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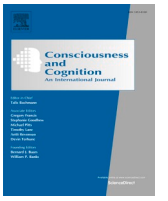

Investigating the role of involuntary retrieval in music-evoked autobiographical memories

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ABSTRACT

Music is a particularly salient autobiographical memory cue. Prior work has indicated that autobiographical memories evoked by music are more episodically rich than those evoked by other sensory cues. One explanation for this effect could be that music evokes autobiographical memories in a more involuntary manner than other cues. Here, we investigated the role of involuntary retrieval in music-evoked autobiographical memories. Results indicated that, regardless of intentionality, music-evoked autobiographical memories were more episodically rich and contained more perceptual details than face-evoked memories. That is, even when directly comparing involuntary music-evoked memories to involuntary face-evoked memories, there was still a consistent difference in episodic richness between memories evoked by the two cue types. This suggests that it is not the involuntary nature of music-evoked memories *alone* that drives this difference, but that the difference in episodic richness between cue types seems at least partially to depend on other stimulus features.

1. Introduction

1. Introduction Autobiographical memories are personal memories of events from one's life (Conway & Pleydell-Pearce, 2000). Such memories can be either recalled in a voluntary manner, in which they require effortful search and retrieval, or an involuntary manner, in which they seem to spontaneously come to mind without any intention to retrieve (Berntsen, 1998; Berntsen, 2009; Mace, 2007). Involuntary autobiographical memories can be elicited in response to external cues in one's environment, such as activities, people, sensory stimuli, and locations, and can also be triggered by internal factors such as thoughts and feelings (Berntsen, 2021, 1996). One particularly salient sensory cue for autobiographical memories is music – For example, hearing a strain of your favorite song from high school could prompt a vivid image of driving around your hometown on a hot summer night with your friends, singing along to the radio with the windows open. Music-evoked autobiographical memories happen quite frequently, with prior work indicating that they occur, on average, once per day (Jakubowski & Ghosh, 2019). While initial work sought to characterize the content of memories evoked by music (Janata et al., 2007), more recently, researchers have begun to investigate whether music is more effective at evoking autobiographical memories than other sensory cues.

Our prior work indicates that music-evoked autobiographical memories are more episodically rich and contain a greater proportion of perceptual details than memories evoked by images of famous persons (Belfi et al., 2016, 2018, 2020). Similarly, others have found that popular songs are more likely to evoke memories in persons with Alzheimer's disease than pictures of famous world events (Baird

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et al., 2018). Music-evoked memories contain more motor-perceptual details than memories evoked by lifetime period or specific event cues (Zator & Katz, 2017), and are associated with greater episodic re-experiencing and more intense emotions than memories evoked by television shows (Jakubowski et al., 2021). While substantial work suggests that music-evoked autobiographical memories may differ in terms of the memory content and phenomenological characteristics than memories evoked by other cues, there is some evidence to the contrary. For instance, one prior study compared autobiographical memories evoked while listening to music, reading lyrics, or viewing an image of the same musical artist, and found no difference in the memories evoked by these conditions (Cady et al., 2007).

One possible explanation for these contradictory results is that there may be differences between the comparison cues themselves (e.g., whether music is being compared to images of persons, events, verbal cues, etc.) and the manner in which memories are evoked by these cues. That is, in the one study that found no difference between autobiographical memories evoked by music, lyrics, or a picture of the artist, all memory cues were pre-selected by the participants, who chose cues that were most likely to evoke memories (Cady et al., 2007). In this way, the intention to retrieve memories and the degree of retrieval effort were likely consistent across all conditions – participants specifically chose cues with the intention to retrieve memories in response to each cue. Although the authors did not measure or control for intentionality or retrieval effort in this case, it is likely that memories were not spontaneously or involuntarily evoked but were intentionally retrieved.

In contrast to this manner of intentional retrieval is involuntary retrieval. Involuntary autobiographical memory retrieval tends to occur when individuals are not engaged in demanding cognitive tasks (Barzykowski & Niedźwieńska, 2016; Vannucci et al., 2014; Vannucci et al. 2018). Memories retrieved involuntarily come to mind spontaneously, without significant intention or perceived retrieval effort (Barzykowski et al., 2021). The resulting memories are accompanied by greater autonoetic consciousness, occur more frequently, and refer to specific episodes more often than memories retrieved voluntarily (Berntsen & Hall, 2004; Berntsen & Jacobsen, 2008; Mace, 2006; Rasmussen & Berntsen, 2011). Involuntary memories also tend to be more specific and are retrieved more quickly than voluntary memories (Berntsen & Hall, 2004; Schlagman & Kvavilashvili, 2008).

Previous research has indicated that different types of cues, and even different instructions given to participants, are more or less likely to evoke memories in an involuntary manner (Barzykowski et al., 2019; Uzer, 2016; Uzer & Brown, 2017; Vannucci et al., 2014). In the realm of music, research has suggested that music may be particularly well-suited to evoking autobiographical memories in an involuntary manner (El Haj, Fasotti, et al., 2012). In a diary study where participants recorded naturally occurring autobiographical memories during everyday life, music-evoked autobiographical memories tended to be retrieved with little intention or cognitive effort (as assessed by self-report), suggesting that music-evoked autobiographical memories may be particularly likely to be involuntary in nature (Jakubowski & Ghosh, 2019).

Therefore, one explanation for why previous research found differences between music-evoked autobiographical memories and memories evoked by other cues (including pictures of faces, events, verbal cues, and television shows), could be that these different cues elicit different degrees of intentionality or retrieval effort. For example, it may be the case that music-evoked memories are retrieved in a more involuntary manner, while retrieving memories in response to a picture requires more voluntary retrieval. In the present study, we sought to control for retrieval intentionality by directly comparing involuntary and voluntary memories evoked by both music and images of famous persons. Participants heard excerpts of popular songs and viewed images of famous persons. After each cue, they reported whether it evoked an involuntary autobiographical memory. If the cue did not evoke an involuntary autobiographical memory, participants were asked to intentionally and effortfully retrieve a related autobiographical memory. Therefore, the present study sought to investigate both the effects of cue type (music vs. faces) and retrieval intentionality (voluntary vs. involuntary) on the episodic richness and other characteristics of autobiographical memories.

