Music as a Cue to Autobiographical Memory: The Role of Emotion

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Abstract

Autobiographical memory recall is influenced by many factors, including the emotional quality of the memory cue itself. The purpose of this study was to understand how a music cued emotional response could explain the quality of autobiographical memory recall. This was conducted by having 72 undergraduate students listen to 16 unfamiliar songs in 15 second clips. They were then prompted to answer questions regarding the autobiographical memory that was evoked while listening, as well as the emotional quality of the song itself and their own felt response. Four main findings were found in the study. First, the strength of perceived emotion for the music cues predicted the strength of felt emotion. Second, the more familiar the song was, the higher individuals rated felt emotion strength, as well as memory vividness, emotional intensity, and importance. Third, stronger felt emotion responses led to more important memories being recalled. Finally, songs with a higher emotional intensity led to more emotionally intense memories being recalled. Thus, music has the ability to elicit accurate emotional responses. Familiarity and the emotional quality of music cues participate in eliciting greater memory recall.

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Music as a Cue to Autobiographical Memory: The Role of Emotion

Most individuals can relate to the feeling of being transported to specific memories from their lives when listening to certain songs. Music is known to be a powerful mnemonic device (Yalch, 1991). and as a mood influencer (Lonsdale & North, 2011) that listeners across the world and marketing campaign companies alike intuitively capitalize on. In fact, music is often referred to as the language of emotion. Its power over us, including its ability to transport us to memories of past events from our lives, may be deeply tied to its ability to cue emotions and moods. To this end, researchers have routinely studied how music changes mood (Swaminthan & Schellenberg, 2015). They have also routinely and independently studied whether music cues autobiographical memories (e.g., Basaglia-Pa et al., 2013; Belfi et al., 2016; Halpern et al., 2018). However, relatively little is known if and how the listener's emotional response mediates music's ability to cue autobiographical memories. The present thesis aims to address this research gap.

Before presenting the study, the next few sections will discuss how the past literature has investigated music's impact on autobiographical memory and emotional response. First, studies examining how listening to music can influence autobiographical memory recall abilities will be discussed. Following that, studies examining how music can influence mood and emotional response within their participants will be reviewed. Finally, studies that investigated emotional response to music cues influence on autobiographical memory recall will be discussed.

Music and Autobiographical Memory

Is music an effective cue to autobiographical memory? An indicator of an effective memory cue is that it promotes vivid recall. To examine whether music cues vividness of autobiographical memories, Belfi et al. (2016) conducted a study comparing participants'

description of recalled autobiographical memories when presented with either popular music clips or pictures of celebrity faces, which formed the non-musical control condition. Participants listened to excerpts from 30 chart-topping songs and also looked at 30 famous faces such that both the songs and the celebrity faces were likely to be very familiar to participants. After each presentation, participants rated their autobiographical association to the stimulus (none, somewhat, or strongly) and then verbally described the memory that was evoked. The researchers found that faces evoked more memories, but music resulted in significantly more perceptual details in the memory descriptors, thereby suggesting that the memories cued by music were more vivid. The autobiographical memories cued by music also had a greater proportion of internal details (information that pertains to the central components of the memory that reflect episodic reexperiencing) whereas the autobiographical memories evoked by the famous faces contained a greater number of external details (information not directly pertaining to the memory). Thus, this study supports the claim that music helps with autobiographical memory recall vividness. However, it does not take into account the emotional response that individuals have to the music or the song cues objective mood. Therefore, it is unknown whether participants' emotional response to the songs influenced the vividness of their autobiographical memory.

In another study, Basaglia-Pa et al. (2013) were interested in how music could influence semantic knowledge as well as autobiographical memory recall in Alzheimer's patients. To explore this question, they had 12 cognitively healthy participants and 12 participants diagnosed with Alzheimer's listen to older classic French songs such as La Vie en Rose. The participants then completed many subtests evaluating both semantic knowledge recall of the song lyrics and tune as well as autobiographical memory recall abilities. Participants verbally described the

autobiographical memory they would recall and were prompted to describe details. The results showed that Alzheimer's patients were less accurate than the cognitively healthy controls on many of the semantic knowledge subtests, but they did not differ significantly from controls on melodic recognition, chorus recognition, and autobiographical memory recall tests. This supports music's ability to enhance autobiographical memory recall in Alzheimer's patients, as they not only performed just as well as controls in recalling memories, but they were able to recall vivid memories with multiple details of the event and the emotions experienced during it. Despite emotions being described during the recall of memories, there was no analysis related to this as well as no specific measures looking at the emotional response to the music played. Thus, there is a lack of measures in the previous literature that address how emotional response to music cues interacts with autobiographical memory recall ability. This leaves a gap in the understanding of how emotional attachment to familiar music may be impacting the results that were found in both the aforementioned studies. The present study will not be examining individuals with any form of cognitive deficit or degenerative disease, but research such as Basaglia-Pa et al. (2013) study illustrates a potential future direction for clinical interventions once the relationship between music, emotion, and autobiographical memory is better understood.

