

As previously mentioned, background music may affect memory by altering the listener's mood and arousal states, which may then influence memory performance (Greene et al., 2010; Husain et al., 2002; Thompson et al., 2001). Mood and arousal represent different but related aspects of emotions. Although *mood* typically refers to a long-term psychological state (Sloboda & Juslin, 2001), here, the definition of mood is analogous to that in the *arousal–mood hypothesis* (Husain et al., 2002), in which mood is similar to valence, and can be positive or negative. For example, positive moods include happiness, contentment, excitement, or calmness. In contrast, negative moods include sadness, anger, nervousness, or boredom. *Arousal*, on the other hand, typically refers to the physiological activation or intensity of the emotion (Sloboda & Juslin, 2001). Thus, descriptions of arousal states may use adjectives such as distressed or elated for high arousal and fatigued or relaxed for low arousal.

According to the *arousal–mood hypothesis* (Husain et al., 2002), listening to music modulates mood and arousal states, which in turn affect cognitive performance. In what is perhaps the most notable study to show that listening to music improves cognition, the "Mozart effect" was reported (Rauscher, Shaw, & Ky, 1993). Immediately after listening to Mozart, participants showed better scores on a spatial reasoning task than after sitting in silence. However, follow-up work have shed doubt on the consistency of the "Mozart effect" with evidence suggesting that the effect is likely driven by the affective changes induced by the music, specifically, music that is positive in mood and high in arousal (Chabris, 1999; Husain et al., 2002; Thompson et al., 2001).

Presently, the *arousal–mood hypothesis* provides the best framework for explaining the favorable effects of background music on cognition. Indeed, the influence of background music on mood and arousal is well established (Gabrielsson, 2001; Krumhansl, 1997; Peretz, 2001). In general, music that is happy and fast in tempo enhances mood and increases arousal, whereas music that is sad and slow in tempo dampens mood and decreases arousal (Thompson et al., 2001). Mood and arousal both influence cognition (Hallam et al., 2002; Mammarella, Fairfield, & Cornoldi, 2007; Schellenberg, Nakata, Hunter, & Tamoto, 2007). Positive changes in emotions appear to be most beneficial (Schellenberg et al., 2007). For example, short-term memory (STM) performance in elderly individuals is significantly improved by positively modulating their mood and arousal states with background music (Mammarella et al., 2007). The same effect is also shown in children (Hallam et al., 2002). When children perceive background music as pleasant, calming, or relaxing, they show better memory performance. In contrast, when they perceive background music as unpleasant, arousing, or aggressive, they show poorer memory performance. Therefore, pleasant and calming background music improves memory performance, whereas unpleasant and arousing background music reduces memory performance.

The effects of background music on memory appear to be most robust when mood and arousal are manipulated together (Greene et al., 2010; Husain et al., 2002; Schellenberg et al., 2007). When the manipulation only affects one of the two dimensions, no significant differences in memory performance are reported (Husain et al., 2002). Furthermore, 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 (Anderson, Wais, & Gabrieli, 2006; Judde & Rickard, 2010; Liu, Graham, & Zorawski, 2008), making it difficult to determine whether mood, arousal, or their interaction is most significant in the modulation of memory. In one study that independently manipulated the mood and arousal dimensions in their music induction process, the researchers found that neither mood nor arousal alone, but their interaction was critical for improving memory performance (Greene et al., 2010). The researchers had participants learn a series of abstract shapes after being exposed to one of the four music conditions that varied in both mood and arousal: (a) high arousal positive music, (b) high arousal negative music, (c) low arousal positive music, and (d) low arousal negative music. Recognition performance was enhanced when participants listened to both high arousal positive music and low arousal negative music. In contrast, when participants listened to high arousal negative music and low arousal positive music, recognition performance was reduced. High arousal positive music and low arousal negative music appeared to be the best combinations of mood and arousal for optimal memory performance (Greene et al., 2010). Thus, it seems that the interaction between mood and arousal is important for inducing the emotional enhancement of memory because the effect of mood depends on arousal and vice versa.

The Encoding Specificity Principle

Background music can also affect memory performance by establishing a "context" that, when reinstated, provides a cue for the associated memory (Balch & Lewis, 1996; Bower, Monteiro, & Gilligan, 1978; Mead & Ball, 2007; Smith, 1985; Standing et al., 2008). For example, when the same piece of background music is present during study and test, memory recall is improved compared with when the background music differs. This contextual effect appears to be quite specific: if the background music is conceptually similar (same genre), but perceptually different (different song), memory recall is significantly reduced compared with when the same background music is used (Standing et al., 2008). Thus, like other contextual cues, background music may facilitate memory performance if it is repeated between periods of study and test (Tulving & Thomson, 1973).

When background music is present at study and test, there are two potential ways that a musical context can be established. The first is that the specific piece of music acts as the contextual cue as previously mentioned (Standing et al., 2008). The second is that the mood and arousal states induced by the music can serve as the contextual cue (Balch & Lewis, 1996; Mead & Ball, 2007; Smith, 1985). In fact, the *encoding specificity principle* can also apply to mood and arousal states (Bower, 1981; Bower et al., 1978; Clark, Milberg, & Ross, 1983). For instance, memory recall is significantly better when the musical mood is congruent (happy–happy or sad–sad) rather than incongruent (happy–sad or sad–happy) during study and test (Mead & Ball, 2007). Similarly, memory performance is enhanced when the musical arousal at study and test is congruent (Balch & Lewis, 1996).

Memory

"Memory" is an all-encompassing concept that denotes several interrelated ideas: "the process in which information is encoded, stored, and retrieved," and there are several types of memory tasks (Roediger, Zaromb, & Goode, 2008). A common task is the recall test, in which participants retrieve encoded information with or without an associated cue (Gillund & Shiffrin, 1984). Another common task is the recognition test, in which participants are asked to judge whether an item was previously presented or not (Gillund & Shiffrin, 1984). Recall and recognition memory are thought to differ in the way that they are processed. According to the *two-stage theory* of memory (Watkins & Gardiner, 1979), the retrieval process is easier for recognition than recall because successful recall involves two processes: (a) a search and retrieval process of the to-be-remembered information and (b) a recognition process in which the correct information is chosen from the retrieved information (Bahrick, 1970). Recognition memory, however, requires only the second of the two processes.

The effect of background music listening on memory is most commonly assessed with either recall or recognition tasks (Balch & Lewis, 1996; Balch, Bowman, & Mohler, 1992; Mead & Ball, 2007). To date, however, only a limited number of studies have investigated the effect of background music on "associative" memory (Reaves et al., 2016). Associative memory is the ability to learn and remember that two pieces of information are associated (Kohonen, 1984), such as the name of a person. A classic paradigm to test associative memory is the paired-associates learning task, in which subjects remember pairs of items (Naveh-Benjamin, Guez, Kilb, & Reedy, 2004; Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003; Old & Naveh-Benjamin, 2008). In such tasks, it is typical to use one item of the to-be-remembered pair as the cue to recall the other item. Past literature has shown evidence of the *arousal–mood effect* as well as the *encoding specificity principle* in recall and recognition tasks, but whether these effects are evident in associative memory is unknown.