If the primary reason music-evoked autobiographical memories were previously found to be more episodically detailed than face-evoked memories was solely due to their involuntary nature, we would expect to see no difference between cue types when we control for retrieval intentionality (i.e., involuntary music-evoked memories would exhibit no differences from involuntary face-evoked memories). Instead, we would expect to only see an effect of intentionality (i.e., involuntary memories would be more episodically detailed than voluntary memories, regardless of cue type). However, if music-evoked autobiographical memories are more episodically detailed for other reasons besides their involuntary nature, we would then predict an effect of stimulus type (e.g., music evoked memories would be more episodically rich than face-evoked memories), regardless of intentionality. In sum, the present work sought to identify the role of involuntary retrieval in music-evoked autobiographical memories to further explore the mechanisms underlying the potential for autobiographical memory enhancement via music.

2. Methods

2.1. Participants

We conducted an a priori power analysis using G*Power software to determine our sample size (Faul et al., 2007). In prior work, we found a large effect size when comparing episodic richness between autobiographical memories evoked by music and faces (Cohen's $d = 0.89$; Belfi et al., 2016). The present study builds off our prior work, moving from a comparison between two conditions to an ANOVA design. We therefore converted our previously-reported Cohen's $d = 0.89$ to Cohen's $f = 0.45$, which can be interpreted as a large effect size (Cohen, 1988). Using this effect size, we conducted a power analysis to determine the sample size necessary to detect within-subjects effects in a repeated-measures ANOVA. Exact parameters of this power analysis are as follows: Significance level of $\alpha = 0.05$, power of 0.95, correlation of 0 between repeated measures (this being the most conservative estimate, since we do not know the exact correlation between the repeated measures in this case), 1 group, and 4 measurements (involuntary music, voluntary music,

involuntary faces, voluntary faces). This power analysis resulted in a total sample size of 23 participants. To account for the possibility that our effects are smaller than we predicted, we therefore recruited a sample of 30 participants. Participants ($N = 30$, 15 M, 15F) consisted of younger adults recruited from the university population of Missouri S&T and from the broader community of Rolla, Missouri. Inclusion criteria were that participants must be under the age of 30, have no history of neurological or psychiatric disorders, and have normal or corrected-to-normal vision and hearing, as self-reported by the participants. Participants ranged from 20 to 29 years old ($M = 21.5$, $SD = 2.05$) and had an average of 15.66 years of education ($SD = 1.49$). Participants were compensated at a rate of $10/h and the experiment generally took 60–90 min to complete.

2.2. Stimulus selection

2.2.1. Musical cues

As in prior work (of our own and others), musical cues were selected randomly from the time period when participants were adolescents and young adults (Belfi et al., 2016, 2018, 2020; Ford et al., 2011; Janata, 2009; Janata et al., 2007). This lifetime period roughly corresponded with the "reminiscence bump," which is the period of life from which individuals tend to recall the most personal memories (Rubin & Schulkind, 1997). Specifically, songs were taken from the Billboard Top 100 charts and were selected on a participant-by-participant basis based on the years in which the participant was between 15 years of age and the present. For example, a 20-year-old participant would hear songs from 2017 to Present. For each song, we selected a 15-s excerpt that corresponded to the chorus or other highly recognizable portions of the song. One alternative way of selecting cues would be to ask participants to individually select music that evokes memories for themselves. However, this would prevent the memories from being entirely involuntary, as participants would be primed to recall memories by selecting the cues. Therefore, for theoretical reasons, we sought to preserve the involuntary nature of the memories by selecting cues that were unexpected to the participants rather than asking participants to select the cues themselves.

2.2.2. Face cues

It is important to note that there is no one "perfect" comparison cue which can match music on all its key dimensions. One important component is the specificity of the musical cues: Songs are specific, semantically unique entities (Belfi et al., 2019; Belfi & Tranel, 2014) and are situated within a particular time period. We chose famous persons as our comparison cue because they match musical cues on this dimension. Famous persons are also similar to the musical cues in that they are a part of popular culture, ubiquitously experienced, and highly familiar to the general population; and importantly, famous individuals are also frequently associated with autobiographical memories (Westmacott & Moscovitch, 2003). Faces were chosen from the Iowa Famous Faces test (Damasio, Grabowski, Tranel, Hichwa, & Damasio, 1996; Grabowski et al., 2001) and have been successfully used in our prior work on autobiographical memory retrieval (Belfi et al., 2016, 2018, 2020). The faces from this test include individuals with various occupations (athletes, politicians, actors, etc.) who were popular during a variety of time periods. Each famous face was assigned to particular years during which they were most popular. Faces were randomly selected in the same way as the music, i.e., based on the years of each participant's adolescence and young adulthood. Therefore, faces are similar to the musical clips in that they are highly familiar and specific to the participants' age but differ in the sensory modality (visual vs. auditory).

2.3. Procedure

Participants were first instructed on the difference between involuntary and voluntary autobiographical memory retrieval, and only proceeded to the experiment when they expressed confidence in their ability to distinguish between the two by verbally explaining the distinction to the experimenter. For full instructions see the **Appendix.** Participants then heard/saw cues from both categories (faces and music) presented in a random order. Each cue was presented for 15 s. Participants were seated in front of a computer screen; face cues were presented visually in the center of the screen and musical cues were played through the computer speakers. If the cue evoked an involuntary autobiographical memory, participants were asked to verbally describe the memory in as much detail as they could. If the cue did not evoke an involuntary autobiographical memory, participants were asked to voluntarily retrieve a memory in response to that cue and subsequently describe the memory. Participants were audio recorded while verbally describing the memories. There was no time limit to how long they had to describe the memory. The experimenter was present during the session but did not provide any additional prompting. After retrieving each memory, participants then were asked to "Rate the level of effort you used to retrieve this memory, where 1 is 'not at all effortful' and 6 is 'very effortful.'" Participants also were asked to "Rate your familiarity with the cue, where 1 is "unfamiliar, completely sure" and 6 is "familiar, completely sure."