In contrast to the two previously mentioned studies, Halpern et al. (2018) conducted a study that led them to conclude music may not help to the extent previously implied with autobiographical memory encoding and recall. They had participants provide brief written descriptions and ratings of personally experienced memories for one self-proclaimed vivid memory and one self-proclaimed ordinary memory. Half the participants were specifically asked to write memories that involved music and half were not. In phase two of the study, they

repeated the same procedures, but they also added conditions where participants were asked to describe holiday or dining memories. This was done to further compare musical memories to memories that have a significant impact on individuals' senses (dining, due to the involvement of taste and atmosphere) and life importance (holiday). The results indicated that when dining and holiday memories were involved in the analyses, musical memories were no longer significantly higher in vividness ratings or emotional content. The researchers thus concluded that future research should be cautious of concluding that musical memories have a special effect on cognition. The key disadvantage of this study is that there was never any music played for the participants as they were told to recall an autobiographical memory that involves music. The conclusions would have been further enriched if a condition where music was played for the participants while recalling their memories was included. This would help examine if music directly enhances autobiographical memory recall vividness. The conclusions of this study should be interpreted with caution because of the change in standard musical study procedure.

Music and Emotional Response

Emotional quality of a song is reliant on multiple factors, Gagnon and Peretz (2003) investigated this by having participants rate the objective mood of unfamiliar music that differed only in mode and tempo. Non-musicians were played unfamiliar melodies that differed only in mode (major/minor chords) and tempo (fast-slow) and were then asked to rate on a 10-point scale how happy or sad the pieces were. The results indicated that structural features of music caused emotionally meaningful interpretations. Music that was in a major mode with a fast tempo were rated significantly more positive than music pieces in a minor mode with a slow tempo. The researchers thus concluded that music is a reliable medium to study emotions due to the objectivity of structural components conveying specific moods. The researchers were focused

on how music objectively conveys mood and therefore did not analyze the participants emotional response to the music and how it may have affected cognition. The results support the claim that mood can be conveyed without there being an emotionally significant memory linked to the song, however there was no examinations of how the participants emotionally responded to it personally.

Schulkind and Woldorf (2005) were interested in how the emotional quality of a memory cue would influence the emotional quality of the actual retrieved memory. They tested this by having 20 participants listen to 40 excerpts of classical or contemporary instrumental pieces. These pieces were previously rated for their level of arousal and level of negative or positive emotional elicitation. There were four musical conditions; positive emotional valence/high arousal, positive emotional valence/low arousal, negative emotional valence/high arousal and negative emotional valence/low arousal. After listening to a song clip, participants wrote a brief description of the memory elicited in response to the stimulus. When finished doing this for all 40 song excerpts, they dated the memories and then rated the arousal and emotional valence level connected to the memory itself. An analysis of the ratings of memories in relation to the ratings of the songs showed that the musical arousal rating did not significantly affect the arousal level of a memory. However, the emotional valence of the song did significantly impact the emotional valence rating of the retrieved memory. Thus, emotional valence cues were shown to facilitate retrieval of memories with similar emotional tones, but it was not exact. Memories that were cued by negative music were still skewed in a relatively positive emotional zone rating, showing a positive bias in memory retrieval. This study supports the idea that the emotional cue of a song influences the recalled memories emotional quality, even if the songs being used are relatively unfamiliar. Nonetheless, there was no measure asking how familiar or unfamiliar the songs were

to individuals- despite most peoples' familiarity with popular classical music. Therefore, it is unclear whether the emotional response to the pieces were related to the emotional valence of the piece alone or if the participants had an emotional connection to the pieces as well. This study was primarily focused on how emotional cues led to an emotional response when using music. Given the past literature, there is an absence of studies that examine how emotional response to music cue can directly influence memory recall quality. Therefore, there is a scarcity of literature on how the three variables of music cue, emotional response, and autobiographical memory recall interact with one another.

Perceived and Felt Emotions

Music includes universal (e.g., tempo, loudness) and culture specific cues (i.e. musical models like the major or minor key) to emotion such that listeners reliably and consistently rate certain pieces as conveying certain emotions. In other words, individuals can perceive the emotional intention of a song. They can also feel emotions in response to listening to songs. Just because an emotion is perceived in a song does not guarantee that the same emotion will be felt by the listener. Hunter et al. (2010) investigated this with the intention of understanding the relationship between perceived and felt ratings after listening to music clips. Participants listened to 32 J. S. Bach instrumental pieces that were meant to be moderately unfamiliar and convey varying degrees of positive or negative emotion by manipulating the tempo (slow/fast) and tone (major/minor). After listening to each music clip the participants rated happy and sad feelings, as well as happy and sad perceptions. Their results indicated that perceived response ratings tended to be higher than felt response ratings, and that felt or perceived ratings of happiness were generally higher than ratings of sadness. Thus, they concluded that the emotional response to music is mediated by listeners' perceptions. The implications of this study lead to questions

involving how perceived and felt emotions may impact memories generated while listening to music clips. If there is a strong felt emotional response to the song will that relate to a strong emotional component in the memory – and will strong felt emotions increase the emotional quality and vividness of the memory recalled? Integrating perceived and felt emotion ratings into this study may help gauge a better understanding of the emotional component of memory recall in response to music.

Music, Emotional Response and Autobiographical memory

Schulkind et al. (1999) wanted to determine if listening to familiar music helped autobiographical memory recall and the recollection of information related to the songs, while also measuring participants' emotional responses. Participants listened to 15 secs of six random songs that were popular between 1935-1994 and then answered a series of questions regarding both the song itself (i.e., What year was this song popular?) and also about memories and emotional response to the song (i.e., Does this remind you of a specific time in your life, how does this song make you feel?). They had two participant groups; a younger age group that were 18-21 years old and an older age group that were aged 66-71 years. Despite having measures that involved autobiographical recall and emotional response to the music, the analysis done in this study primarily focused on how well the two age groups remembered information about the songs. The researchers found that the younger age group outperformed the older age group in the retention of information about the music. However, both age groups were more likely to recall musical information and autobiographical memories when they were shown a song that strongly resonated with them emotionally. The analysis indicated promising results for how emotional responses can influence memory retrieval with music, yet the researchers did not investigate how

mood portrayed by music can influence autobiographical memory quality. It is not clear whether these results would generalize to unfamiliar music.