The Current Study

In the current study, we assessed whether background music enhances verbal memory performance, and if so, whether that enhancement is attributable to mood, arousal, context, or some combination of these factors. Participants learned and remembered lists of words, which is different from other studies that have examined the effect of background music on other types of memory, such as visual (Boltz, Schulkind, & Kantra, 1991; Greene et al., 2010; Proverbio et al., 2015). To fully understand the combined role of mood and arousal on learning and verbal memory, it was necessary to examine their individual effects. Therefore, four music conditions were used to manipulate mood and arousal: (a) high arousal positive (HAP) music, (b) high arousal negative (HAN) music, (c) low arousal positive (LAP) music, and (d) low arousal negative (LAN) music. The music was chosen based on mood and arousal ratings made by a group of pilot participants. Other studies that have also examined the effect of musical mood and arousal on cognition often modified mode and tempo to manipulate the emotional tone of the music (Dalla Bella, Peretz, Rousseau, & Gosselin, 2001; Gabrielsson & Lindström, 2001; Husain et al., 2002; O'Malley, Seror, & Friedman, 2016; Peretz, Gagnon, & Bouchard, 1998). However, this approach does not closely mimic how we experience background music in our daily lives. We felt that using a selection of different music is more representative of the naturalistic environments where we experience background music. To assess whether the effect of musical mood, musical arousal, and context were consistent across different memory tasks, three experiments were conducted concurrently using: (a) a recall task, (b) a recognition task, and (c) an associative memory task. Unlike previous studies that played music only before the task (Greene et al., 2010; Husain et al., 2002; Thompson et al., 2001), music was playing *while* participants completed the memory tasks, which again is more representative of the naturalistic environments where we experience background music. In all three tasks, the background music was presented in three different contexts: (a) music played during studying only, (b) music played during testing only, and (c) music played during both studying and testing. This enabled us to examine how the emotional and the contextual aspects of music influence memory performance. Although previous studies were careful to ensure that their musical stimuli resulted in an emotional induction, performance was never compared with a silent condition (Greene et al., 2010; Husain et al., 2002; Jefferies, Smilek, Eich, & Enns, 2008), so the facilitation of background music versus silent was never tested. Therefore, a silent condition was included in all three tasks to address whether background music facilitates verbal memory.

We hypothesized that the effect of mood and arousal would interact, consistent with previous work: we predicted that memory performance for the HAP and the LAN music conditions would be better than memory performance for the HAN and LAP music conditions (Greene et al., 2010). Furthermore, we predicted that background music would establish a context that when reinstated, would aid memory performance. Therefore, when the same background music was present at study and test, it would create a contextual cue that would enhance memory performance (Balch & Lewis, 1996; Bower et al., 1978; Mead & Ball, 2007; Smith, 1985; Standing et al., 2008). Finally, we hypothesized that the predicted effects of mood, arousal, and context would be present for all memory tasks.

Methods

Pilot Experiments—Music Rating and Manipulation Check

We first conducted a pilot music rating experiment to select stimuli in the four musical conditions (HAP, HAN, LAP, and LAN) for use in the three subsequent memory experiments. To ensure that the music selected did elicit the desired levels of mood and arousal, we also conducted a manipulation check where participants rated their changes in mood and arousal over time.

Participants

Fifteen students (10 females and 5 males) from the University of Western Ontario participated (M_{age} = 22.20 years, SD = 3.51 years) in the rating task and 30 students (25 females and 5 males) participated (M_{age} = 19.23 years, SD = 2.64 years) in the manipulation check task. All had normal hearing and normal or corrected-to-normal vision. Participants either received one research credit or were paid $10.00 (CAD) for their participation. All participants provided informed consent in accordance with the guidelines approved by the University of Western Ontario Psychology Research Ethics Board.

Materials

Background music stimuli. A total of 150 musical excerpts were rated. The excerpts were 90-s instrumental (no lyrics) clips drawn from a variety of different genres (e.g., blues, classical, jazz, metal, and rock). In the music rating experiment, participants only heard the first 10 s of each clip. Great effort was made to select musical excerpts that had a stable mood and arousal level for the entire 90 s. We also selected excerpts that were likely to be unfamiliar to the participants to ensure that familiarity was similar across participants. The 12 musical excerpts selected based on the ratings were then used in the manipulation check task (Table 1). There were three, 60 s, excerpts for each music condition and they were presented in a 3-min block based on their respective music conditions (HAP, HAN, LAP, or LAN). The presentation of the excerpts in each block was randomized.

Rating scales. Participants were shown two separate scales: a mood scale and an arousal scale. The mood scale ranged from −3.00 (very negative) to +3.00 (very positive), with 0 labeled as neutral mood. The arousal scale ranged from 1.00 (very low arousal) to 7.00 (very high arousal), with 4 labeled as moderate arousal. The numbers were arranged horizontally (left to right) on a laptop screen for the mood and arousal scales, respectively.

Procedure

Music rating. Participants were seated at a comfortable distance in front of a Dell Vostro 3400 laptop. The procedure was controlled by an experimental program created with E-Prime (2.0) (Psychology Software Tools, 2002). The excerpts were presented through Sennheiser HD 280 headphones at a comfortable listening volume. Participants rated each musical excerpt 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 whereas arousal referred to the energy level of the music. For example, a positive piece would bring to mind words like "happy," "exciting," or "calming" and a negative piece would bring to mind words like "sad," "angry," or "boring." Correspondingly, a low arousal piece would bring to mind words like "relaxing" or "dull," whereas a high arousal piece would bring to mind words like "distressing" or "thrilling." To ensure that ratings of mood and arousal were not confounded, the order of ratings was counterbalanced across participants: either they rated the mood of all the excerpts, then the arousal, or vice versa. Therefore, participants heard each excerpt twice, each time for 10 s, before making their ratings for either mood or arousal. A screen prompted the participants to respond using the number keys on the keyboard. Participants were given an optional break between ratings of mood and arousal.

