Effects of familiar music exposure on deliberate retrieval of remote episodic and semantic memories in healthy aging adults

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Abstract

Familiar music facilitates memory retrieval in adults with dementia. However, mechanisms behind this effect, and its generality, are unclear because of a lack of parallel work in healthy aging. Exposure to familiar music enhances spontaneous recall of memories directly cued by the music, but it is unknown whether such effects extend to deliberate recall more generally—e.g., to memories not directly linked to the music being played. It is also unclear whether familiar music boosts recall of specific episodes versus more generalized semantic memories, or whether effects are driven by domain-general mechanisms (e.g., improved mood). In a registered report study, we examined effects of familiar music on deliberate recall in healthy adults ages 65-80 years (N=75) by presenting familiar music from earlier in life, unfamiliar music, and non-musical audio clips across three sessions. After each clip, we assessed free recall of remote memories for pre-selected events. Contrary to our hypotheses, we found no effects of music exposure on recall of prompted events, though familiar music evoked spontaneous memories most often. These results suggest that effects of familiar music on recall may be limited to memories specifically evoked in response to the music (Preprint and registered report protocol at https://osf.io/kjnwd/).

Introduction

Music & enhanced memory recall

Many people report that certain songs they have heard years before allow them to mentally 'travel back in time' and recall vivid memories from earlier in life (Rossato-Bennett, 2014). This phenomenon suggests that familiar music may have a particularly powerful role in cueing autobiographical memory recall (declarative memory for events in one's life). Indeed, recent work found that approximately 96% of young adults experienced music-evoked autobiographical memories (MEAMs) while listening to Billboard Top 100 songs released between birth and age 20, and approximately 30% of all songs played triggered a MEAM (Janata, 2009; Janata et al., 2007). Though not all familiar songs evoke MEAMs, both younger and older adults experience this phenomenon, and MEAMs can occur for songs that have not been heard in many years (Belfi et al., 2016; Krumhansl & Zupnick, 2013; Platz et al., 2015; Schulkind et al., 1999).

In concurrence with work on MEAMs, multiple lines of evidence indicate that music facilitates retrieval of content encoded when the music was played (Alonso et al., 2016; Balch et al., 1992; Palisson et al., 2015; Peretz et al., 1998; Wallace, 1991). For example, compared to silence, attaching text to melody during encoding (Ratovohery et al., 2018, 2019; Samson & Zatorre, 1991; Serafine et al., 1986; Wallace, 1994) or playing background music (Ferreri et al., 2014) enhances word recall. Binding of musical tones to words through singing can also help aphasic patients retrieve and enunciate words and phrases (Kasdan & Kiran, 2018; Merrett et al., 2019; Schlaug et al., 2008, 2010; Wan & Schlaug, 2010). Further, music heard during certain 'sensitive periods'—youth and early adulthood in particular—may cue associations to non-musical stimuli experienced around the same time (Krumhansl & Zupnick, 2013; Schubert, 2016). Taken together, such evidence indicates that music may serve as a context to which perceptual, episodic, or semantic associations can be mapped at encoding, and later retrieved (Schiller et al., 2015; Smith & Vela, 2001).

In recent years, both clinicians and researchers have cited such memory-enhancing properties of music in recommending music listening as a potential therapy for patients with Alzheimer's disease or other forms of dementia (Baird et al., 2019; Brotons et al., 1997; Koger et al., 1999; Larkin, 2001; Peck et al., 2016; Sambandham & Schirm, 1995). Supporting this claim, patients with dementia or severe acquired brain injuries experience MEAMs (Baird & Samson, 2014; Baird, Brancatisano, et al., 2020; Baird, Gelding, et al., 2020; Baird & Samson, 2009, 2015; Basaglia-Pappas et al., 2013). One group of 29 dementia patients demonstrated better remote autobiographical memory while exposed to background music compared to silence or background cafeteria noise (Foster & Valentine, 2001). In this study, autobiographical memory was assessed through questions about personal semantic memories (for example, *'which school did you attend'*) developed based on the Mini-Mental State Exam (MMSE; Folstein et al., 1975), and caregivers verified correct answers. In a different experiment, 10 patients with mild Alzheimer's disease scored higher on average on the Autobiographical Memory Interview (AMI; Kopelman et al., 1989) following listening to Vivaldi's 'Four Seasons' than following silence (Irish et al., 2006). In addition, effects of music on autobiographical recall were stronger for remote memories (events occurring from 0-20 years of age) than mid-remote (20-50 years) or recent memories ('the recent past or present') across several studies using MMSE-based questions to evaluate retrieval (Foster & Valentine, 2001; García et al., 2012).

The studies mentioned above played all participants the same pieces of music. This leaves open the possibility that the music may have been familiar to some individuals and not others. However, clinical work has emphasized the benefits of individualized music, or music particularly familiar to a given patient (Gerdner, 2000, 2012; Gerdner et al., 2000; Thomas et al., 2017). In two studies, Alzheimer's patients showed better autobiographical memory recall with exposure to self-chosen music relative to experimenter-chosen music (El Haj et al., 2015; El Haj et al., 2012). Those studies used the TEMPau scale to score the specificity of freely recalled autobiographical narratives on a scale from 0-4 (Piolino et al., 2009). Self-chosen music, relative to experimenter-chosen music, improved autobiographical memory whether it was played before recall (El Haj et al., 2012) or in the background during recall (El Haj et al., 2015). In both of these studies, however, the experimenter-chosen music (*la Boheme*, performed by Charles Aznavour, and *Spring* from Vivaldi's *Four Seasons*) may have been familiar to many participants, so familiarity per se might not explain the benefit for self-chosen music. Although these studies are promising, several other studies failed to find a benefit of putatively familiar music. For example, no benefits to memory were found when examining exposure to researcher-chosen pieces aimed to be familiar (Vivaldi and Handel pieces) compared to "novel" pieces (contemporary compositions by Graham Fitkin). However, in these studies it is unclear to what degree participants were truly familiar with the music in either condition (Foster & Valentine, 1998; Foster & Valentine, 2001).