In another study, Sheldon and Donahue (2017) wished to investigate emotion at time of memory retrieval to better understand the link between emotion and memory. This was done by having participants listen to solo-piano classical musical cues that empirically varied in their ratings of emotion valence (positive or negative) and arousal (high or low). Participants listened to the 32 music cues in two testing blocks. During the first block, they were asked to think of an autobiographical memory and describe it. They then rated the memory on, vividness, uniqueness, social content, energizing nature, emotional content, and emotional intensity. In the second testing block, participants were asked to rate their enjoyment of the song, what emotion was depicted, and their feeling of that emotions intensity. Their response time was recorded. There were three main findings. First, memories that were highly arousing and positive in emotion were recalled the fastest. Second, there was a relation between cue and elicited memory's emotional valence, but not arousal. Third, music cues predicted how fast memories were accessed, how specific the memories were, and how the valence cue affected memory vividness. The findings of this study demonstrate promising implications for emotion's role in memory recall. The present study will use soundtrack stimuli rather than classical music, as they are both ecologically valid stimuli because of their unfamiliar nature while still sounding realistic. Additionally, this present study will see if these findings extend to when discrete emotions ratings are used.

Present Study

It is relatively unknown whether emotions explain some of music's ability to cue autobiographical memories. A greater understanding of the role of emotions in memory recall

can better inform clinical interventions in future studies researching topics such as music therapy. If the salience of autobiographical memories can be increased by the use of more emotionally relevant music without the familiarity of the song or the use of lyrics, then it can be better understood how clinical interventions should be addressed in future studies. Finally, most of the past studies testing music's ability to help with autobiographical memory recall utilized familiar music to bolster the emotional response to the songs. This leaves the question as to whether the emotional responses to the music is only because of the emotional memories connected to the familiar songs. Use of unfamiliar music may ensure that the results rely solely on the emotional impact of the song itself on the participant. Therefore, the present study's aim is to better examine the influence that unfamiliar music has on the emotional response and quality of autobiographical memory recall. This study will address these limitations by having cognitively healthy undergraduate students think of autobiographical memories after listening to 16 unfamiliar songs in 15 second clips. They then rate their familiarity with the song, the emotional response they relate to the song (both perceived and felt), and also questions related to the quality of the autobiographical memory they thought of. Of the 16 songs, there will be four of each mood: happiness, sadness, fear, and tenderness. The expectation is that the emotional quality and vividness of the generated memory will relate to the emotional quality of the music (i.e., sad mood music that causes a negative emotional response in the participant will elicit a vivid negative memory). Considering the findings of previous studies (e.g., Hunter et al., 2010), we hypothesize that perceived and felt emotions will correlate with one another, and that perceived emotion strength ratings will be stronger than felt emotion strength ratings. Additionally, the combination of a stronger emotional response and music cues will increase autobiographical memory vividness and emotional quality. Thus, the present study will be

examining the question; does the emotion expressed by a piece of music influence the emotional quality of autobiographical memories generated when listening to the piece?

Method

Participants

Eighty-five undergraduate students were recruited using the University of Western Ontario's psychology research participation pool, SONA. The participants were given partial course credit in their psychology courses for completing the study. Thirteen participants were removed from the analysis for failing to complete the study, leaving us with a final study sample of 72 participants. The basic demographics and musical background questionnaire (see Appendix B) indicated that there were 31 men and 41 women in the final sample, aged between 18 – 24 years (M = 18.8 SD = 1.11). All participants reported being fluent English speakers with no hearing problems. 64 participants had reported playing a musical instrument sometime in their life. 63 participants rated their music skill abilities to be above 1 on a 6-point (i.e., 1 = *no skills/experience, 6 = very skilled/ experienced)* (M = 3.5, SD = 1.44). None of the participants reported any previous knowledge or experience with the study.

Stimuli and Measures

Music Stimuli

The musical stimuli were taken from a database by Eerola and Vuoskoski, (2011) which includes instrumental background soundtrack music from Hollywood movies selected for how strongly they convey emotion. They had participants rate the emotion expressed by each piece and picked four soundtracks for each emotion category (happiness, fear, tenderness, and sadness) that had the most consistent ratings across the participants (Eerola & Vuoskoski, 2011; Vuoskoski et al., 2012). Thus, the musical stimuli used have been previously tested for their

ability to be perceived as conveying an emotion strongly. For a chart listing the 16 song excerpts used and the movies they came from see Appendix A (Vuoskoski et al., 2012). During the study, participants also rated how familiar each song sounded to them on a 6-point scale (1 – *I've never heard it before* to 6- *extremely familiar*). On average, participants rated the tracks as sounding more unfamiliar than familiar (M = 3.04, SD = 1.56).

Autobiographical Memory

The questions used were generated by the researchers with the goal of determining if there was an autobiographical memory recalled, how vivid the memory was, if there was a strong emotional component to the memory, as well as the felt emotion, perceived emotion and emotional strength of the music clip. The questions related to autobiographical memory were: (1) Briefly describe the memory you associated with this song, (2) How important is this memory to you? (1- *it is a very trivial memory and did not affect my life* to 6- *it was a life changing event*), (3) How vividly could you recall this memory to mind? (1- *I could recall it only vaguely with very little details* to 6- *I could recall it as if I were reexperiencing it in my mind*), (4) Which emotion would you associate with this memory? (Happiness/Fear/Tenderness/Sadness), (5) How strong was the emotion you felt when recalling the memory? (1 – *not at all/I felt nothing* to 6 - *extremely strong*), (6) What age were you (in years) when this memory occurred?