Manipulation check. Again, participants were seated at a comfortable distance in front of the laptop. The procedure was controlled by an experimental program created with E-Prime (2.0) (Psychology Software Tools, 2002). The experiment consisted of four blocks, each consisting of three, 60 s, musical excerpts. Each participant completed the four blocks in random order. Prior to each block, participants were asked to rate their current mood and arousal level to establish a baseline measure. Then the excerpts were presented through headphones at a comfortable listening volume, and at every minute for three minutes (length of the longest experimental block) participants were asked to rate their mood and arousal. Unlike the music rating experiment, participants were instructed to rate each musical excerpt according to how the music made them feel rather than what the music expressed or conveyed. To ensure that ratings of mood and arousal were not confounded, the order of ratings was counterbalanced across participants: either they rated mood first, then arousal, or vice versa. A screen prompted the participants to respond using the number keys on the keyboard. Participants were given an optional break between blocks.

Statistical Analysis

For the music rating experiment, responses on the arousal scale (1 to 7) were converted to the −3.00 to +3.00 scale for analysis. Ratings of mood and arousal for each excerpt were averaged across all participants and the excerpts were chosen based on a criterion, described in detailed in the results section. For the manipulation check, responses on the arousal scale (1 to 7) were

Table 1
Mean Ratings of Arousal and Mood for the Music Used in the Three Experiments

Music	Condition	Arousal rating		Mood rating	
		M	*SD*	*M*	*SD*
Montenegro David Guetta	HAPS	2.33	0.62	1.67	1.05
Satch Boogie Joe Satriani	HAPT	2.27	1.28	1.73	1.34
Ghost N Stuff Deadmau 5	HAPB	2.47	1.13	2.13	0.99
OVERALL	HAP	2.36	1.01	1.84	1.12
Burn Apocalyptica	HANS	1.93	1.49	−1.27	1.53
SFX The Upbeats	HANT	1.53	2.04	−1.2	1.51
Tempting Time Animals As Leaders	HANB	1.67	1.36	−1.53	2.09
OVERALL	HAN	1.71	1.63	−1.33	1.71
You'd Be So Nice To Come Home To Cole Porter	LAPS	−1	1.58	1.07	1.41
Killer Joe Benny Golson	LAPT	−1.13	0.99	0.87	1.41
Hello My Lovely Charlie Haden Quartet West	LAPB	−1.27	1.52	0.8	1.49
OVERALL	LAP	−1.13	1.36	0.91	1.44
Static Godspeed You Black Emperor	LANS	−2.47	0.9	−1.33	0.74
Hear Me Cry Thomas C. Sanchez	LANT	−2.2	1.77	−1.13	0.86
Prelude In E Minor (Op. 28: No. 4) Frédéric Chopin	LANB	−1.73	0.7	−1.93	1.34
OVERALL	LAN	−2.13	1.12	−1.47	0.98

Note. Arousal is denoted as *HA* (high arousal) or *LA* (low arousal) and mood is denoted as *P* (positive mood) or *N* (negative mood). Musical context is denoted as *S* (music played at study only), *T* (music played at test only), and *B* (music played at both study and test).

also converted to the −3.00 to +3.00 scale for the analysis. Ratings of mood and arousal for each time point (baseline to three minutes) were averaged across all participants. The mood and arousal ratings were analyzed with a paired samples *t* test for each time point. All hypothesis tests used $\alpha = .05$ for significance. Data were analyzed with SPSS (20.0) software.

Experiment 1—Recall Memory

Participants. Thirty undergraduate students (15 females and 15 males) from the University of Western Ontario participated ($M_{age} = 20.00$ years, $SD = 2.32$ years). All had normal hearing and normal or corrected-to-normal vision. Participants were compensated one research credit for an hour of participation.

Materials.

Background musical stimuli. Twelve musical excerpts were used (Table 1). The excerpts were the 90-s instrumental clips selected in the pilot music rating experiment. There were three excerpts for each music conditions (HAP, HAN, LAP, and LAN).

Word list stimuli. A total of 270 English nouns were used to create 14 study lists (one list for each of the 12 music conditions, one list for the silent condition, and one list for the practice condition). With the exception of the shorter practice list, all lists were randomized between conditions, thus no particular list was always associated with a particular condition. All words were five to nine letters long ($M = 6.66$ letters $\pm$ 1.26 letters), with a mean written 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 14 word lists.

Procedure. Participants were seated at a comfortable distance in front of a Dell Vostro 3400 laptop. The procedure was controlled by an experimental program created with E-Prime (2.0) (Psychology Software Tools, 2002). The experiment consisted of 13 blocks, each with a study phase and a test phase: 12 music blocks and one silent block. Each participant completed all 13 blocks in random order. During the study phase of each block, participants learned a list of 20 randomly ordered words. Individual words were presented in black lowercase letters in the center of a white screen for 3 s each with an interstimulus interval of 0 s. After the study phase, a red screen appeared for 3 s to indicate that the study phase for that block was over and the test phase would begin. During the test phase, participants were given 3 min to recall as many of the 20 words as possible in any order by typing out their responses. Between each block of study and test, a white screen with the word "break" in capital letters appeared for 5 s to indicate that the participant was moving on to a new block.

Participants were told that sometimes music would be playing in the background presented through Sennheiser HD 280 headphones at a comfortable listening volume, as they performed the task, but that they did not need to pay any attention to it, as they would not be asked to make any decisions about the music. To manipulate context, background music was presented only during the study block (study-only condition), only during the test block (test-only condition), or during both the study block and the test block (both study and test condition). When background music was present during study only or during test only, the context at encoding was considered different from the context at retrieval. In contrast, when the same background music was present at both study and test, the context at encoding matched the context at retrieval. During the study phase, which was 60 s long, the music ended once the phase was completed. Conversely, during the test phase, which was 3 min long, the music was repeated until the phase was completed. In addition to the 12 music conditions, there was one silent control condition. Before beginning the task, participants performed a short practice block with only 10 words to ensure they understood the task. The practice block was performed with no background music.

Statistical analysis. The number of correctly recalled words in each block was analyzed. Percent correct was calculated as the number of correctly recalled words divided by 20, multiplied by 100. The score for each music block were analyzed with a 2 (*musical mood*: positive and negative) $\times$ 2 (*musical arousal*: high and low) $\times$ 3 (*context*: study-only, test-only, both study and test) repeated measures analysis of variance (ANOVA). To assess whether background music affected recall performance relative to silence, the score for each of the music blocks was tested against the score for the silent block in a paired samples t test. All hypothesis tests used $\alpha = .05$ for significance and all post hoc comparisons were corrected using Bonferroni correction. Data were analyzed with SPSS (20.0) software.

Experiment 2—Recognition Memory

Participants. Participants were 30 undergraduate students (15 females and 15 males) from the University of Western Ontario ($M_{\text{age}} = 21.07$ years, $SD = 2.89$ years). All had normal hearing and normal or corrected-to-normal vision. None of the participants had participated in Experiment 1. They were compensated one research credit for their participation.

Materials.

Background musical stimuli. The musical stimuli were the same as those in Experiment 1 (Table 1).