Cues were presented until participants recalled 20 memories total: five voluntary and five involuntary for each cue type. Once a participant reached five trials of a particular type (e.g., five involuntary music-evoked memories), then they stopped providing that type of memory. For example, if a participant reported five involuntary memories to the first five musical cues, musical cues continued to be presented until they also reported five voluntary memories in response to musical cues. If any of the musical cues evoked involuntary memories beyond the first five reported, those were not reported by the participant and instead they proceeded on to the next cue. This total number of trials (20; five of each cue type and each level of retrieval intention) was selected to provide a sufficient amount of data for each memory type while still minimizing the total time of the experimental session (approximately 60–90 min) to reduce participant fatigue.

2.4. Data quantification

2.4.1. Likelihood of autobiographical memories evoked by face and musical cues

First, we sought to investigate if music and face cues differ in the frequency with which they evoke voluntary and involuntary autobiographical memories. In the task, participants were randomly presented with music and face cues and reported whether each cue evoked an involuntary memory. If a cue did not evoke an involuntary memory, participants were asked to retrieve a voluntary memory in response to the cue. Participants were presented with face and music stimuli until they retrieved five involuntary and five voluntary memories in response to each type of cue. For example, one participant may have retrieved five involuntary autobiographical memories in response to the first five musical cues, while in contrast, they may have needed to see ten faces before they reported five involuntary face-evoked memories. We sought to investigate whether there was a difference in the number of cues necessary to evoke five involuntary and five voluntary memories for face and music cues. To determine this likelihood of involuntary and voluntary memories, we counted the total number of stimuli required to achieve five involuntary and five involuntary memories of each cue type for each participant.

2.4.2. Autobiographical Interview coding of episodic richness

Recordings of memory descriptions were transcribed and coded according to the Autobiographical Interview protocol (as in Levine et al., 2002). Memories were coded by three trained raters using the training materials provided and each memory was coded by only one rater. Five memories from the Autobiographical Interview training dataset were coded by all three raters and intraclass correlation was performed (using a two-way mixed model) to assess interrater reliability. The ICC value for internal composite was 0.89 and for external composite was 0.99. These values reflect very high agreement among the three raters. In this coding scheme, each memory was segmented into details (single pieces of information) that were coded as either internal or external. Internal details pertain to the central memory and reflect episodic reexperiencing, and include details about the event (e.g., actions, happenings), time (e.g., year, season, day), place (e.g., city, building, room), perceptions (e.g., auditory, tactile, visual details), and thoughts or emotions (e.g., emotional states). External details do not directly pertain to the memory and primarily reflect semantic content (e.g., general knowledge or facts, for example, personal facts or general statements about the world), but also can include external events (e.g., details from other unrelated incidents outside of the main event being discussed), repetitions (e.g., repeating details already stated), or metacognitive statements and editorializing comments. After all details were coded, internal and external composite scores were calculated by summing the total number of internal and external details for each memory for each participant. The internal and external composite scores were then used to calculate a ratio of internal/total details. This ratio provides a measure of episodic detail that is unbiased by the total number of details (Levine et al., 2002). We included both the composite internal and external scores, as well as the ratio of internal/total details, in our statistical analyses.

2.4.3. Linguistic Inquiry and Word Count coding of word categories

In addition to coding the memories using the Autobiographical Interview method, we used the Linguistic Inquiry and Word Count as an automated text analysis technique (LIWC; Pennebaker et al., 2015). The LIWC uses a dictionary method to categorize words in a text into various groups, ranging from parts of speech to affective dimensions of a text. Our prior work indicated that music- and face-evoked memories differed on several features assessed by the LIWC (Belfi et al., 2020). Based on this, we selected a subset of LIWC categories. First, we included word count to assess whether retrieval effort or cue type influenced the total amount of verbal output. Given that our prior research found that music-evoked autobiographical memories had significantly greater "authenticity" than memories evoked by faces (Belfi et al., 2020), we included the "Authentic" summary variable. The authenticity summary variable is calculated within the LIWC from a combination of features. Texts rated with higher purported "authenticity" are those that can be predicted to be more truthful. That is, the measure of authenticity was developed by comparing texts containing truthful information to texts that contained untruthful information: Texts with higher authenticity ratings were more cognitively complex, contain more self-references and other-references, and use fewer negative emotional words (Newman et al., 2003). We also included the variables of affective processes (e.g., words like "happy", "cried"), social processes (e.g., "talk", "mate"), cognitive processes (e.g., "cause", "know"), and perceptual processes (e.g., "look", "heard"). To summarize, we included the following six variables in the LIWC analysis: word count, authenticity, affect, social, cognitive, and perceptual processes.

2.5. Data analysis

To assess differences between cue types in terms of the number of cues necessary to evoke five involuntary and five voluntary memories, we conducted a 2x2 repeated-measures ANOVA to test for differences between stimulus type (music, faces) and intentionality (voluntary, involuntary) on the number of cues presented. Next, we sought to investigate differences in the qualities of the memories themselves. To look at episodic richness, we conducted a series of 2x2 repeated-measures ANOVAs to test for differences between stimulus type (music, faces) and intentionality (voluntary, involuntary) on our dependent variables of interest: ratio of internal/total details, external composite score, and internal composite score. To assess differences in the text content as measured by the LIWC, we conducted a 2x2 MANOVA with all LIWC output variables as dependent variables in a single analysis. Follow-up tests consisted of univariate ANOVAs to investigate the effects on individual LIWC components. Finally, we conducted 2x2 ANOVAs to investigate subjective ratings of retrieval effort and familiarity. All ANOVAs were calculated using the anova_test function of the rstatix package in r (Kassambara, 2020).

3. Results

3.1. Likelihood autobiographical memories evoked by face and musical cues

First, we sought to investigate the likelihood of involuntary and voluntary memories evoked by music and face cues. A repeated-measures ANOVA indicated a significant main effect of stimulus type, $F(1,29) = 5.46$, $p = 0.02$, $_p\eta^2 = 0.15$, but no main effect of intentionality $F(1,29) = 3.32$, $p = 0.07$, $_p\eta^2 = 0.10$, nor interaction between the two, $F(1,29) = 0.34$, $p = 0.56$, $_p\eta^2 = 0.01$ (Fig. 1). To further investigate the main effect of stimulus type, we conducted a post-hoc pairwise comparison, which was not significant, $t(59) = 1.69$, $p = 0.09$, 95% CI:[-0.24, 2.91]. Therefore, although the overall number of stimuli for face cues (M = 11.6, SD = 6.26) was higher than the overall number of stimuli for musical cues (M = 10.3, SD = 4.72), this effect was quite small.