By what mechanism does music affect memory?

While patients with Alzheimer's disease demonstrate enhanced autobiographical retrieval when memories are music-evoked, leveraging such memory enhancements to develop and improve music-based therapies will depend crucially on a deeper understanding of the mechanisms behind such effects (Blackburn & Bradshaw, 2014; Fang et al., 2017; Hobeika & Samson, 2020; Peck et al., 2016). For instance, the generality of such music effects is unknown due to a lack of parallel work in healthy participants. Similar memory-enhancing effects of familiar music in healthy individuals might indicate that music plays a more general role in enhancing remote memory retrieval, as opposed to specifically rescuing processes impaired in dementia patients. In addition, research with healthy individuals may allow for examining the mechanisms of music effects with higher statistical power (e.g., number of distinct events recalled per participant, or number of total participants) than is feasible with dementia patients (Halpern & O'Connor, 2000; Sartori et al., 2004). Thus, parallel work focusing on healthy aging individuals could enable more rigorous examination of the mechanisms behind music effects observed in patients with dementia.

It is certainly possible that different processes might underlie effects of music on memory recall in healthy versus memory-impaired populations. Even if the mechanisms behind memory-enhancing effects of familiar music do not directly translate from healthy individuals to patients with dementia, an understanding of such mechanisms would be useful. In particular, knowledge of whether music can enhance autobiographical retrieval in healthy aging individuals could inform therapies for alleviating declining memory or building cognitive reserve during healthy aging (Fan et al., 2019; Hays et al., 2002; Tucker & Stern, 2011). More understanding of music effects on memory in healthy individuals may also help inform music-based treatments for other clinical groups, such as patients with amnesia (Baker, 2001, 2009; Baur et al., 2000; Bower & Shoemark, 2012) or depression (Aalbers et al., 2017; Cross et al., 2012; Hanser & Thompson, 1994; Semkovska et al., 2012). To date, few studies have pursued such questions in an approach tailored for directly studying healthy aging individuals. While most studies of music and autobiographical memory with dementia patients also included control groups, the healthy participants scored at or near ceiling on most of the autobiographical memory measures (e.g., questions developed from the MMSE, AMI, and TEMPau scale; El Haj et al., 2013, 2015; Irish et al., 2006). Thus, most prior work has lacked tools for measuring autobiographical memory sensitively enough to detect effects of music on recall in healthy individuals.

Because little work has addressed whether healthy individuals show improved recall of remote memories following familiar music, the mechanisms underlying this effect are not particularly clear. One possibility is that such boosted recall in patients is primarily the result of domain-general effects. For example, observed effects of music on autobiographical recall in Alzheimer’s patients have been attributed to enhanced arousal (Foster & Valentine, 2001), changes in affect (El Haj, Postal, et al., 2012; García et al., 2012), reductions in anxiety (Irish et al., 2006; Narme et al., 2014) or agitation (Sánchez et al., 2016; Wall & Duffy, 2010), increased self-consciousness (Arroyo-Anlló et al., 2013), or improved linguistic function (Brotons & Koger, 2000; El Haj et al., 2013) following music listening. This can be contrasted to a more specific benefit of music, for example if music acts as a mnemonic cue or helps the formation of an attentional state that promotes memory retrieval (Tarder-Stoll, Jayakumar, et al., 2020). Individualized music therapies for such patients have also been suggested for the purpose of reducing stress and agitation alone (Gerdner, 2012), and familiar music tends to evoke more positive emotions in healthy individuals as well (Peretz, 2006; Peretz et al., 1998; Schulkind et al., 1999; Stalinski & Schellenberg, 2013). Whether observed effects of enhanced recall in patients with memory impairments are the result of a boosted state of retrieval versus more domain-general or affective processes (Balteş et al., 2011) thus remains an open question.

What kinds of memories are enhanced by music?

Understanding of the mechanisms by which music enhances autobiographical recall would also benefit from more detailed characterization of which specific features of recalled memories are enhanced. In particular, there is not yet consensus on whether exposure to music enables recall for specific episodes, more generalized semantic memories, or both (Tulving, 1972). García and colleagues (2012) argue that music-related memory enhancement is semantic in nature, based on evidence that music exposure improved recall of personal semantic memories (general facts about one's past and extended events), but not recent episodes (Baird et al., 2018). At the same time, the presence of both semantic and episodic content in MEAMs within healthy individuals suggests that familiar music may be an associative cue for recall of specific events as well (Belfi et al., 2016; Blais-Rochette & Miranda, 2016; Cady et al., 2008; Ford et al., 2011; Janata et al., 2007). Moreover, Alzheimer's patients scored higher on subscales of the Autobiographical Memory Interview measuring both personal semantic and episodic memory following exposure to music in comparison to silence (Irish et al., 2006). Unfortunately, the evidence from most other patient studies is limited due to the fact that the autobiographical memory measures used (questions derived from the MMSE or TEMPau scale) do not explicitly distinguish episodic from semantic recall. Ultimately, instruments designed specifically to capture differential episodic and semantic recall will be needed for a better understanding of how music impacts remote memory retrieval.