Word list stimuli. A total of 405 English nouns were used to create 14 study and 14 test lists (one set of study and test lists for each of the 12 music conditions, one set for the silent condition, and one set for the short practice condition). Half of the words used in the study list were intermixed with new words to create the test lists. The words were all five to nine letters in length ($M = 6.62$ letters $\pm$ 1.25 letters), with a mean written 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 28 word lists.

Procedure. The setup for this experiment was identical to Experiment 1. The procedure for this experiment was also identical to Experiment 1, except that during the test phase, participants were presented with 10 old words, taken from the study list, and 10 new words. Participants indicated, using the keyboard, whether the word had appeared in the previous study list, by pressing the key labeled "yes" if the word had been presented and the key labeled "no" if not.

Statistical analysis. Recognition performance was analyzed with both percent correct and corrected hit rate. Percent correct was calculated by taking the number of correct responses and dividing it by the total number of responses, multiplied by 100. The corrected hit rate for each block was calculated by subtracting the false alarm rate from the hit rate. False alarms were defined as incorrectly selected new words (indicating that a word is old when it is new) and hits were defined as correctly responding to old words (indicating that a word is old when it is old). The proportion of false alarms (number of incorrect responses/number of new word) was subtracted from the proportion of hits (number of correct response/number of old words) to get the corrected hit rate for each block (Snodgrass & Corwin, 1988). Both percent correct and corrected hit rate for each block were analyzed with a 2 (*musical mood*: positive and negative) $\times$ 2 (*musical arousal*: high and low) $\times$ 3 (*context*: study-only, test-only, both study and test) repeated measures ANOVA, one for each measure. Analyses of recognition performance using percent correct and corrected hit rate showed comparable results; therefore, only the analysis of corrected hit rate is reported. Unlike percent correct, corrected hit rate measures accuracy and corrects for any response biases. Moreover, reporting corrected hit rate allows for direct comparisons between the results of this study with the results of similar studies (Aubé et al., 2013; Greene et al., 2010; Ochsner, 2000). Lastly, to assess whether background music affected recognition performance relative to silence, the score for each of the music blocks was tested against the score for the silent block in a paired samples t test. All hypothesis tests used $\alpha = .05$ for significance and all post hoc comparisons were corrected using Bonferroni correction. Data were analyzed using SPSS (20.0) software.

Experiment 3—Associative Memory

Participants. Thirty-three undergraduate students (16 females and 17 males) from the University of Western Ontario ($M_{\text{age}} = 19.27$ years, $SD = 2.81$ years) participated. All had normal hearing and normal or corrected-to-normal vision. None of the participants had participated in the two previous experiments. Participants were compensated one research credit for an hour of participation.

Materials.

Background musical stimuli. The musical stimuli were the same as those in Experiments 1 and 2 (Table 1).

Word list stimuli. A total of 540 English nouns were used to create 14 study and 14 test lists (one set of study and test lists for each of the 12 music conditions, one set for the silent condition, and one set for the short practice condition). The words were all five to nine letters in length ($M = 6.61$ letters $\pm$ 1.22 letters), with a mean written 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 28 word lists.

Procedure. The setup for this experiment was identical to Experiments 1 and 2. The procedure for this experiment was also identical to Experiment 2, except that in this experiment, participants were presented with a list of 20 randomly ordered word pairs and were told to learn the association between the words for each pair. The word pairs were presented in black lowercase letters, separated by a "+" in the center of a white screen for 3 s each, with an interstimulus interval of 0 s. During the test phase, participants were presented with the same 40 words, so no new words were presented, but half of the pairings in the test phase were not paired with the same word as in the study phase. Participants indicated, using the keyboard, if the word pairings in the test phase were the same as the word pairings in the study phase.

Statistical analysis. Again, performance was analyzed using percent correct and corrected hit rate. The corrected hit rate for each block was calculated by subtracting the false alarm rate from the hit rate. False alarms and hits were defined as incorrectly responding to correctly matched word pairs and correctly responding to incorrectly matched word pairs, respectively. The proportion of false alarms (number of incorrect responses/number of matched pairs) was subtracted from the proportion of hits (number of correct response/number of mismatched pairs) to get the corrected hit rate for each block, where chance is zero (Snodgrass & Corwin, 1988). Both percent correct and corrected hit rate for each block were analyzed with a 2 (*musical mood*: positive and negative) × 2 (*musical arousal*: high and low) × 3 (*context*: study-only, test-only, both study and test) repeated measures ANOVA, one for each measure. Again, because analyses of associative memory performance using percent correct and corrected hit rate showed comparable results, only the analysis of corrected hit rate is reported. Unlike percent correct, corrected hit rate measures both accuracy and response biases. Finally, to assess whether background music affected performance relative to silence, the score for each of the music blocks was tested against the score for the silent block in a paired samples *t* test. All hypothesis tests used $\alpha = .05$ for significance and all post hoc comparisons were corrected using Bonferroni correction. Data were analyzed using SPSS (20.0) software.

Results

Pilot Experiments—Music Rating and Manipulation Check

Music rating. The initial cut-off criterion was an average rating greater than +2.00 or less than −2.00 on both the mood and arousal scales to select the excerpts for each of the four music conditions. Thus, the HAP excerpts would ideally be rated higher than 2.00 on both the mood and arousal scales, whereas all LAN excerpts would ideally be rated lower than 2.00 on both the mood and arousal scales. However, in some cases (e.g., LAP music) the initial criteria were too stringent to yield three stimuli, thus each criterion was lowered or raised by 0.25 points until all 12 excerpts were selected (see Figure 1). The average arousal and mood ratings for the selected stimuli in each of the conditions are shown in Table 1.

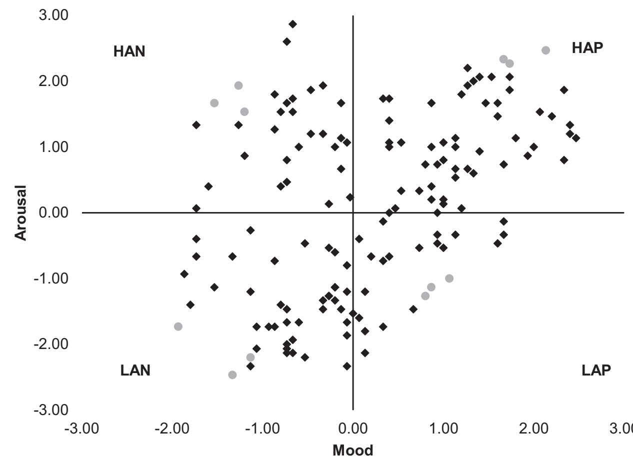

Figure 1. Mean ratings of mood and arousal for the 150 musical excerpts used in the pilot experiment. The gray-circle data points represent the 12 musical excerpts (three per condition) used in the three experiments.