3.2. Autobiographical Interview coding of episodic richness

When assessing the effect of stimulus type (music, faces) and intentionality (voluntary, involuntary) on episodic richness (as measured by the ratio of internal/total details), an ANOVA revealed a significant main effect of stimulus type, $F(1,29) = 18.82$, $p < 0.001$, $_p\eta^2 = 0.39$, and a main effect of intentionality, $F(1,29) = 10.10$, $p = 0.003$, $_p\eta^2 = 0.25$, but no significant interaction between the two, $F(1,29) = 0.028$, $p = 0.86$, $_p\eta^2 < 0.001$. Post hoc pairwise comparisons, Bonferroni corrected for multiple comparisons, indicated that involuntary memories had a significantly higher ratio of internal/total details than voluntary memories, $t(59) = 3.24$, $p = 0.01$, 95% CI:[0.02, 0.08], and that music-evoked memories had a significantly higher ratio of internal/total details than face-evoked memories, $t(59) = -4.45$, $p < 0.001$, 95% CI:[-0.10, −0.04].

In addition to looking at the ratio of internal/total details as a measure of episodic richness, we also looked at the individual composite scores for internal and external details. For internal details, the ANOVA revealed a significant main effect of intentionality, $F(1,29) = 5.14$, $p = 0.03$, $_p\eta^2 = 0.15$, but no main effect of stimulus type, $F(1,29) = 0.89$, $p = 0.35$, $_p\eta^2 = 0.03$, or interaction between the two, $F(1,29) = 3.90$, $p = 0.058$, $_p\eta^2 = 0.11$. Post hoc pairwise comparisons, Bonferroni corrected for multiple comparisons, indicated that involuntary memories contained significantly more internal details than voluntary memories $t(59) = 1.92$, $p = 0.05$, 95% CI:[0.05, 2.58]. For external details, the ANOVA revealed a significant main effect of stimulus type, $F(1,29) = 7.88$, $p = 0.009$, $_p\eta^2 = 0.21$, but no main effect of intentionality, $F(1,29) = 0.20$, $p = 0.65$, $_p\eta^2 = 0.007$, or interaction between the two, $F(1,29) = 0.60$, $p = 0.44$, $_p\eta^2 = 0.02$. Post hoc pairwise comparisons, Bonferroni corrected for multiple comparisons, indicated that face-evoked memories contained significantly more external details than music-evoked memories, $t(59) = 2.68$, $p = 0.009$, 95% CI:[0.54, 3.74]. See Fig. 2 for a graphical depiction of these data.

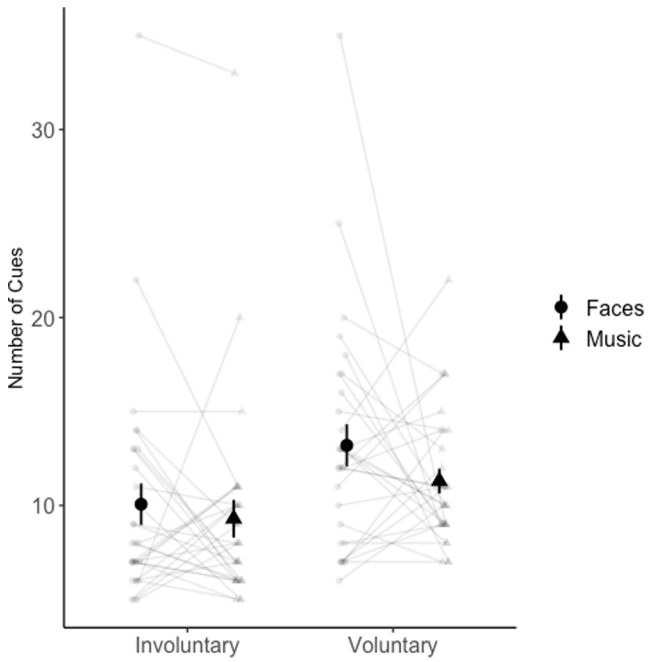

Fig. 1. Number of cues required to evoke five involuntary and five voluntary memories for each cue type. Solid circle/triangles (circles indicating face-evoked memories, triangles indicating music-evoked memories) indicate means across participants, dark lines indicate standard error of the mean. Gray points indicate individual subjects' data. Gray lines connect individual subject datapoints to illustrate the pattern of results for each subject.