Ratings of Emotional Responses to Music

The questions related to perceived and felt emotion of the music clips were: (1) What emotion is portrayed by this song? (Happiness/Fear/Tenderness/ Sadness), (2) How strongly does this song portray the emotion? (1 – *not at all* to 6 -*extremely strong*), (3) What emotion do you feel when listening to this song? (Happiness/Fear/Tenderness /Sadness), (4) How strong of an

emotional response do you feel in response to this song? (1 – *not at all/I felt nothing* to 6 - *extremely strong*) (5) Did you like the music? (1- *I hated it* to 6- *I loved it*).

Procedure

Participants completed the study online through the SONA program on Qualtrics, once they read the letter of information and gave consent (Appendix C) they filled out the demographic questionnaire and were then told to listen to the music clips presented to them and answer the presented questions to the best of their ability. Participants were informed clearly that they could end the study at any time if they were uncomfortable since they were being asked to describe personal memories. The music was presented in random order and the participants listened to 15 second excerpts of each song. There were four music clips from each four categories (happiness, sadness, fear, and tenderness) presented to them in total. While listening to the clip the participants were prompted to think of a memory from their life that the music reminds them of. They were then asked to answer questions about their autobiographical memory recall after each music clip. To avoid participants answering questions with the purpose of giving favorable responses, they then listened to the 16 music clips again and were prompted to answer questions about their perceived and felt emotions regarding the music itself. The responses were self-paced. Once the participants completed listening to the music clips twice over and answering the prompted questions, they were debriefed and thanked for their time.

Results

Do Participants Perceive and Feel the Same Emotion that the Music Intended to Portray?

First, we sought to understand whether participants perceived the same emotion that the 16 sounds were meant to convey. For each participant, four separate emotion match scores were calculated as the percentage of total trials where the participant perceived the same emotion as

the one conveyed by the song. For example, if a participant perceived happiness in three out of the four cues in the happy category, they got a match percentage score of 75% for the happy category. One-sample *t*-tests were then used to tell us whether participants' perceived emotions when listening to songs matched with the emotions the songs intended to convey. As shown in Table 1, these analyses revealed that participants did indeed perceive the same emotion as the songs were intending to convey at a rate significantly above chance (*ps* < .001). Thus, participants reliably perceived the emotions they were meant to when listening to the songs in the study.

Table 1

Perceived Emotion Percentage by Music Cue

	Song Clip Intended Emotion			
Perceived Emotion	Fear	Happiness	Sadness	Tenderness
Fear	**78.1 (32.8)**	2.1 (8.1)	8.3 (13.3)	0.3 (2.9)
Happiness	9.02 (21.9)	**93.4 (15.1)**	2.8 (7.9)	17.4 (24.3)
Sadness	4.5 (13.5)	0.7 (4.1)	**71.5 (25.6)**	8.7 (15.8)
Tenderness	8.3 (20.6)	3.8 (9.9)	17.4 (23.6)	**73.6 (29.6)**

Note. Bold font shows that participants perceived the same emotion as the cue intended to portray at a rate that was significantly above chance (chance probability = 25%).

Next, we examined the emotions participants stated they felt when they heard music portraying different types of emotion. We similarly calculated percentage match scores, but this time with participants' felt emotion responses. One-sample *t*-tests revealed that participants felt emotions that matched with the emotions that the songs intended to convey at a rate significantly above chance (*ps* < .01; see Table 2).

Next, using paired-samples *t*-tests, we asked whether participants' felt emotion and perceived emotion differed in how much they matched with the intended emotion of the songs. Happiness was just as likely to be felt as it was to be perceived in response to happy sounding songs, $t(71) = 0.82$, $p = .42$, just as fear was equally likely to be felt as it was perceived in response to fear category songs, $t(71) = 1.76$, $p = .08$. On the other hand, sadness, $t(71) = 15.49$, $p < .001$, and tenderness, $t(71) = 2.95$, $p < .01$, were more likely to be perceived than felt in response to sad and tender sounding songs, respectively (see Figure 1). Thus, the music clips accomplished manipulating the participants to feel the intended emotions, but songs conveying happiness and fear did so better than songs conveying sadness and tenderness.

Table 2

Felt Emotion Percentage by Music Cue

	Song Clip Intended Emotion			
Felt Emotion	Fear	Happiness	Sadness	Tenderness
Fear	**75 (30.8)**	1.7 (7.7)	11.1 (15.1)	0.3 (2.9)
Happiness	11.8 (22.9)	**92.7 (14.8)**	3.5 (11.3)	22.2 (25.7) †
Sadness	5.2 (16.7)	1.04 (5.03)	**61.5(19.2)**	13.1 (19.2)
Tenderness	7.9 (20.5)	4.5 (10.6)	23.9 (27.9) †	**64.3 (30.8)**

Note. Bold font shows that participants felt the same emotion as the cue intended to portray at a rate that was significantly above chance (chance probability = 25%). † signifies values that are not significantly different from chance.