Perhaps most importantly, it is yet unclear whether familiar music cues can enhance recall of autobiographical memories beyond those immediately and involuntarily evoked by the music. In addition to these spontaneously triggered memories (i.e., MEAMs), it is possible that such music may facilitate more deliberate, or ‘voluntary’, recall of other memories (Jakubowski et al., 2018). If familiar music can boost deliberate recall more generally for autobiographical events beyond those directly and spontaneously evoked by the music, familiar music cues might have far broader clinical potential. As the vast majority of studies on MEAMs in healthy individuals examine only such spontaneously evoked memories (Belfi et al., 2016, 2020; Jakubowski & Ghosh, 2019; Janata, 2009; Janata et al., 2007; Platz et al., 2015), the limits of music-evoked enhancements to memory retrieval are unknown. It is possible that music may invoke a ‘retrieval mode’ of increased attention to internal states and intention to retrieve memories (Tarder-Stoll, Jayakumar, et al., 2020). If familiar songs can induce such a particular focus on retrieval, this could enhance both involuntary and voluntary recall of remote autobiographical episodes. This hypothesis is supported by findings that familiar stimuli decrease acetylcholine release in the hippocampus, which promotes a state optimized for memory retrieval (Decker & Duncan, 2020; Duncan et al., 2019; Duncan & Shohamy, 2016; Hasselmo & Schnell, 1994; Meeter et al., 2004).

Alzheimer’s patients’ music-evoked autobiographical memories have been argued to have many features of involuntary memories (e.g., more specific and more quickly retrieved; El Haj et al., 2012). However, that patients also score higher on MMSE and AMI items probing personal semantic memories (e.g., ‘where were you born’) might indicate broader memory enhancement (Foster & Valentine, 2001). One group of patients retrieved memories that were more ‘self-defining’, or central to their identities, with exposure to self-chosen music compared to experimenter-chosen music (El Haj et al., 2015). Overall, while there is some evidence that familiar music can help patients with dementia deliberately retrieve autobiographical details, it is yet unclear whether familiar music can evoke a state of broadly enhanced voluntary retrieval. If familiar music can invoke such a retrieval mode to boost both involuntary and voluntary recall, such an effect could have broad therapeutic potential for both memory-impaired and healthy aging individuals.

The present study

The present registered report study asked whether familiar music, compared to unfamiliar music or non-musical auditory stimuli, can enhance voluntary retrieval. The participants were healthy older adults 65-80 years old. We played participants clips from individualized playlists of familiar music selected from popular music charts, unfamiliar music, and non-musical audio clips across three study sessions. We sought to test deliberate recall for remote events that were distinct from any memories spontaneously evoked by the clips. We did this by prompting participants after each clip to describe autobiographical events that had already been selected from a list of prompts in a pre-screening call. Because prior work has highlighted larger music effects for remote than recent events (Foster & Valentine, 2001), all prompts focused on events occurring before age 25. Further, we aimed to examine whether any effects of music on memory retrieval were specific to episodic or semantic recall. To accomplish this, we scored participants' recall of each event for the number of episodic details specific to the event prompted (details ‘internal’ to the prompted episode) versus more general semantic details (details ‘external’ to the prompted episode) using Autobiographical Interview procedures (Levine et al., 2002). Finally, we determined whether music also impacted more domain-general processes of mood, and whether differences in mood were associated with episodic or semantic recall.

In pre-planned analyses (see the Registered Report protocol at https://osf.io/kjnwd/), we estimated effects of both experimenter-manipulated and participant-reported music familiarity on deliberate recall (Table 1 Questions 1-2). Specifically, we examined whether familiar music affected the retrieval of internal episodic details, external semantic details, and their relative proportions. Further, to assess more general effects of music not specific to familiar songs, we estimated how these recall outcomes were impacted in both music conditions in contrast with the no-music condition (Table 1 Question 3). In order to examine the robustness of potential findings, all primary analyses were accompanied by specification curve analyses with pre-registered specification choices (Simonsohn et al., 2015).

Most generally, we hypothesized that familiar music would enhance deliberate recall of remote autobiographical memory details in our sample of healthy aging adults. More specifically, we predicted that exposure to familiar music, compared to unfamiliar music, would promote voluntary retrieval of specific events and result in enhanced recall of internal details, relative to external details (see Table 1, hypothesis M1). However, we also tested competing hypotheses that familiar music would specifically enhance retrieval of external details (see Table 1, hypothesis A1a), or would increase retrieval of both internal and external details, but not the relative proportion of either detail type (see Table 1, hypothesis A1b). We made similar hypotheses for the effects of both familiar and unfamiliar music in contrast with non-music clips (see Table 1, hypotheses M3, A3a, A3b).