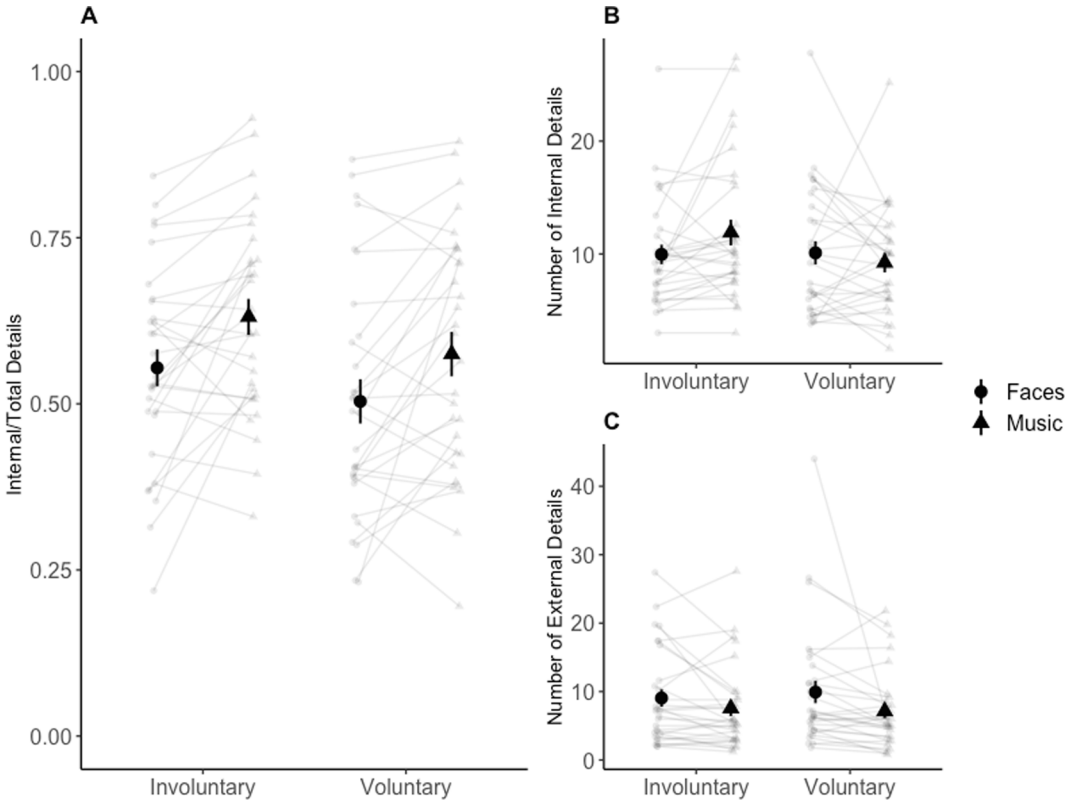

Fig. 2. Autobiographical Interview coding results. A) Ratio of internal/total details. Music-evoked memories had a significantly higher ratio of internal/total details than face-evoked memories. **B)** Composite number of internal details. Involuntary memories had a significantly larger number of internal details than voluntary memories. **C)** Composite number of external details. Face-evoked memories had a significantly larger number of external details than music-evoked memories. In all graphs, solid circle/triangles (circles indicating face-evoked memories, triangles indicating music-evoked memories) indicate means across participants, dark lines indicate standard error of the mean. Gray points indicate individual subjects' data. Gray lines connect individual subject datapoints to illustrate the pattern of results for each subject.

3.3. Linguistic Inquiry and Word Count coding of word categories

To investigate differences between conditions in terms of the words used in participants' memory descriptions, we conducted a 2x2 MANOVA with our two factors as independent variables (intentionality: voluntary, involuntary; stimulus type: face, music) and the six LIWC features as dependent variables. This analysis revealed a significant multivariate main effect of stimulus type, $F(6,111) = 8.24$, $p < 0.001$, ${}_{p}\eta^2 = 0.30$, but no significant main effect of intentionality, $F(6,111) = 1.05$, $p = 0.39$, ${}_{p}\eta^2 = 0.05$, or interaction between the two, $F(6,111) = 0.83$, $p = 0.54$, ${}_{p}\eta^2 = 0.04$.

To further investigate the multivariate effect of stimulus type, we conducted follow-up univariate ANOVAs for each dependent variable. These revealed significant main effects of stimulus type for the variables of authenticity, $F(1,116) = 10.51$, $p = 0.002$, ${}_{p}\eta^2 = 0.08$, social processes, $F(1,116) = 4.88$, $p = 0.02$, ${}_{p}\eta^2 = 0.02$, and perceptual processes, $F(1,116) = 31.63$, $p < 0.001$, ${}_{p}\eta^2 = 0.21$. Post hoc pairwise comparisons, Bonferroni corrected for multiple comparisons, indicated that music-evoked memories showed higher levels of authenticity, $t(59) = -3.84$, $p < 0.001$, 95% CI:[-15.33,-4.83] and contained more perceptual words, $t(59) = -6.16$, $p < 0.001$, 95% CI:[-1.77,-0.90], while face-evoked memories contained more social words, $t(59) = 2.65$, $p = 0.01$, 95% CI:[0.26,1.84]. There were no significant main effects of stimulus type for word count, $F(1,116) = 0.52$, $p = 0.46$, affective processes, $F(1,116) = 0.14$, $p = 0.70$, or cognitive processes, $F(1,116) = 0.08$, $p = 0.77$. See Fig. 3 for a graphical depiction of these data.

3.4. Subjective ratings of familiarity and retrieval effort

We also sought to investigate differences between conditions on the two subjective ratings made by participants. First, participants rated their familiarity with the stimuli on a six-point scale. For familiarity, a 2x2 ANOVA revealed a significant main effect of intentionality, $F(1,29) = 62.61$, $p < 0.001$, ${}_{p}\eta^2 = 0.68$, but no main effect of stimulus type, $F(1,29) = 3.30$, $p = 0.80$, ${}_{p}\eta^2 = 0.10$, or interaction between the two, $F(1,29) = 3.99$, $p = 0.055$, ${}_{p}\eta^2 = 0.12$. Post hoc pairwise comparisons, Bonferroni corrected for multiple comparisons, indicated that stimuli that evoked involuntary memories were rated as significantly more familiar than stimuli that evoked voluntary memories, $t(59) = 7.69$, $p < 0.001$, 95% CI:[0.89, 1.52]. Participants also rated their perceived retrieval effort for