Manipulation check. For mood, at baseline, participant's ratings of their mood did not significantly differ from each other, $t(29) = 0.70$, $p = .49$, $d = .12$. However, after 1 min, $t(29) = 3.60$, $p = .001$, $d = .66$; 2 min, $t(29) = 5.82$, $p < .001$, $d = 1.06$; and 3 min of music exposure, $t(29) = 3.99$, $p < .001$, $d = .73$, the excerpts selected from the rating experiment to be positive in mood did elicit significantly more positive changes in mood ratings than the excerpts selected from the rating experiment to be negative in mood (see Figure 2). Furthermore, Cohen's effect size values suggest a moderate to high practical significance for the effects of the mood induction. For arousal, again at baseline, participant's ratings of their arousal level did not significantly differ from each other, $t(29) = -1.87$, $p = .07$, $d = .34$. Similar to mood, after 1 min, $t(29) = 3.80$, $p = .001$, $d = .69$; 2 min, $t(29) = 4.76$, $p < .001$, $d = .87$; and 3 min of music exposure, $t(29) = 3.45$, $p = .002$, $d = .63$, the excerpts selected from the rating experiment to be high in arousal did elicit significantly higher arousal ratings than the excerpts selected from the rating experiment to be low in arousal (see Figure 3). Again, Cohen's effect size values suggest a moderate to high practical significance for the effects of the arousal induction. Thus, we can conclude our stimuli did elicit the intended mood and arousal states and that the induction was as early as after a minute of music exposure.

Experiment 1—Recall Memory

All data sets were included in the analysis. Mauchly's Test of Sphericity indicated that the assumption of sphericity had not been violated, $\chi^2(2) = 2.29$, $p = .32$, and therefore all statistics are reported with sphericity assumed. Participants recalled more words correctly with low arousal music compared with high arousal music, resulting in a significant main effect of arousal, $F(1, 29) = 6.33$, $p = .02$. Neither the mood manipulations, $F(1, 29) = 0.38$, $p = .54$, nor the context manipulations, $F(2, 58) = 1.42$, $p = .25$, produced any significant results. There were also no significant interactions between mood, arousal, and context. Finally, recall performance did not significantly differ from silence for any of the 12 music conditions. (see Figure 4).

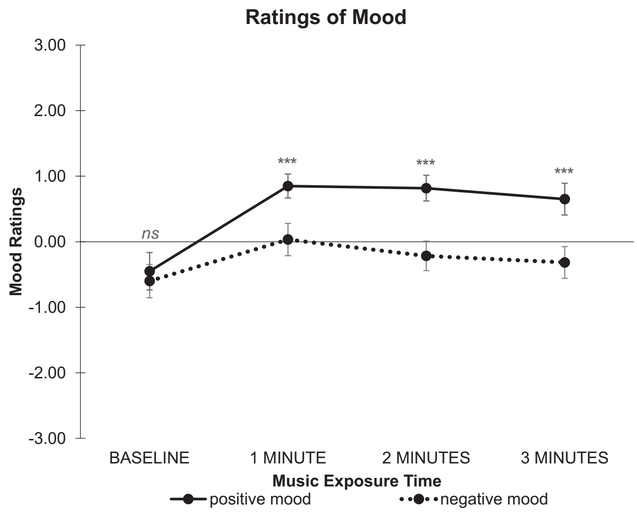

Figure 2. Ratings of mood. At baseline, participant's ratings of their current mood did not significantly differ from each other. However, after 1, 2, and 3 min of music exposure, the excerpts that were intended to be positive in mood did significantly elicit more positive changes in mood than the excerpts that were intended to be negative in mood. Asterisks indicate significance. Error bars indicate standard error of the mean. *** $p < .001$.

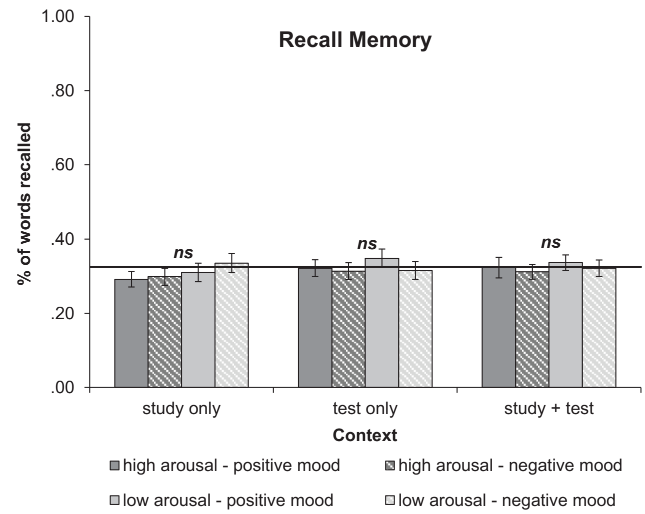

Figure 4. Recall memory performance in Experiment 1. When the data are collapsed across mood and context, participants recalled more words correctly with low arousal music compared with high arousal music resulting in a main effect of arousal on performance, but no other significant main effects or interactions. The solid black line represents performance in the silent condition. Recall performance in each of the 12 conditions did not significantly differ from that during silence. Error bars indicate standard error of the mean.

Experiment 2—Recognition Memory

All data sets were included in the analysis. Mauchly's Test of Sphericity indicated that the assumption of sphericity had not been violated, $\chi^2(2) = 3.27$, $p = .20$, and therefore all statistics are reported with sphericity assumed. There were no significant main effects of arousal, $F(1, 29) = 3.17$, $p = .09$, mood, $F(1, 29) = 0.36$, $p = .56$, or context, $F(2, 58) = 2.51$, $p = .09$. However, there was a significant interaction between mood and arousal, $F(1, 29) = 4.61$, $p = .04$, $\eta^2 = .14$. Participants recognized the most number of words correctly when they listened to LAN music, the least number of words correctly when they listened to HAN music, and an intermediate number of words when they listened to HAP and LAP music. Follow-up paired samples *t* tests confirmed that participants performed better in the LAN condition than in the HAN condition, $t(29) = 2.52$, $p = .02$, but performance did not differ between any other conditions (see Figure 5). Participants also recognized more words correctly with low arousal music compared with high arousal music, but only when the music was played at both study and test. Follow-up paired samples *t* tests confirmed that the arousal and context interaction, $F(2, 58) = 3.49$, $p = .04$, $\eta^2 = .11$, was driven by better recognition performance when participants listened to low arousal music compared with high arousal music at both study and test, $t(29) = 2.63$, $p = .01$, compared with at study only, $t(29) = 0.82$, $p = .42$, or at test only $t(29) = 1.61$, $p = .12$ (see Figure 6). No other interactions were significant.