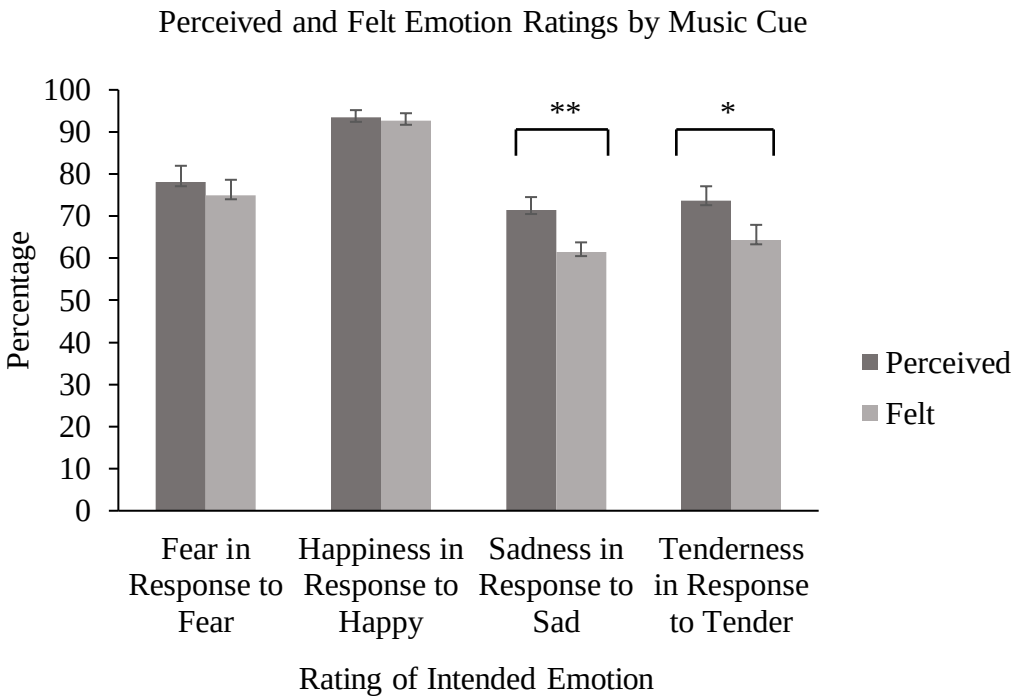

Figure 1. When listening to tender and sad songs participants were more likely to perceive the emotion than they were to feel it themselves. When listening to fearful and happy songs, participants were just as likely to perceive the emotion as they were to report feeling it.

The preceding analyses were conducted with the discrete emotion responses participants made to indicate their perceived and felt emotion in response to songs. Participants also rated how strongly they perceived and felt emotion in response to listening to each song, and we wanted to see just how closely felt and perceived emotion strength correlated. A two-level linear mixed-effects model predicted felt emotion strength as a function of perceived emotion strength, song familiarity, participant age, music skill and gender, with random intercepts for participants and song. Song familiarity, participant's age, gender and music skill were included in the model as potential confounding variables. We used a Variance Components covariance matrix and the Satterthwaite method of estimating degrees of freedom. The analysis revealed significant independent effects of perceived emotion strength and song familiarity on felt emotion strength. When participants perceived emotion strongly in response to a song, they also reported feeling

that emotion strongly, $F(1, 747.110) = 717.269$, $ß = 0.69$, 95% CI [0.64,0.74], $p < 0.001$, and when a song sounded more familiar, participants felt emotion in response to the song more strongly, $F(1, 821.409) = 26.933$, $ß = 0.12$, CI [0.08, 0.17], $p < 0.001$.

What Predicts Qualities of Memories Recalled?

In the next analysis, we asked whether the emotion participants associated with their recalled memories matched with the song's emotion. As with perceived and felt emotion, here again we calculated percentage match scores for each of the four song emotion categories for each participant. One sample *t*-tests were conducted on these percentage match scores, revealing that the emotional quality of memories generated after listening to music cues were matched with the emotional quality of the music cue significantly above chance (See Table 3). However, tender sounding pieces additionally cued happy memories at a rate significantly above chance. A paired sample *t*-test revealed that happy and tender memories in response to tenderness cued songs significantly differed, $t(71) = 2.16$, $p < 0.05$, with tender sounding songs being more likely to cue happy memories than tender memories.

Table 3

Memory Emotion Percentage by Music Cue

	Song Clip Intended Emotion			
Memory Emotion	Fear	Happiness	Sadness	Tenderness
Fear	**55.2 (26.5)**	2.8 (11.5)	18.8 (19.6)	3.8 (14.3)
Happiness	31.9 (23.8)	**85.8 (19.6)**	16.3 (20.6)	**49.3 (30.8)**
Sadness	4.2 (9.4)	3.5 (8.7)	**47.9 (27.4)**	10.4 (17.2)
Tenderness	6.9 (16.9)	7.3 (14.2)	14.6 (20.5)	**35.1 (29.9)**

Note. Bold font shows that participants recalled memories of the same emotion as the cue intended to portray at a rate that was significantly above chance (chance probability = 25%).

We then sought to understand whether participant's perceived and felt emotion ratings in response to songs predicted the emotional strength of their recalled memories. We were also interested in understanding whether felt and perceived emotional responses predicted memory vividness and importance. To answer these questions, we ran three different linear mixed-effects models predicting (1) emotional intensity of memories, (2) memory vividness, and (3) memory importance ratings. Felt emotion (anger, happiness, sadness, tenderness), felt emotion strength, perceived emotion (anger, happiness, sadness, tenderness), perceived emotion strength, song familiarity, age of the participant, gender and music skill were included as predictors in the models, with random intercepts for participant and track.