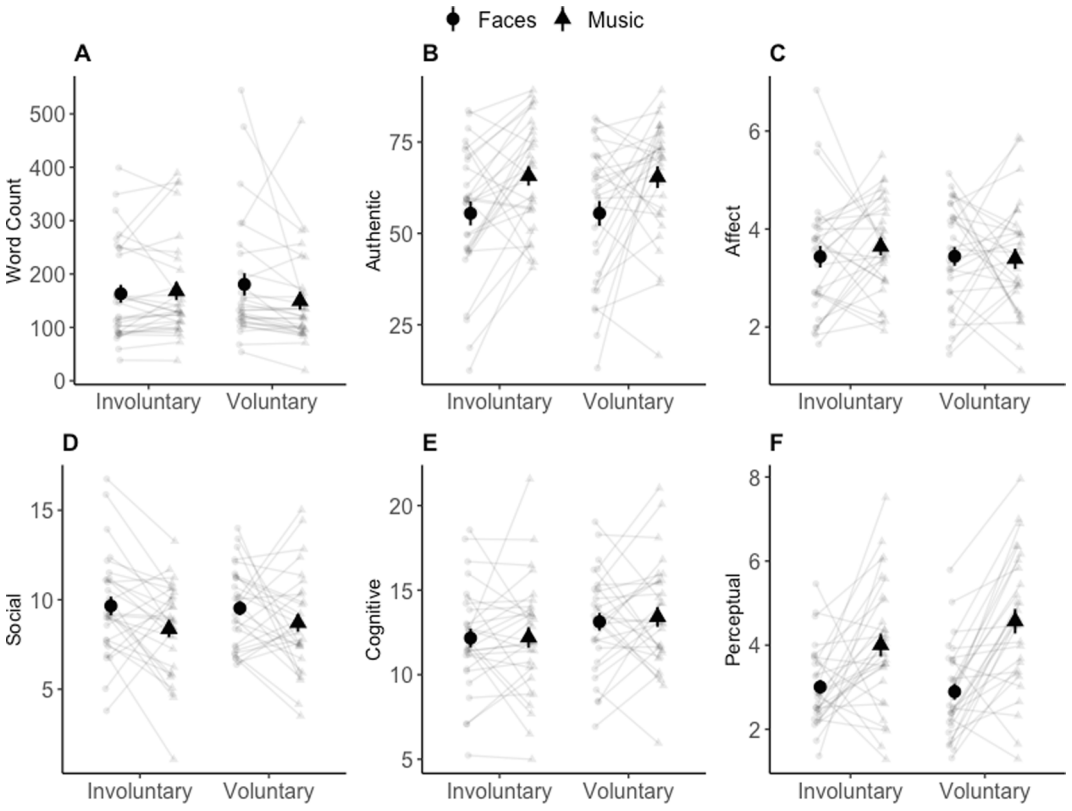

Fig. 3. LIWC Results. (**A**) Word Count, (**B**) Authenticity, (**C**) Affective processes, (**D**) Social Processes, (**E**) Cognitive Processes, (**F**) Perceptual processes. Music-evoked memories had significantly higher ratings of authenticity (**A**) and contained significantly more words reflecting perceptual processes (**F**). Face-evoked memories contained significantly more words reflecting social processes (**D**). There were no significant effects of intentionality. In all graphs, solid circle/triangles (circles indicating face-evoked memories, triangles indicating music-evoked memories) indicate means across participants, dark lines indicate standard error of the mean. Gray points indicate individual subjects' data. Gray lines connect individual subject datapoints to illustrate the pattern of results for each subject.

each memory on a six-point scale. For retrieval effort, a 2x2 ANOVA revealed a significant main effect of intentionality, $F(1,27) = 193.08$, $p < 0.001$, ${}_{p}\eta^{2} = 0.87$, but no main effect of stimulus type, $F(1,27) = 0.42$, $p = 0.52$, ${}_{p}\eta^{2} = 0.01$, or interaction between stimulus type and intentionality, $F(1,27) = 1.57$, $p = 0.22$, ${}_{p}\eta^{2} = 0.05$. Post hoc pairwise comparisons, Bonferroni corrected for multiple comparisons, indicated that involuntary memories were rated as requiring significantly less retrieval effort than voluntary memories, $t(57) = -17.43$, $p < 0.001$, 95% CI:[−2.69, −2.06]. See Fig. 4 for a graphical depiction of these data.

4. Discussion

The present work sought to investigate the role of involuntary retrieval in music-evoked autobiographical memories by directly comparing involuntary (and voluntary) autobiographical memories evoked by music to those evoked by pictures of famous persons. First, we investigated whether music or faces more frequently evoked voluntary or involuntary autobiographical memories. We found minimal difference in the total number of cues required to evoke five involuntary and five voluntary memories for each cue type, with slightly more cues needed for faces overall. Our prior work (Belfi et al., 2016) found that, out of 30 cues each for music and faces, faces evoked significantly more autobiographical memories than music (on average, participants retrieved twelve memories in response to 30 face cues, and nine memories in response to 30 musical cues). That is, when we did not control for intentionality of retrieval in our prior study, participants retrieved more autobiographical memories in response to faces than music. In the present work, when we controlled for intentionality, it appears that excerpts of popular music and images of famous persons evoke involuntary autobiographical memories at a similar rate.

4.1. Greater episodic richness for music-evoked and involuntary autobiographical memories

When examining the episodic richness of autobiographical memories evoked by faces and music, we found significant effects of both stimulus type (music, faces) and intentionality (voluntary, involuntary) but no interaction between the two. First, we replicated our prior work (Belfi et al., 2016, 2020) by finding that music-evoked memories had a significantly larger ratio of internal-to-total