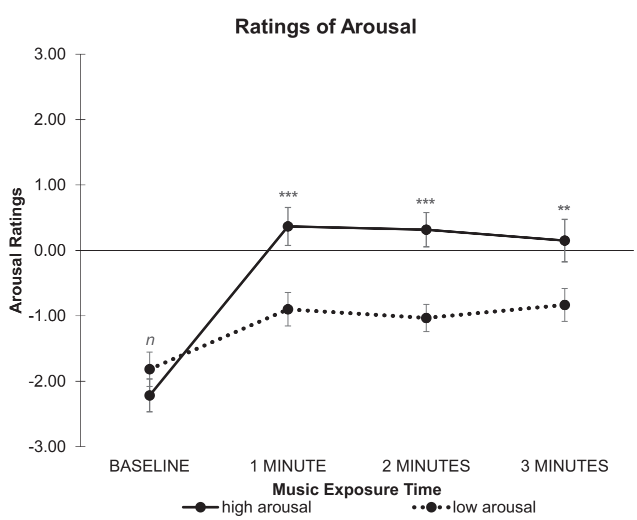

Figure 3. Ratings of arousal. At baseline, participant's ratings of their current arousal level did not significantly differ from each other. However, after 1, 2, and 3 min of music exposure, the excerpts that were intended to be high in arousal did significantly elicit higher changes in arousal than the excerpts that were intended to be low in arousal. Asterisks indicate significance. Error bars indicate standard error of the mean. ** $p < .01$, *** $p < .001$.

In comparison with silence, HAN music had a detrimental effect on recognition performance when heard at all three contexts: at study only, at test only, and at both study and test. LAP music when heard at study only and HAP music when heard at study and at test also had a detrimental effect on recognition performance compared with silence. Performance in all the other conditions was not significantly different from silence.

Experiment 3—Associative Memory

Data from three participants were excluded from the analysis due to a large number of missing responses. Mauchly's Test of

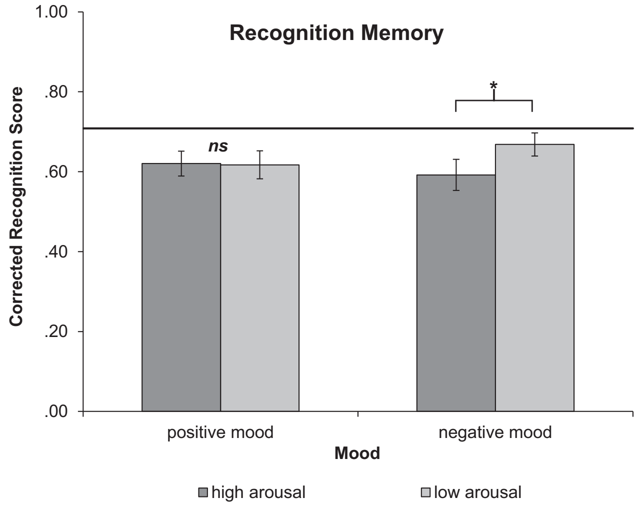

Figure 5. Recognition memory performance in Experiment 2. Recognition memory during LAN music was significantly better than HAN music, but LAP and HAP did not differ, resulting in a significant interaction between mood and arousal for recognition performance. The solid black line represents performance in the silent condition. Error bars indicate standard error of the mean. $^{*}p < .05$.

Sphericity indicated that the assumption of sphericity had not been violated, $\chi^2(2) = 3.27$, $p = .20$, and therefore all statistics are reported with sphericity assumed. None of the mood, arousal, and context manipulations produced any significant results. There were no significant main effects of arousal, $F(1, 29) = 0.001$, $p = .98$, mood, $F(1, 29) = 0.004$, $p = .95$, or context, $F(2, 58) = 0.78$, $p = .47$. There were also no significant interactions between mood, arousal, and context. Finally, associative memory performance did not significantly differ from silence for any of the 12 music conditions (see Figure 7).

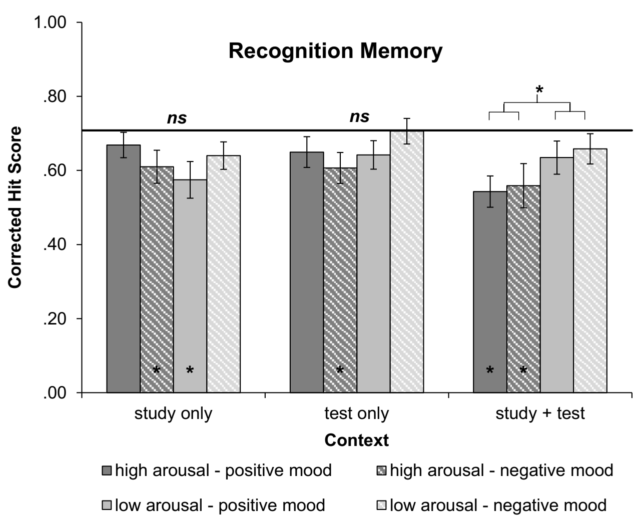

Figure 6. Recognition memory performance in Experiment 2. Participants performed better when listening to low arousal music, but only when played at both study and test, resulting in a significant interaction between arousal and context. The solid black line represents performance in the silent condition. Asterisks at the base of the bars indicate conditions in which performance significantly differed from silence. Error bars indicate standard error of the mean. $^{*}p < .05$.

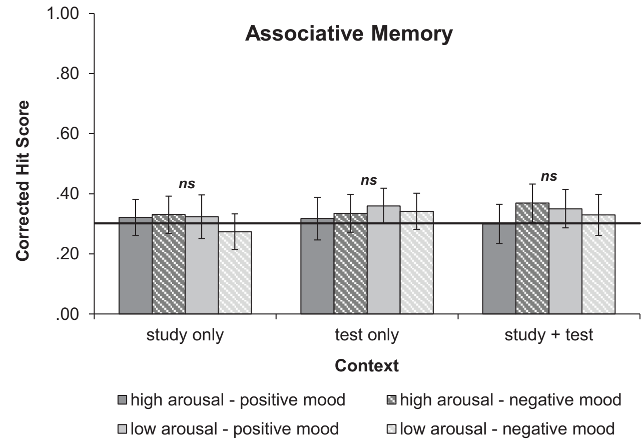

Figure 7. Associative memory performance in Experiment 3. There were no significant differences between conditions, and performance in each the 12 conditions did not significantly differ from that during silence. The solid black line represents performance in the silent condition. Error bars indicate standard error of the mean.