In the first model predicting the emotional intensity of the recalled memory, felt emotion strength was a significant independent predictor, $F(1, 1061.271) = 4.521$, ß = 0.09, CI [0.01, 0.166], $p < .05$. Memories with greater emotional intensity were generated to songs that made participants feel, rather than simply perceive, emotions strongly. Songs that participants rated as sounding more familiar also corresponded with more emotionally intense memories, $F(1, 872.966) = 61.676$, ß = 0.25, CI [0.19, 0.31], $p < .001$. The specific emotion participants said they felt or perceived when listening to the songs did not seem to matter, and neither did gender, participant age or music skill (ps > .05).

In the second model that predicted memory vividness, only song familiarity was a significant predictor, $F(1, 863.220) = 65.197$, ß = 0.25, CI [0.19, 0.31], $p < .001$, felt and perceived emotions were not (ps > .05). In the final model predicting the importance of the memory, participants recalled more significant memories when they perceived emotions strongly in a piece, $F(1, 707.657) = 7.623$, ß = 0.13, CI [0.04, 0.23], $p < .01$, but not necessarily when they felt emotions strongly, $p = .73$. Song familiarity was also a significant predictor of memory

importance, $F(1, 794.643) = 27.937$, ß = 0.19, CI [0.12, 0.64], $p < .001$. Moreover, neither the specific emotion participants said they felt or perceived when listening to the songs nor their gender, age or music skill mattered ($ps > .05$).

Discussion

The purpose of the present study was to understand how the emotional response to music cues relates to the emotional and general quality of memories recalled while listening to music. Participants listened to 16 different music clips that were intended to portray happiness, sadness, fear, and tenderness. They rated the memories they generated while listening to the cue as well as the emotional quality they perceived and felt while listening to these songs. As expected, the music cues achieved their intended outcome and participants perceived and felt emotions that matched with the emotion that the songs intended to convey. Perceived and felt emotion were positively and strongly correlated, but individuals were more likely to perceive sadness and tenderness in the song clips than they were to feel it. On the other hand, there was no significant difference between perceived and felt happiness and fear in response to happy and fearful sounding songs, respectively. Additionally, the stronger participants perceived emotions in songs, the stronger they felt the emotion themselves. Felt emotion strength predicted the emotional intensity of a memory recalled, but perceived emotion strength did not. Finally, higher song familiarity ratings corresponded with stronger felt emotion strength, memory vividness and memory importance ratings. No other variables predicted the vividness of memories, but increased perceived emotion related to the generation of more important memories. Importantly, these results support the notion that emotional processes during music listening are key for music-cued autobiographical memory recall.

Perceived vs. Felt Emotions Relationship

The integration of perceived and felt emotion ratings into this study facilitated a better understanding of (1) ensuring that the music cues were accomplishing their intended purpose of portraying particular emotions and (2) parsing what aspects of the emotional component of music may be influencing autobiographical memory recall. The former was confirmed to have been accomplished when the perceived emotion ratings and intended music cue were compared using a paired *t*-test. Past studies such as the one conducted by Hunter et al. (2010) found that participants were more likely to report perceiving an emotion than they were to feel it themselves. The results that were found are consistent with this finding, individuals were able to properly identify the emotional cue of unfamiliar songs but that did not guarantee the participant would feel the emotion themselves. Individual learned associations or triggered memories brought on by the music cues could lead to unrelated felt emotions while listening to music. This may divert the felt emotion from the intended portrayed emotion. However, the perceived emotion still had an impact on what is being felt by the individual and thus memory recall as well. There was also variance between the different emotions in their ability to be felt by the listener. Sadness and tenderness, the two emotion cues that were less successful at eliciting a felt response, tend to be rated as a lower arousal emotion. Sheldon and Donahue (2017) found that more emotionally arousing pieces led to a faster retrieval of more unique memories. It is possible arousal has a similar effect on felt emotional response, but future studies integrating perceived and felt ratings with valence and arousal ratings would have to be conducted in order to support this speculation.

Determinants of the Emotional Quality of Memories

Overall, the emotional quality of the recalled memories appears to be influenced by musical cues, felt emotion strength ratings, and song familiarity. The music cues successfully

influenced the emotional quality of memories, but there appeared to be a positive bias to the memories recalled. Sadness and fear had lower match proportions than happiness, and tender music pieces elicited more happy than tender memories. Positive bias in memory retrieval is consistent with past studies' findings (Schulkind & Woldorf, 2005; Sheldon & Donahue, 2017). This is likely because of an individual's desire to maintain a form of positive mental well-being and sense of self (Alea & Bluck, 2003). What is causing the emotional quality match, then, to be mostly accurate after listening to the musical cues? It is possible that mood congruent states are leading to a form of encoding specificity such as ecphory (Tulving, 1982). Thus, because of the similarity between the emotion at time of retrieval and emotion at time of encoding, the memories being recalled are congruent with the music cue and may possibly be of better quality. Future research may find it beneficial to study if cue emotion congruent memories are of better vividness or quality than those that are not. Additionally, stronger felt emotion strength led to more emotionally intense memories to be recalled. Perceived emotion strength did not have the same effect, thus suggesting that felt emotion intensity plays a more important role in the emotional intensity of memories when listening to musical cues. Increased song familiarity also corresponded with more emotionally intense memories, signifying that a reason past studies may have found promising results in music's ability to elicit high emotional quality memories had to do with the familiarity of pop chart music.