Question	Hypotheses	Analyses	Results
1. Does exposure to familiar music (in contrast to unfamiliar music) impact subsequent voluntary retrieval of internal details, external details, or the proportion of internal details? **Will be conducted only if familiarity manipulation is successful**	**M1:** Exposure to familiar music will increase the number of internal, but not external, details retrieved, thereby increasing the proportion of retrieved details that are internal **A1a:** Exposure to familiar music will increase the number of external, but not internal, details retrieved, thereby decreasing the proportion of retrieved details that are internal **A1b:** Exposure to familiar music will increase the number of both internal and external details retrieved, but will not affect the proportion of retrieved details that are internal	• Bayesian multilevel linear regression model with number of details as outcome, and contrasts for familiar > unfamiliar music • Corresponding specification curves	• No support for Q1 hypotheses. • No effects of familiar music (versus unfamiliar music) exposure on subsequent voluntary (prompted) recall of internal details, external details, or the proportion of internal details.
2. Is participant-rated familiarity with individual songs associated with voluntary retrieval of internal details, external details, or the proportion of internal details after exposure to those songs?	**M2:** Higher ratings of song familiarity will be related to increases in the number of internal, but not external, details retrieved, such that familiarity will be positively associated with the proportion of retrieved details that are internal **A2a:** Higher ratings of song familiarity will be related to increases in the number of external, but not internal, details retrieved, such that familiarity will be negatively associated with the proportion of retrieved details that are internal **A2b:** Higher ratings of song familiarity will be related to increases in the number of both internal and external details, but not the proportion of retrieved details that are internal	• Bayesian multilevel linear regression model with number of details as outcome, contrasts for a 1-unit increase in familiarity rating • Corresponding specification curves	• No support for Q2 hypotheses • No associations between familiarity with individual songs and voluntary (prompted) retrieval of internal details, external details, or the proportion of internal details.
3. Does exposure to music (in contrast to non-music clips) impact subsequent voluntary retrieval of internal details, external details, or the proportion of internal details?	**M3:** Exposure to music will increase the number of internal, but not external, details retrieved, thereby increasing the proportion of retrieved details that are internal **A3a:** Exposure to music will increase the number of external, but not internal, details retrieved, thereby decreasing the proportion of retrieved details that are internal **A3b:** Exposure to music will increase the number of both internal and external details retrieved, but will not affect the proportion of retrieved details that are internal	• Bayesian multilevel linear regression model (same model as Q1) with number of details as outcome, and contrasts for both music conditions > no music • Corresponding specification curves	• No support for Q3 hypotheses. • No effects of music (versus non-music clips) exposure on subsequent voluntary (prompted) recall of internal details, external details, or the proportion of internal details.

Table 1: Main questions and corresponding hypotheses, planned analyses, and results. Main hypotheses are labeled with M (e.g., M1) and alternative hypotheses are labeled with A (e.g., A1a).

Materials and Methods

Methods were preregistered and accepted in-principle as a Stage 1 Registered Report protocol on February 11, 2021. The full protocol can be found at https://osf.io/kjnwd/.

Participants

We recruited healthy adults between ages 65-80 years. Recruitment continued until our target N=75 was reached for participants meeting all inclusion criteria (see Supplemental Fig. 1). We screened a total of 112 participants to meet our target sample size and accrual criteria. Participants were recruited through paper and electronic newsletters at retirement communities, social media (Facebook), paper flyers posted in New York City, and word of mouth. Because of the ongoing COVID-19 pandemic, all interactions with participants were conducted remotely via Zoom videoconferencing software. Participant consent was obtained via REDCap before the pre-screening call, and participants had opportunities to ask any questions about the consent form before starting study procedures. Participants were compensated $20/hour for their time (following the end of their participation in the study) via electronic gift cards.

Participants reported their ages in years, and their gender, race, and ethnicity in open-ended questions (all verbal reports; see Supplemental Table 1). Participants also reported their annual household income and level of education through multiple-choice questions (see Supplemental Tables 3-4). Overall, the included participants were highly educated, with 74 out of 75 participants reporting at least some form of postsecondary education. 73 participants were in the United States at the time of participation, and 2 were in Canada.

Pre-screening call

Study inclusion criteria were: (1) willingness to schedule three videoconference memory interview sessions, (2) fluency in English, (3) age between 65-80 years, (4) no known neurological conditions or hearing impairments, (5) access to a computer, internet connection, and a quiet space, (6) memory for a sufficient number of early-life events (details below), (7) reporting having listened to a sufficient number of popular music artists before age 25 (details below), and (8) a score of 16/22 or higher on the T-MoCA. In addition to the above criteria, we aimed for nearly equal proportions of participants identifying as male and female. To ensure this, we capped accrual of any gender at 45 participants (60% of the total sample). We also aimed to recruit a sample as racially heterogeneous as the 2019 US population, such that at least 19/75 participants (~25%) identified as a race other than White (census.gov, 2019).

Participants first took part in a Zoom call to determine study eligibility and provide information for selecting participant-specific music stimuli and memory probes. Participants were encouraged to find a quiet and private space with strong internet access to conduct this call. Experimenters kept their video feeds on for the duration of all calls with participants (unless there were connection issues that were resolved by turning video off), and participants had the option to keep their cameras on or off. At the start of the pre-screening call, experimenters first offered any necessary support for navigating the Zoom software, thanked participants for joining the call, troubleshot any technological or call quality issues, and read participants a short overview of the study. Participants were then asked about eligibility criteria 1-5.