Discussion

The current study investigated how background music that varied in mood, arousal, and context affected verbal memory performance. In Experiment 1, we measured recall memory and found that participants recalled more words when they listened to low arousal music than high arousal music, regardless of positive or negative mood or whether music was present during study only, test only, or both study and test. In Experiment 2, we measured recognition memory and found that similar to Experiment 1, participants recognized more words when they listened to low arousal music than high arousal music, however, only for negative music. Specifically, accuracy was highest when participants listened to LAN music, lowest when participants listened to HAN music, and intermediate when participants listened to LAP or HAP music. Finally, in Experiment 3, we measured associative memory and found no significant effects of mood, arousal, or context on accurate recognition of previously studied word pairs: memory performance was similar across all conditions. Across all experiments, background music did not significantly improve verbal memory performance compared with silence, and in some cases, background music significantly reduced memory performance.

The results of our study were not consistent with our predictions, which were based on two nonmutually exclusive hypotheses: the *arousal–mood hypothesis* (Husain et al., 2002) and the *encoding specificity principle* (Tulving & Thomson, 1973). Based on the *arousal–mood hypothesis* (Husain et al., 2002), we anticipated that HAP and LAN music would enhance memory performance relative to HAN and LAP music, as this pattern of interaction between mood and arousal has been observed in previous memory studies (Greene et al., 2010). However, this hypothesis was not supported by our results: we found a main effect of arousal only, with no mood interaction for recall memory. For recognition, there was an interaction, but not exactly as predicted: LAN music elicited better performance than HAN music, but LAP and HAP did not differ. Finally, for associative memory, we found no notable effects of mood and arousal at all.

Based on the *encoding specificity principle*, which states that having the same context present at study and at test enhances memory (Tulving & Thomson, 1973), we also predicted that when the same background music was present during both study and test, memory performance would be better compared with when the background music is present during study only or test only. However, context did not significantly influence memory performance in any of our experiments.

Our recall and recognition results are most consistent with previous studies showing that moderate arousal is associated with improved memory performance (Diamond et al., 2007; Dutton & Carroll, 2001; Ochsner, 2000). Our participants recalled and recognized more words correctly when they listened to low arousal music compared with high arousal music; a finding that is potentially consistent with the *Yerkes-Dodson Law*, which asserts that there is an inverted-U relationship between arousal and task performance (Yerkes & Dodson, 1908). More specifically, too little or too much arousal hinders performance, but moderate arousal is associated with improved performance. It is possible that high arousal music may have evoked too much arousal compared with low arousal music, and thus performance was negatively affected. Different tasks also require different levels of arousal for optimal performance. For example, lower arousal is required for difficult or cognitively demanding tasks to facilitate attention and concentration, whereas higher arousal is required for tasks demanding endurance or persistence to increase motivation (Diamond et al., 2007). Therefore, low arousal music may have evoked a more optimal arousal state than high arousal music leading to better recall and recognition performance.

However, the inverted-U relationship does not explain why performance was better on the silence conditions compared with the low arousal music conditions, as it is unlikely silence changed arousal (Dousty, Daneshvar, & Haghjoo, 2011; Krumhansl, 1997; Zimny & Weidenfeller, 1963). Thus, a more likely explanation is that high arousal music is more distracting, hindering recall and recognition memory more than low arousal music. According to *changing state effects* (Banbury, Macken, Tremblay, & Jones, 2001; Campbell, Beaman, & Berry, 2002; Jones, Alford, Macken, Banbury, & Tremblay, 2000), background music with rapidly changing auditory information is more distracting than slowly changing music. High arousal music often has more distinct events per unit of time than low arousal music, potentially making it more distracting. We do note that a possible limitation of the current study is that participants were not asked to report how distracting they found the background music while they were performing the task. Thus, it is possible that some participants may have found certain genres or musical excerpts more distracting than others. In particular, genres with rapidly changing auditory information, such as jazz or metal, may be more distracting than genres with slowly changing auditory information, such as blues or classical. It is also possible that some participants may have found the background music enjoyable, thereby more engaging, whereas others found the background music irritating, thereby more distracting. Future studies may want to consider these possible confounds and collect reports of music distraction or preference at the end of the study to explore any potential differences in distraction and preference rating following music induction. Nonetheless, in comparison with silence, background music reduced recall and recognition performance.

Although the background music did not elicit consistent improvements in memory performance, the interaction between mood and arousal observed in the recognition experiment may still shed some light on how musical emotions influences memory. We found that recognition accuracy was highest when participants listened to LAN music, lowest when participants listened to HAN music, and intermediate when participants listened to LAP or HAP music. Thus, arousal alone does not appear to influence recognition performance because when background music was positive (LAP and HAP), low and high arousal conditions did not significantly differ. Perhaps the positive mood negated beneficial or detrimental effects of arousal on recognition memory, hence intermediate performance was observed. In previous studies, the effects of positive moods on memory are variable, with both detrimental and beneficial effects on memory observed (Davelaar, Goshen-Gottstein, Ashkenazi, Haarmann, & Usher, 2005; Dreisbach & Goschke, 2004; Phillips, Bull, Adams, & Fraser, 2002). Positive moods may impair memory by increasing distractibility, impairing planning, and reducing storage capacity (Dreisbach & Goschke, 2004; Martin & Kerns, 2011; Phillips, Smith, & Gilhooly, 2002). However, there is also evidence that positive moods facilitate memory by broadening attention (Phillips et al., 2002). Thus, the effects of positive moods are variable, and it appears that in the current study dependent on arousal.

The recognition memory enhancement for low arousal negative music compared with the other three music conditions may seem contradictory, but other studies have also shown performance benefits for low arousal negative music. For example, low arousal negative music in combination with a mood rating procedure improves attention in an attentional blink task (Jefferies et al., 2008). In addition, other studies have proposed that the combination of low arousal and negative mood narrows attention to task-relevant information, leading to more detailed representations of the to-be-remembered items, which may lead to better memory performance (Gasper & Clore, 2002; Greene et al., 2010; Huber, Beckmann, & Herrmann, 2004). The finding of a mood and arousal interaction highlights that the interplay between mood and arousal is significant in the modulation of recognition memory.

Although there was a significant mood and arousal interaction for recognition memory, the pattern of interaction was not as predicted. One possibility for this departure from previous literature may result from our use of naturalistic music to manipulate mood and arousal. We felt that playing different music in the study was more representative of the naturalistic environments where we experience background music, and the intent of our study. Inherently though, this introduced certain confounds into the study because different songs are written and performed by different artists in different styles, which might confound the content of the music with their emotional implications. One solution is to modify the mode and tempo of one song to manipulate the emotional tone of the music (Dalla Bella et al., 2001; Gabrielsson & Lindström, 2001; Husain et al., 2002; O'Malley et al., 2016; Peretz et al., 1998). Future studies should be cognizant of these possible confounds and consider the approach that is most appropriate for the intent of their study.