Determinants of Memory Vividness and Importance

It was hypothesized that more emotionally intense responses to music cues would lead to increased memory vividness, but this was not found within our study. The only variable that predicted memory vividness ratings was song familiarity. The more familiar the individual found the music clips to be, the more vivid they rated the memory recalled while listening to the song.

The use of popular chart music in previous studies similar to those done by Belfi et al. (2016) is likely a large factor in why quality of memory retrieval is increased in response to music cues. The memories individuals associate with familiar music likely lead to an easier time retrieving a memory and thus cause more vivid recall. Furthermore, higher memory importance ratings were predicted by both greater perceived emotion strength and song familiarity. Felt emotion strength did not have the same relationship with memory importance. Thus, only if an individual found the music cue to portray an emotion strongly, were they more likely to recall a memory that they considered more significant in their life. This is an unexpected finding and requires further study to understand why this relationship occurred. Song familiarity consistently improved emotional quality and memory recall quality, subsequently song familiarity and its relationship with memory importance is not surprising but also requires further study to better understand.

Limitations and Future Directions

A focus of the present study was to understand if unfamiliar music has the ability to elicit strong emotional responses and memory recall. Hence, there was no control to compare memory recall ability with vs. without music, as well as in response to unfamiliar vs. familiar music. A closer look at comparing these two variables may lead to a better understanding of what is occurring in the results of this study. Song familiarity predicted many of the variables we were focused on analyzing (felt emotion strength, memory vividness, memory importance, and memory emotional intensity), this suggests that a study comparing memory recall and emotional response to familiar vs. unfamiliar music would be beneficial in future studies so the depth of this relationship can be better understood.

Additionally, there were some limitations with the methodology employed in the study. All participants were young adults and undergraduate students at the University of Western

Ontario, a more diverse participant sample would make these results more generalizable. Also, participants were asked to rate perceived and felt emotions one after another and this may have led to favorable answers. Finally, participants were given forced choice options when selecting emotion ratings for memories and the emotional response. Although this was meant to be counteracted by the intensity ratings, it is worth mentioning as a possible limitation.

Conclusions

To date, researchers have been attempting to explore the various ways autobiographical memory recall can be improved as well as how music plays a role in this process. Understanding the different facets of this area of research is important for future directions in memory studies that may lead to aiding clinical intervention strategies. The results of the present study provide a greater understanding of how music can impact autobiographical memory recall and meaningful emotional responses. The analysis has demonstrated that there is a strong emotional component to memory retrieval when listening to music cues, and that emotionality and familiarity of songs should be included in future studies examining autobiographical memory retrieval if music is being used as the stimuli. In conclusion, utilizing more familiar and emotionally intense songs will elicit the best emotional and memory recall response.

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Appendix A

Excerpt	Emotion	Soundtrack name	Track	Time	Duration	Number in the set of 110**
F1	Scary	The Alien Trilogy	9	00:00-00:56	56 s	003
F2	Scary	Batman Returns	5	00:00-00:46	46 s	011
F3	Scary	The Fifth Element	17	00:00-01:01	61 s	018
F4	Scary	The Alien Trilogy	11	02:04-02:58	54 s	091
H1	Happy	Oliver Twist	8	01:32-02:09 L*	72 s	027
H2	Happy	Dances with Wolves	10	00:00-00:46	46 s	055
H3	Happy	The Untouchables	6	01:26-02:06 L*	67 s	071
H4	Happy	Pride & Prejudice	4	00:10-01:06	56 s	105
S1	Sad	The English Patient	18	00:00-00:59	59 s	031
S2	Sad	The Portrait of a Lady	9	00:00-00:23 L*	45 s	033
S3	Sad	Running Scared	15	01:45-02:40	55 s	086
S4	Sad	Pride & Prejudice	13	00:40-01:30	50 s	109
T1	Tender	The Portrait of a Lady	3	00:23-01:08	45 s	029
T2	Tender	Shine	10	01:01-02:00	59 s	041
T3	Tender	Pride & Prejudice	1	00:10-00:49 L*	77 s	042
T4	Tender	The Godfather III	5	01:13-02:19	66 s	107

*L = looped

**see the list of stimuli for the set of 110 excerpts, Eerola & Vuoskoski (2011)

Appendix B

Participant ID: _____ Date: ___/___/_____ (dd/mm/yyyy)

Demographic information

Important: You are free to leave any question blank

Gender: Male Female Non-binary/third gender Prefer not to say

Age: _____

Which country do you currently live in? _____

Which country did you spend the formative years of your childhood and teens in? _____

What level did you attain in school (please check one):

□ Elementary School.
□ Less than Grade 12.
□ High school diploma.
□ Some university undergraduate schooling
□ Other (please specify): ___

□ College Degree (2 years)
□ Bachelor's degree.
□ Postgraduate degree.

What is your first language? _____

Do you consider yourself bilingual? ○ **Yes** ○ **No**

What language are you fluent in other than your first language: _____

How would you describe your musical skills/experiences (please cycle one number)?

(not skilled/experienced) 1 2 3 4 5 6 (very skilled/experienced)

Have you ever played a musical instrument? Yes No

If yes, which instrument(s)?

_____

For how many years did/have you played? _____

What type of training did you receive? (ex. conservatory, private lessons, self-taught)?

_____

Are you currently practicing music? Yes No

If yes, how many hours per week do you practice?

_____

How important is music to your identity?

(not important) 1 2 3 4 5 6 (very important)

Do you wear a hearing aid? No Right Left Both

How would you describe your general hearing abilities (please cycle one number)?

(bad) 1 2 3 4 5 6 (good)

Thank you for your participation.