Next, participants were asked to report on the degree of early-life exposure to different musical artists to guide selection of participant-specific clips for the familiar music condition. Experimenters read participants a list of musical artists who had songs ranked on the Billboard Hot 100 United States year-end charts between 1946-1983 (see https://osf.io/r3sxd/ for the full list of songs and artists, and for more music list details see https://osf.io/jvb3m/). The artists on these lists were those who released charting songs when participants were ages 5-9 years (childhood), ages 14-18 years (adolescence), and ages 20-25 years (early adulthood). We selected these age ranges to maximize the likelihood that participants would have been familiar with popular music released during these periods in life (Krumhansl & Zupnick, 2013; Schulkind et al., 1999; Spivack et al., 2019). Music heard during these age ranges may also be more integral to the development of participants' sociocultural identities (Miranda et al., 2015; Stras, 2011). Participant-specific lists contained the 30 artists with the most songs ranked on the top 100 chart for each respective time period. If artists were redundant (e.g., in the top 30 across multiple time periods), more artists were added such that each list contained 30 unique artists (additional artists were added for the time period for which redundant artists had fewer songs on the charts). For each artist, participants reported how much they listened to that artist from birth to age 25 (either 0 = '*never heard of this artist'*, or a numerical scale from 1-*'barely listened*' to 5-*'very frequently listened*'). To increase the likelihood that all study participants were familiar with the music clips in the familiar music condition, only participants who gave ratings ≥3 for at least five artists in each of the three time periods were included for participation in the study.

Next, participants were read a list of events that they may have experienced during each of the three time periods (childhood, adolescence, and early adulthood), and reported whether or not they could recall a memory of each specific event (Materials available at https://osf.io/6d3hr/). Events were specific to a certain developmental time period (e.g., *'Your high school graduation'*, or '*A time receiving a holiday present in childhood'*). Events were split into three distinct time periods to ensure that participants retrieved memories from a distribution of times early in life, rather than just one span of a few years. We did not include any events occurring later in life to ensure that all probed memories are of remote events (Acevedo-Molina et al., 2020; St. Jacques & Levine, 2007). Participants were told to say 'no' to any events that they knew happened in their lives but could not recall specifically, or events they did not feel comfortable discussing later in detail. We encouraged participants to provide quick responses (within 10s) to these prompts and not to dwell on any event in detail. Participants who reported being able to recall at least 15 events (out of 50 possible) in each time period were eligible for participation. This inclusion criterion was meant to ensure that participants would be able to complete a sufficient number of trials for adequate statistical power (see Power Calculations in Supplement).

Lastly, participants completed the telephone version of the Montreal Cognitive Assessment (T-MoCA) protocol to assess cognitive health (Nasreddine et al., 2005; Pendlebury et al., 2013). The T-MoCA is equivalent to the standard MoCA with all visual items removed, and participants can receive a maximum score of 22. We used a cutoff of 16 points or higher (out of 22 possible) for inclusion, and all prescreened participants scored at or above this cutoff. This cutoff was chosen based on the fact that some pilot participants scored as low as 70% correct on the full MoCA (87% is the usual cut-off for healthy cognition), but no pilot participants struggled to understand the instructions or remember events in response to memory prompts. We chose 16/22 on the T-MoCA as a cutoff to roughly match this 70% correct threshold on the full MoCA.

Pre-screening calls on average took 30 minutes. At the end of the pre-screening call, participants who met the inclusion criteria were scheduled for the three music and memory interview sessions. Participants who completed the pre-screening call but did not meet inclusion criteria were paid for their time, but not invited to participate in further sessions.

Music clip selection

After pre-screening, 15 participant-specific music clips were selected for the familiar music condition. For each time period (childhood, adolescence, and early adulthood), we first selected the 5 artists on the Billboards charts that each participant rated having listened to most (e.g., highest listening ratings on a scale from 0-5 during the pre-screening call). If there were ties in participant ratings, artists with more total songs on the charts during the time period were selected. For each of these 5 artists, we selected their top-charting song released within the respective time period. Only one song was selected from any one artist in each time period, though songs from the same artist (up to a maximum of three, or one in each time period) could be selected if the artist had songs on the Billboard charts across multiple time periods. Thus, songs in the familiar music condition were selected on a participant-specific basis to maximize potential familiarity without participants selecting songs themselves. This is important because playing music to the participant prior to the memory recall sessions may serve as a reminder or probe for memory, which would then confound our ability to identify how single-shot exposure to familiar music affects retrieval. In addition, we wanted to distinguish effects of music familiarity from potential effects of participants having chosen specific clips, so our procedures were aimed to maximize familiarity without participants directly choosing songs beforehand.

One caveat is that this process cannot guarantee that participants were exposed to the music clips during the intended time periods, as opposed to later in life. However, the use of top-charting songs may maximize the likelihood that participants were exposed to them shortly after their release, particularly through radio or television airplay (Bartlett & Snelus, 1980; Krumhansl, 2017). To test whether participants listened to the familiar music clips most during the approximate time period they were released, we included a manipulation check to assess the timing of music exposure (see Fig. 2).

Clips for the unfamiliar music condition were selected from a list of more obscure songs released after the year 2000 to ensure that participants had no exposure to them before age 45 (i.e., a 65-year-old participant recruited in 2021), and minimize participant familiarity overall (Schulkind et al., 1999). Before the study, a set of 300 clips was selected by the experimenters for stylistic similarity to the popular music clips used in the familiar music condition (see https://osf.io/6d3hr/). These clips were also selected to have fewer than 500,000 total streams on Spotify, and to neither have appeared on Billboard Hot 100 charts nor received major film/TV/radio features to minimize the likelihood that participants will be familiar with them. For each participant, 15 clips were selected from this list using an algorithm designed to maximize similarity with the corresponding familiar music clips on 6 auditory features generated by Spotify (valence, tempo, loudness, danceability, energy, acousticness, see https://developer.spotify.com/documentation/web-api/reference/tracks/get-audio-features/) and experimenter-rated genre. For all participants, algorithm-selected playlists for the unfamiliar music condition did not significantly differ from the familiar music condition on any of the auditory features (pairwise t-tests for all participants for all features $p > .05$).