In our study, musical context did not significantly influence memory performance, thus not supporting the *encoding specificity principle* (Tulving & Thomson, 1973). However, various factors may promote or hinder the demonstration of the encoding specificity effect (Fernandez & Glenberg, 1985; Newman et al., 1982; Saufley, Otaka, & Bavaresco, 1985). For example, the effect emerges most reliably when the to-be-remembered items and contexts are actively processed by the participants compared with when they are passively presented (Beck & McBee, 1995; Eich, Macaulay, & Ryan, 1994; Eich & Metcalfe, 1989). Active processing allows for deeper levels of processing of the to-be-remembered items and contexts and deeper levels of analysis may produce longer lasting and stronger memory traces than shallow levels of analysis (Craik & Lockhart, 1972). In our study, the participants were aware that they would be tested following the study phase. Thus, we can only speculate whether the knowledge of being tested would promote active processing, but we cannot determine how deep the levels of processing were. Even if participants were actively processing the words, they may have been ignoring the music context (indeed, they were instructed that it was irrelevant), thus reducing context effects. Given that participants were instructed that the background music was irrelevant to the task at hand, it is puzzling to see that music reduced their performance relative to silence. However, it is possible that the mere presence of the background music was distracting enough to affect performance, but not actively processed enough to demonstrate any context effects.

Failure to find an encoding specificity effect may also be associated with the lack of distinctive mood and arousal states due to rapid switches between contexts (Balch & Lewis, 1996; Eich, 1995; Fernandez & Glenberg, 1985). We selected music that was maximized for our four musical conditions, ensuring distinctive mood and arousal states; however, the frequent switches in background music between conditions may have led to carry-over effects that reduced the effectiveness of the mood and arousal manipulation, thus sufficiently distinctive contexts between conditions may not have been created. Majority of studies that have found robust encoding specificity effects often use a between-subjects design where participants are required to encode and recall only one word list under the same context or a different context (Balch & Lewis, 1996; Balch et al., 1999; Mead & Ball, 2007; Smith, 1985; Standing et al., 2008). In contrast, here, participants encoded and recalled multiple word lists without long delays between blocks of studying and testing. Thus, the effects of context may have been negated by the multiple iterations of study and test.

It is possible that the mood and arousal induction may not have been strong enough for the manipulation to last throughout the experiment (Bower, 1992; Eich et al., 1994; Isen, 1984). However, we think that this is unlikely because, unlike previous studies that played music only before the task (Greene et al., 2010; Husain et al., 2002; Thompson et al., 2001), music was playing *while* participants completed the memory tasks, which should have increased effectiveness because of its continuous presence. Furthermore, the pilot results indicate that the stimuli chosen for the experiments did elicit the intended mood and arousal states, and that these affective changes arose within a minute of music exposure. Although we have shown that emotional induction via music is quick, it may still call into question the emotional state of the participant within the first 30–60 s of music exposure. However, previous studies using psychophysiological measures have provided strong evidence that emotional induction via music can be almost immediate (Blood, Zatorre, Bermudez, & Evans, 1999; Etzel, Johnsen, Dickerson, Tranel, & Adolphs, 2006; Krumhansl, 1997). For example, in one study measuring cardiovascular and respiratory responses during musical mood induction, different types of music (happy, sad, and fearful) elicit different effects on self-reported ratings of mood and measures of cardiac and respiratory function, and these effects can arise as early as after 10 s of music exposure (Etzel et al., 2006). Thus, the encoding–retrieval specificity effect may not occur when depth of processing of the context is shallow, and/or when many different contexts are experienced by the participant, but it is unlikely that the encoding–retrieval specificity effect did not occur because the induction of mood and arousal was not effective.

Previously, the effect of background music on memory was most commonly assessed using either recall or recognition memory tasks (Beck & McBee, 1995; Bower, 1981; Eich & Metcalfe, 1989; Greene et al., 2010; Mead & Ball, 2007). To date, however, only a limited number of studies have investigated the effect of background music on associative memory (Reaves et al., 2016). Although much evidence supports the *arousal–mood hypothesis* as well as the *encoding specificity principle* in recall and recognition memory, it is unknown whether or not these effects are also evident in associative memory. We had predicted that the effect of mood, arousal, and context would uniformly affect performance on all three memory tasks. However, the pattern of results differed across the three memory types in our study. In the associative memory task, we found no significant effects of mood, arousal, or context on accurate recognition of previously studied word pairs. This is consistent with one previous study that investigated the effects of background music on associative memory: in that study, neither the arousal nor the context manipulation produced significant differences in memory performance (Reaves et al., 2016). Therefore, taken together, our study and the previous study suggest that associative memory is less affected by musical mood and arousal, as well as musical context.

Overall, background music did not improve memory performance. Background music had either no effect or significantly hindered memory performance compared with silence. Based on previous literature, the effects of background music on memory are inconsistent. Some find that background music has no effect on memory (Hirokawa, 2004; Jäncke & Sandmann, 2010; Miller & Schyb, 1989), others find memory worsens (Hallam et al., 2002; Iwanaga & Ito, 2002; Reaves et al., 2016), and others find that it improves (de Groot, 2006; Eschrich et al., 2008; Richards et al., 2008). Listening to music can be cognitively demanding. When music listening is combined with another cognitive task, the same limited pool of resources may be taxed (Konečni, 1982), leading to cognitive interference. For example, listening to music interferes with driving, gait, creativity, reading comprehension, and IQ (Anderson & Fuller, 2010; Brown, de Bruin, Doan, Suchowersky, & Hu, 2009; Smith & Morris, 1977). These dual-task costs seem to emerge with all types of music: lyrical, stimulating, sedative, loud, and soft (Smith & Morris, 1977). Therefore, when music is presented during a cognitive task, it may compete for resources and impair performance.

Finally, individuals may differ in the modulatory effect of background music on memory. For example, participants who often study with background music perform better on a memory task in the presence of music, whereas those who do not study with music perform better in silence (Etaugh & Ptasnik, 1982). Moreover, the *Eysenck's arousal theory* (1967) describes the difference in arousal states of people who are extraverted versus people who are introverted. The theory states extraverts are naturally under stimulated, whereas introverts are naturally over stimulated. Therefore, whether background music enhances or hinders memory may depend on the individual, thus producing variable effects when averaged across the group.

Conclusion

In our study, the effect of music-induced mood, arousal, and context on verbal memory varied across the three memory tasks. For the recall memory task, we found a main effect of arousal only, with no mood interaction, and no context effect. For the recognition memory task, we found a mood and arousal interaction, but not exactly as predicted based on previous literature. Finally, for the associative memory task, we found no notable effect of mood, arousal, or context. Although many studies have reported significant effects of mood, arousal, and context, as well as significant mood and arousal interactions on memory, other studies have reported no effects or a different pattern or trend of effects. It is evident from our study that the effects of background music on verbal memory are variable and may not generalize across different memory tasks. Thus, how the different mechanisms underlying music's effects on memory interact remains to be fully clarified.

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