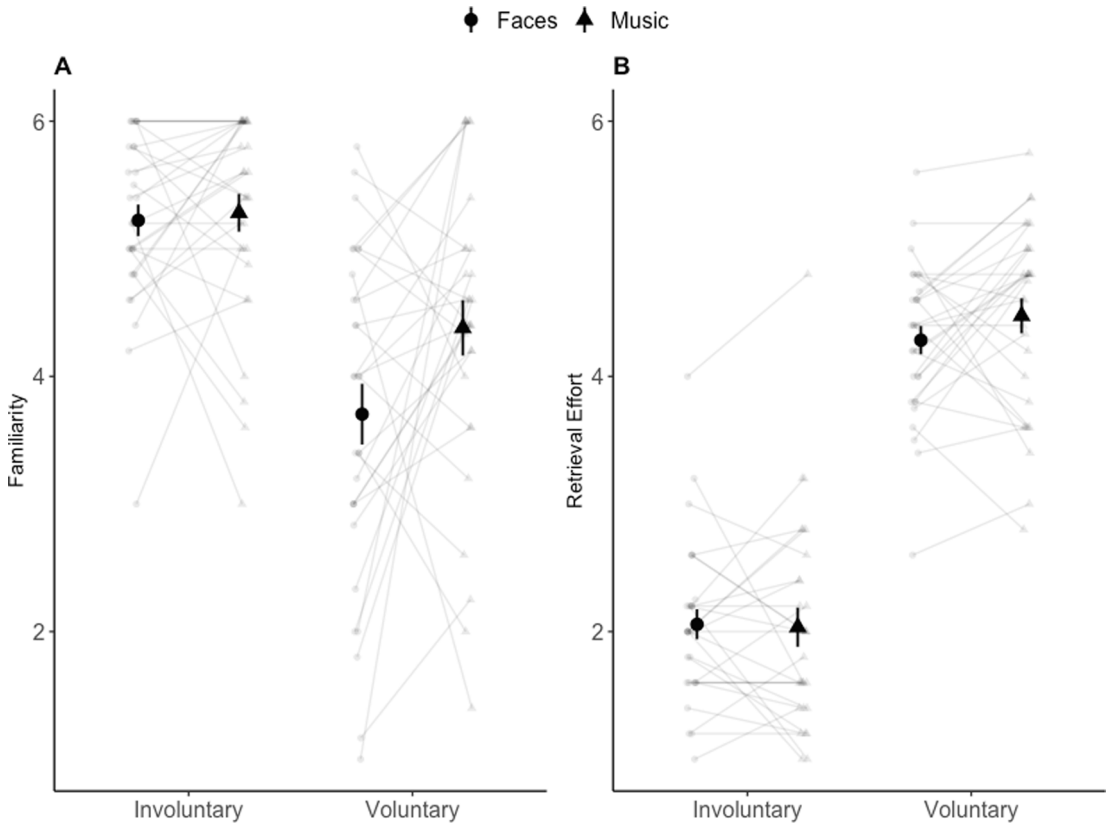

Fig. 4. Subjective ratings. A) Familiarity ratings. **B)** Retrieval effort ratings. In both graphs, solid circle/triangles (circles indicating face-evoked memories, triangles indicating music-evoked memories) indicate means across participants, dark lines indicate standard error of the mean. Gray points indicate individual subjects' data. Gray lines connect individual subject datapoints to illustrate the pattern of results for each subject.

details, reflecting greater episodic richness, than memories evoked by famous faces. The present study advances our previous research by controlling for intentionality of retrieval. That is, even when directly comparing *involuntary* music-evoked memories to *involuntary* face-evoked memories, there was still a consistent difference in episodic richness between memories evoked by the two cue types. This suggests that it is not the involuntary nature of music-evoked memories *alone* that drives this difference (or retrieval effort, as music-evoked memories were not rated as any less effortful than face-evoked memories), but that there is something else about music as a memory cue that contributes to increased episodic richness of the evoked memories.

Therefore, the question remains – what could be driving this effect of increased episodic richness in music-evoked, as compared to face-evoked memories? One possible explanation is that music may be a better contextual cue than faces. It is likely that the music participants heard in this task was the exact same stimulus that was present during the initial encoding of the memories. Prior work has illustrated that episodic memories encoded during music listening show a context-dependent memory effect, such that recall is improved when listening to the same music at retrieval as at encoding (Balch et al., 1992; Balch & Lewis, 1994). In contrast, a picture of a famous person may not be identical to what was previously seen, and therefore could be less likely to trigger a vivid memory of a specific instance.

It could also be the case that strong emotions evoked by music, or specific acoustical features of the music itself, lead to increased autobiographical salience of music. For example, the intensity of emotions while listening to music is highly correlated with the autobiographical salience of the music; additionally, musical features including pulse strength and brightness have also been associated with autobiographical salience (Salakka et al., 2021). Another potential explanation for increased episodic richness of music-evoked memories is the role music may play in identity formation and the importance of music to one's sense of self (Lamont & Loveday, 2020). Recent work has suggested that music, and particularly musical experiences during adolescence, contributes to an individual's sense of identity (Peck & Grealey, 2020). Self-reference has been shown to facilitate memory retrieval, and therefore a strong connection between music and one's sense of self may promote more episodically detailed memories evoked by music. Future work should further explore the other possible mechanisms underlying autobiographical memory enhancement via music, although we suspect that it is likely due to a combination of factors, including intentionality, retrieval effort, contextual cuing, and the emotional and self-referential qualities of music, among others.

In addition to finding that music-evoked memories are more episodically detailed than face-evoked memories, we identified a main effect of intentionality: involuntary memories contained a significantly higher ratio of internal/total details than voluntary memories.

This finding seems consistent with other work, which has found that involuntarily-retrieved memories are rated as being more vivid, clearer, and more pleasant than generatively recalled voluntarily retrieved memories; additionally, involuntary memories were found to be more important and relevant to one's current life than voluntarily recalled memories (Barzykowski & Staugaard, 2016). Our current data add to this previous work by indicating that involuntary autobiographical memories are also more episodically detailed than voluntarily retrieved memories, regardless of the cue which evoked the memory.

4.2. Memory content differs between music- and face-evoked memories

In addition to looking at the episodic richness of memories evoked by music and faces, we also assessed differences in memory content by measuring the types of words used in the memory descriptions. Replicating our prior work (Belfi et al., 2020), we found that music-evoked autobiographical memories contained a higher degree of purported "authenticity" than face-evoked memories, as measured by the LIWC. Texts with higher authenticity ratings are more cognitively complex, contain more self-references and other-references, and use fewer negative emotional words (Newman et al., 2003). Overall, this suggests that music-evoked memories contain more self-referential content and reflect positive emotions. However, we also found no difference in the frequency of affective words between music- and face-evoked memories. While prior work has suggested that music-evoked autobiographical memories tend to be highly emotional (e.g., Janata et al., 2007), it may be that the *experience* of recalling these memories feels more emotional, while the *content* of these memories does not differ in terms of its emotional characteristics. Future work could examine this potential contrast between the emotional experience of the participants versus the emotional content of memories evoked by music (Sakka & Saarikallio, 2020).

Complementing the episodic richness findings, we also found that music-evoked memories contained a greater number of perceptual details than face-evoked memories. This suggests that the memories evoked by music were both richer and more vivid. Also, this may partially be driving the effect we see on episodic richness – perceptual details are one category of internal details, which may explain the higher ratio of internal-to-total details found in music-evoked memories. Additionally, autobiographical memory is thought to involve multiple component processes and engages distinct neural systems, depending on the context (Sheldon et al., 2019). Thus, it may be that music elicits greater engagement from the perceptual component of the system, whereas face cues may engage more conceptual, less vivid components of memory. Finally, our text analysis also revealed that face-evoked memories contained a greater number of words reflecting social processes. Social words include words about friends ("pal", "buddy"), family ("mom", "brother"), and humans in general ("boy", "woman") as well as social processes ("talk", "us"). It may be that since the face images depict other *people*, the memory descriptions include descriptions of the person in the image themselves.