Clips for the no-music control condition were 15 audio segments from news, weather, and traffic reports selected to be neutral in valence. These clips were the same for all participants. Control condition clips and materials for song clip selection are available via the Open Science Framework at https://osf.io/6d3hr/.

Music and memory interview sessions

Participants each took part in three 60-90 minute sessions (familiar music, unfamiliar music, and no-music control conditions; order counterbalanced across participants) occurring at least one week after the pre-screening call and with at least one week between sessions (see Figure 1). Participants were sent email reminders both one week and one day prior to each session with time details and videoconference call information. At the beginning of each session, experimenters worked with participants to ensure that the call quality was sufficient for participants to clearly hear the music and elaborate on their memories (including playing a sample audio clip to test audio quality). If technological issues prevented a session from starting, sessions were rescheduled. If technological issues caused a call to prematurely end during the middle of a session, experimenters first tried to restore the call to finish the session. If the call could not be completed, experimenters scheduled an additional partial session to finish the incomplete session. If participants missed scheduled sessions, experimenters made three attempts to re-contact participants via email and phone, with the third contact attempt at least 1 week after the second. If participants did not respond or indicated that they did not want to continue in the experiment, they were regarded as having ‘dropped out’ of the study and were not included in primary analyses (see Supplemental Fig. 1). No participants dropped out after having completed any sessions, although several participants declined participation after prescreening and before starting any sessions (see Supplemental Table 1).

At the beginning of each session, participants were told to think of the upcoming session as “recording a journal” of their memories, rather than a conversation with the experimenter. During each session, participants completed 15 trials, each consisting of listening to one 30s clip, then recalling one memory. These 15 trials were split into 3 blocks of 5 trials each corresponding to childhood, adolescent, and early adulthood event prompts (order counterbalanced across participants). During the familiar music condition, the developmental time period of the release of each song clip matched the time period of the events (e.g., songs released during the participant’s childhood were paired with event prompts referring to the participant’s childhood).