Appendix C

Behavioral studies of rhythm and music perception

Principal Investigator:
Dr. Jessica Grahn
Department of Psychology, University of Western Ontario, London, ON
Telephone: (519) 661-2111: Email: jgrahn@uwo.ca

Introduction

You are being invited to participate in a research study about human perception of music and rhythm. The purpose of this study is to investigate how humans perceive rhythm and music, and how rhythm and music might change our experience of or memory for other sights and sounds.

The purpose of this letter is to provide you with information required for you to make an informed decision regarding participation in this research. It is important for you to understand why the study is being conducted and what it will involve. Please take the time to read this carefully, and feel free to ask questions if anything is unclear or if there are words or phrases you do not understand.

Research Procedures

The experiments conducted as part of this study will test how humans hear, see, remember, and move when they listen to auditory rhythms (including music) or see visual rhythms. If you agree to participate, you will be asked to listen to or watch rhythmic stimuli. You may be asked to make simple responses about whether you detect the presence of or differences between stimuli, to tap, bounce, or walk in time with the stimuli, and/or to make ratings about your impressions of the stimuli. You might also be asked to perform a task testing your memory or attention while you are listening to music. Finally, your brain activity might be recorded using a technique called electroencephalography (EEG), where electrodes placed on the scalp measure electrical signals that brain cells use to communicate. It is anticipated that the entire task will take no more than 3 hours. In-person task(s) will be conducted in the Brain and Mind Institute in the Natural Sciences building, the Social Sciences Building, or the Robarts Research Institute on the University of Western Ontario campus.

Inclusion and Exclusion Criteria

Individuals who are at least 17 years of age having hearing and vision adequate to perform the task are eligible to participate in this study. Individuals who are younger than 17 years of age or who have hearing damage or vision problems too severe to complete the task will be excluded from the study.

Risks and Benefits

There are no known or anticipated risks or discomforts associated with participating in this study. Although you may not directly benefit from participating in this study, the information gathered may provide benefits to society as a whole which include enhancing our scientific understanding of music perception and leading to advancements in medical care (for example, music or motor therapy) for disorders like Parkinson's disease.

Compensation

You will receive course credit (1 credit per hour) or monetary compensation for your participation ($5 per half hour for an in-person study or $2.50 per half hour for an online study).. If you do not complete the entire study you will still be compensated the full amount (e.g. 10 minutes of participation for a 1/2 hour study will gain $5).

Voluntary Participation

Participation in this study is voluntary. You may refuse to participate, refuse to answer any questions or withdraw from the study at any time with no effect on your future academic status.

Confidentiality

Any information obtained from this study will be kept confidential and will be accessible only to the investigators of this study. In the event of publication, any data resulting from your participation will be identified only by case number, without any reference to your name or personal information. The data will be stored on a secure computer in a locked room. Both the computer and the room will be accessible only to the investigators. Online survey responses will be collected anonymously through secure online survey platforms such as Qualtrics, Pavlovia or Mturk. These online platforms use encryption technology and restricted access authorizations to protect all data collected. Western's Qualtrics server is in Ireland, where privacy standards are maintained under the European Union safe harbour framework. Pavlovia server is in the United Kingdom and servers have a high level of security whereby, encryption is maintained to a level suitable for HIPAA. Lastly, Mturk adheres to the Privacy Shield Framework and Principles. The data will then be exported from the online platforms and securely stored on Western University's server. After completion of the experiment, data will be archived on storage disks and stored in a locked room. Any documents identifying you by name will be kept separately from your data, and will be destroyed after 5 years.

Representatives of the University of Western Ontario Health Sciences Research Ethics Board may require access to your study-related records or may follow up with you to monitor the conduct of the study.

Open Data:

All identifiable information will be deleted from the dataset collected so that individual participant's anonymity will be protected. The de-identified data will be accessible by the study investigators as well as the broader scientific community. More specifically, the data may be posted on a database OR made available to other researchers upon publication so that data may be inspected and analyzed by other researchers. The shared data will not contain any information that can identify you.

OurBrainsCan Database:

Your contact and demographic information, will be stored in a secure, password-protected database. If you would like to be contacted about future research studies for which you (or your child) may be eligible, you can choose to have your information entered into "OurBrainsCAN: University of Western Ontario's Cognitive Neuroscience Research Registry". This is a secure database of potential participants for research at the University of Western Ontario that aims to

enrol 50,000 volunteers over a period of 5 years. The records are used only for the purpose of recruiting research participants and will not be released to any third party.

Contacts for Further Information

If you would like to receive a copy of the overall results of the study, or if you have any questions about the study please feel free to contact the Principal Investigator at the contact information provided above.

If you have any questions about your rights as a research participant or the conduct of the study you may contact:

The Office of Research Ethics
The University of Western Ontario
519-661-3036
E-mail: ethics@uwo.ca

This letter is yours to keep for future reference.

Consent Form

Project Title: Behavioral studies of rhythm and music perception
Study Investigator's Name: Dr. Jessica Grahn

I have read the Letter of Information, have had the nature of the study explained to me and I agree to participate. All questions have been answered to my satisfaction.

Participant's Name (please print): _____

Participant's Signature: _____

Date: _____

Person Obtaining Informed Consent (please print): _____

Signature: _____

Date: _____

Do you consent to entering your information into “OurBrainsCAN: University of Western Ontario’s Cognitive Neuroscience Research Registry” (REB 111944) to be contacted about future research studies for which you (or your child) may be eligible?

Yes, I already signed-up ☐

Yes ☐

No ☐