4.3. Limitations and Future directions

One important limitation to mention is the manner in which cues were chosen in the present experiment. Our cue selection method required that cues be presented until participants retrieved five memories of each type, for a total of 20 memories. That is, we did not set a number of stimulus presentations (as we have done in our prior work, for example, by presenting 30 cues and measuring how many memories were evoked; Belfi et al., 2016). Instead, we set the total number of memories for each participant, to ensure that an equal number of memories were reported by all participants. One limitation of this approach is that it may have resulted in an unequal number of cues depending on the cue type and participant. For example, some participants may have retrieved five involuntary music-evoked memories in the first five cues, while other participants may have needed ten cues to evoke five involuntary memories. Of course, this may have influenced the participants' responses, for example, by encouraging participants to report memories if they felt they had proceeded through many cues without reporting any memories. However, we have attempted to account for this by measuring the number of cues presented for each type (see "Likelihood of autobiographical memories evoked by face and musical cues" section of the results), and our results suggest little difference in the number of cues needed for each stimulus type and retrieval intention.

An additional limitation to this approach is that participants' voluntary retrieval attempts tended to follow failed involuntary retrieval in response to a stimulus. That is, if a stimulus did not evoke an involuntary memory, participants attempted to retrieve a voluntary memory in response to that stimulus. This could potentially have influenced the results here, perhaps by inducing demand characteristics. Future work on this topic could circumvent this issue by simply measuring all memories in response to a set of stimuli and taking additional measures in order to categorize the memories as involuntary or voluntary in a post hoc manner. We did collect some data to this point in the present study, that is, by collecting ratings of perceived retrieval effort. This data indicated that memories categorized as "involuntary" were associated with lower levels of perceived effort. However, future work could improve on this approach by, for example, taking more implicit measurements associated with involuntary retrieval, such as response time or physiological arousal.

A limitation related to the particular cues used here is that musical cues were popular songs selected from the Billboard charts and face cues were popular celebrities. While these cues have been used successfully to evoke memories in our prior work (Belfi et al., 2016; 2018; 2020) it is worth mentioning that both Billboard tracks and US-based celebrities are likely only familiar to a certain subset of the population. That is, some individuals may not be as familiar with or have as much exposure to these cues as others. However, ratings of familiarity for both face and musical cues were high overall in the present sample (an average familiarity rating of 4.64 on a six-point scale, for all stimuli in all conditions; see Fig. 4). That said, it is important to note that historically, the field of music cognition has focused primarily on certain types of music while ignoring others (Baker et al., 2020). Therefore, Billboard tracks may not be an appropriate musical cue to use in populations who may have had less exposure to this music, and it is important to not generalize to

"music" overall from such a restricted set of musical cues. To account for these issues, future research could employ self-selected music or expand the set of musical cues to better generalize to other populations as well as other musical styles.

A final limitation worth mentioning is that by revealing to participants that the study was about autobiographical memory, this may have impeded the true involuntary nature of such memories. That is, the self-reported involuntary memories in the present study may have been more similar to directly retrieved voluntary memories (Barzykowski et al., 2019). Some work has distinguished involuntary memory retrieval from other modes of retrieval based on retrieval latencies and subjective ratings of phenomenological characteristics of the memories themselves (Barzykowski et al., 2021). However, we did not collect these variables in the present study and therefore instead must rely on participants self-report that the memories retrieved were indeed involuntary in nature.

4.4. Conclusions

To conclude, our results indicate that even when familiarity and intentionality are held constant across stimulus categories, autobiographical memories evoked by music are still more episodically detailed than those evoked by images of famous persons. Therefore, this difference in episodic richness between cue types seems to at least partially depend on stimulus features other than the ability to evoke memories in an involuntary manner. As music is becoming a more popular therapeutic tool used to aid in memory retrieval, particularly in persons with memory disorders (El Haj, Postal, et al., 2012; Reschke-Hernandez, 2020), it will be important to continue exploring the mechanisms underlying the ability of music to evoke vivid and episodically detailed autobiographical memories.

CRediT authorship contribution statement

Amy M. Belfi: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition. **Elena Bai:** Formal analysis, Writing – review & editing. **Ava Stroud:** Investigation, Writing – review & editing. **Raelynn Twohy:** Investigation, Writing – review & editing. **Janelle N. Beadle:** Conceptualization, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Analysis and experimental presentation code will be shared with researchers upon request. The experiment reported in this manuscript was not preregistered.

Appendix

The following are the instructions given to participants to distinguish between voluntary and involuntary memory retrieval. Instructions were read by an experimenter out loud to the participants. At the end of the instructions, the experimenter asked the participant if they understood the distinction between voluntary and involuntary memory retrieval, and if not, continued to provide clarification until the participant expressed confidence.

Instructions

In this task, you will hear a series of songs and see a series of images of famous persons. Some of these songs and images may evoke personal memories of things that happened in your life. Sometimes, the memories you recall might be **voluntary** and other times they could be **involuntary.**

An example of an **involuntary** memory might be when you hear a song on the radio, or see a picture in a newspaper, or smell a certain scent, and it automatically reminds you of a memory from your life. For example, you might smell the scent of freshly-baked cookies, and it could trigger a memory of a specific instance from your childhood when you were baking cookies with your grandmother. You may find that memories from your past come into your mind spontaneously without any deliberate attempt to retrieve them. In other words, this would be like a memory that simply 'pops' into your head without you trying to intentionally remember anything.

In contrast – **voluntary** memories are those that require you to actively search and retrieve a memory. If you saw a picture and I asked you to tell me about a memory that the photo reminded you of, this would likely require you to think for a bit before a memory

comes to mind.

In this study, we are interested in both your voluntary and involuntary memories in response to the song and image cues.

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