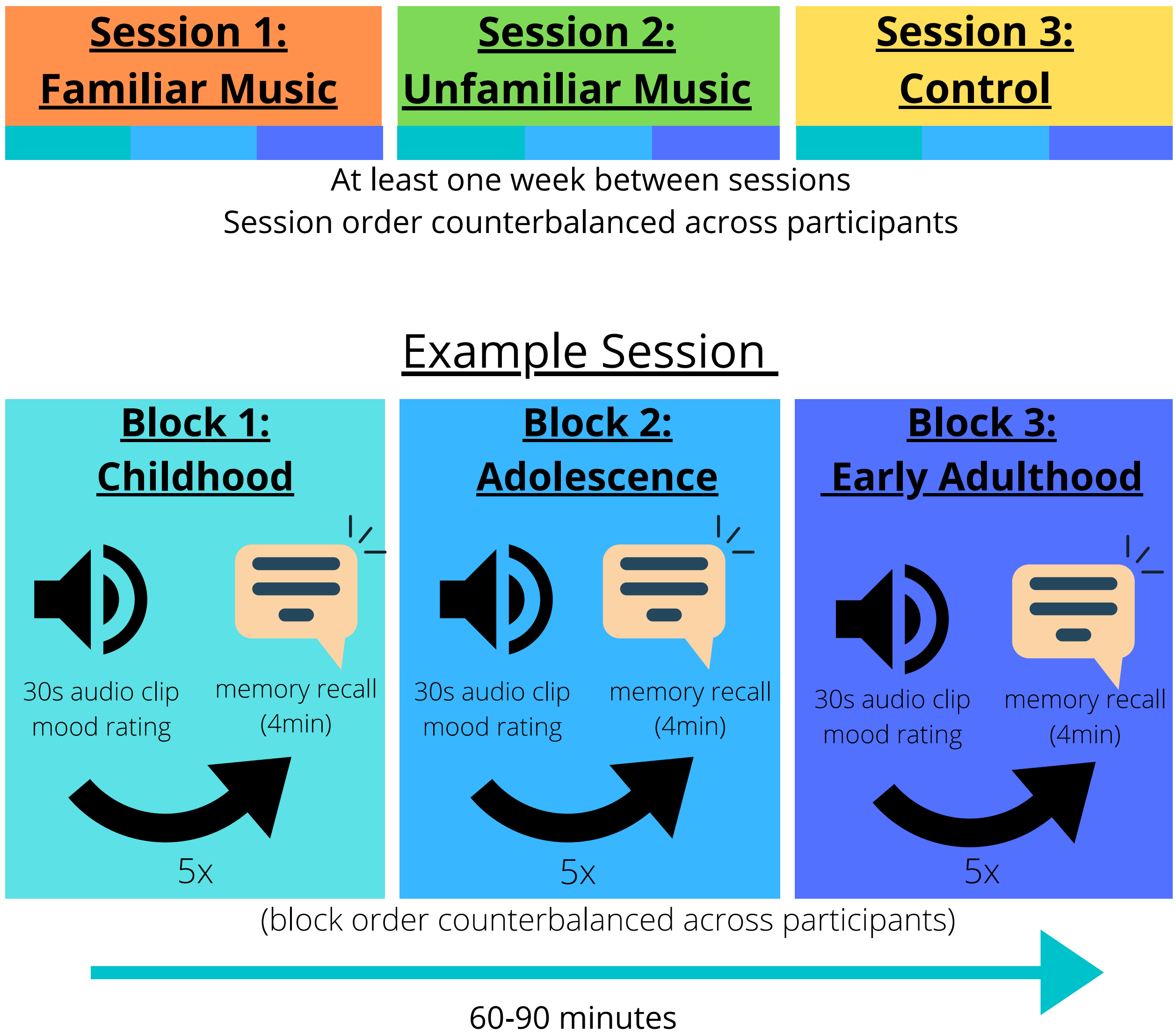

Figure 1: Study design. **Top:** Participants each took part in three sessions, in which they were exposed to either familiar music, unfamiliar music, or control non-music clips. After each clip, they were prompted to recall an autobiographical memory. **Bottom:** Schematic of an example session. Each session was split into 3 blocks, in which participants were prompted to recall events from either childhood, adolescence, or early adulthood. Each block consisted of 5 trials, in which participants first heard a music clip and then were prompted to recall an event.

Audio recordings were made of each session using Zoom. During each trial, participants were first instructed to relax and listen to a 30s audio clip. Participants were then asked to rate their mood based on the prompt "*how did the clip you just heard made you feel?"* on a numerical scale from 1-7 scale (1 = '*extremely negative*', 4 = '*neutral*', 7 = '*extremely positive*'). Next, participants were prompted to elaborate on one of the events they had reported being able to recall during the prescreening call. Within each time period, events were randomly assigned to each session. Following standard protocols for the Autobiographical Interview (Levine et al., 2002), participants were prompted to focus on a specific event, rather than general facts. If participants elaborated on events occurring in a different developmental time period than the one prompted, they were prompted again to focus on an event occurring during the prompted time period. If participants started to talk about events already elaborated upon for a previous prompt, they were asked to focus on a different event fitting the prompt description (see Supplemental Fig. 2). Participants were given up to 4 minutes to elaborate upon the prompt. If participants finished within this time, they were given a general probe for more details (*"is there anything else you can remember about that event?")*. No probes for specific types of details were given.

After 4 minutes total, participants were asked to rate the positivity and vividness of each memory on a numerical scale from 1-7. Following this, we assessed whether the audio clips also evoked spontaneous memories (i.e., MEAMs). Participants were asked whether the clip they heard during the trial brought any memories to mind spontaneously. If participants reported a spontaneous memory, they were then asked how closely related the prompted event was to the spontaneous memory on a numerical scale from 1 *(completely different)* to 5 *(the same memory).* Participants were not asked about the content of spontaneous memories.

At the end of the final session, participants listened to 10s clips of both the familiar and unfamiliar music clips an additional time, and rated familiarity with each individual clip on a numerical scale from 1-5 (1 = *'not familiar at all'*, 5 = *'extremely familiar'*). Participants also rated how much they listened to each clip during childhood (5-9 years of age), adolescence (14-18 years of age), early adulthood (20-25 years of age), and after age 25 on the same scale. Participants were thanked and had the opportunity to participate in a debriefing conversation in which they were given time to discuss the study and any questions they had.

Memory Interview Transcription and Scoring

Experimenters generated text transcriptions of participants' recall of each event. To do this, experimenters ('transcribers') compared automatically generated (by Zoom) text transcripts of each videocall to the audio recording and made any necessary corrections. Transcriptions included all utterances made by both the participant and experimenter during the recall and general probe periods. If a participant recalled more than one event following a probe, all events were transcribed.

Each transcribed memory was scored by experimenters ('coders') using the Autobiographical Interview guidelines developed by Levine et al. (2002). Consistent with prior work, details were coded as episodic (or 'internal') if they reflected occurrences, locations, perceptions, thoughts, or emotions specific to the primary event described in response to the probe (Wardell, Esposito, et al., 2020). Details not specific to the time and place of the primary event were coded as 'external'. Specifically, external details included semantic details (e.g., "*We always went to the cabin in the summer")* and episodic details that were not pertinent to the primary recalled episode. In particular, if more than one episode was recalled during a single prompt, the episode judged by the coding experimenter as most related to the prompt was considered the 'internal' or 'primary' episode, and any others were scored as 'external' episodes. Sum scores for total internal and external details were calculated for each memory prompt. Coders did not score any utterances by the experimenter running the session. Coders were not present at the experiment sessions they scored and were blind to the music condition. Study-specific manuals for transcribers and coders are available at https://github.com/pab2163/amfm_public.

For each participant, two coders initially scored each memory. If for that participant, reliability (as measured by the intraclass correlation coefficient; ICC2K) between coders was less than .9, the coders examined discrepancies and re-scored memories, along with one additional coder. This process was then repeated, adding an additional coder each time, until reliability ≥ .9 was reached. Once reliability ≥ .9 was achieved, final scores for each memory were calculated by averaging the ratings across all coders scoring that participant. While this resulted in more total number of coders for some participants than others, it ensured a minimum reliability of .9 for every participant. This procedure also ensured consistency in scoring across all memories of a given participant, removing potential confounds that might be introduced by varying the coders for different experimental sessions or blocks.

Inclusion Criteria

Only data from participants meeting all inclusion criteria from the prescreening call were analyzed. All main analyses only included participants who completed all three music and memory interview sessions. Although we planned additional analysis specifications including participants who dropped out after completing only one or two sessions, no participants who completed any sessions dropped out. Trials were included in primary analysis according to Supplemental Fig. 2. Any trials where technological or other factors (other people, pets, etc.) interrupted memory recall for more than 10s were also excluded from analysis. If such interruptions fell during music listening (prior to memory recall), we restarted the trial by playing the music clip again from the beginning and included the trial in analyses. Under all trial-level inclusion criteria, 6.8% of all trials were excluded from analyses (see Supplemental Table 5).

Question	Analysis	Analysis Contingencies	Result
1. Music familiarity manipulation check: Do participants rate clips played in the familiar condition as more familiar than clips played in the unfamiliar condition?	Bayesian multilevel ordinal regression model with familiarity ratings as outcome	Planned analysis #1 will only be conducted if the manipulation is successful, such that participants rate clips in the familiar condition as more familiar than clips played in the unfamiliar condition on average.	Participants rated clips in the familiar music condition as more familiar than clips in the unfamiliar music condition, indicating the familiarity manipulation was successful (Fig. 2A).
2. Music exposure timing manipulation check: Do participants report having listened to familiar music clips more within the time period when they were released (childhood, adolescence, or early adulthood) than other times in life?	Bayesian multilevel logistic regression model with outcome indicating whether participants rate the time period of song release as the time at which they listened to it most	No analyses will be contingent on this. However, our interpretation of any observed effects will be adjusted based on whether this manipulation check holds or not — namely if participants report listening to songs in the familiar music condition more within the time period when they were released than during other times in life for >80% of songs in the familiar music condition.	Participants reported listening to clips most during the time period of release roughly 82% of the time for songs released during young adulthood, 77% of the time for songs released during adolescence, and 40% of the time for songs released during childhood. This indicates that our manipulation of music exposure timing was often not specific to the time window of the music release, especially for songs released during childhood (Fig. 2B).
3. Spontaneous music-evoked recall manipulation check	Bayesian multilevel logistic regression model with outcome indicating whether clips evoke spontaneous recall.	No analyses will be contingent on this. This analysis will inform interpretations of whether our music manipulation impacts spontaneous autobiographical memory recall.	Participants reported having spontaneous memories most often in the familiar music condition, less often in the non-music clips condition, and least often in the unfamiliar music condition (Fig. 2C).
4. Check for coincidence between spontaneous and prompted recall	Bayesian multilevel logistic regression model with outcome indicating whether spontaneously evoked and prompted memories coincide	Planned specification curve analyses will include a fork with an additional covariate for coincidence if there is an effect of music condition on coincidence.	Overall coincidence between the content of spontaneous and prompted memories was rare. However, such coincidence occurred more often in the familiar music condition compared to unfamiliar music and non-music clips, so specification curve analyses included forks with coincidence as a covariate.

Table 2: Manipulation checks for music familiarity, music exposure timing, spontaneous music-evoked recall, and coincidence between spontaneous and prompted recall will be conducted first to inform primary planned analyses.

Manipulation checks

Music familiarity manipulation check

To examine the effectiveness of our music familiarity manipulation, we tested whether participants reported being more familiar with the songs used in the familiar music condition compared to the unfamiliar music condition. Only data from the familiar music and unfamiliar music sessions was used in this analysis. Because music familiarity ratings are ordinal responses on a 5-point scale, we used a cumulative ordinal regression model with a probit link function (Bürkner & Vuorre, 2019). This model was fit with package default weakly informative priors, and included participant-specific random effects of music condition. Effectiveness of the music manipulation was examined through the fixed-effect term for music condition in a model using the following R syntax:

familiarity_rating ~ music_condition + (music_condition | id)

We set criteria such that if 97.5% of draws from the posterior distribution for the music condition parameter had the same sign, this would be interpreted as evidence for an effect of music condition on familiarity ratings. If there was an effect of music condition, such that familiarity ratings are higher for songs in the familiar music condition, we would conduct planned analysis #1 (see Table 1 Question 1).

Music exposure timing manipulation check:

The goal of this analysis was to determine the degree to which participants' exposure to songs in the familiar condition was highest during the time period of the song's release (i.e., matching the time period of the corresponding event prompt). To that end, we tested whether participants rated listening to each song most during this time period, relative to several other time periods in life. For each song in the familiar music condition, we compared each participant's 1-5 ratings of exposure during childhood (5-9), adolescence (14-18), early adulthood (20-25), and later in adulthood (25+). A song was coded as 'matching' if the participant rated their exposure as highest (or tied for highest) during the time period of the song's release, compared to the other time periods. We estimated the proportion of 'matching' songs using a logistic regression model with random effects of time period of release (childhood, adolescence, or early adulthood) for each participant:

matching ~ time_period + (time_period | id)

We extracted posterior predictive distributions of the group-level proportion of matching songs in each time period. We set decision criteria such that we would consider the song exposure timing manipulation to have been successful if the median posterior estimate for the proportion of songs matched was greater than 0.8 among songs released in each of the three time periods (childhood, adolescence, early adulthood). No other analyses were conditional on the results of this manipulation check, though our interpretations of any potential music effects were based on whether this manipulation was successful.

Spontaneous music-evoked recall manipulation check

Although the primary focus of the current study was voluntary (prompted) recall, we also assessed whether involuntary recall (i.e., memories that are spontaneously evoked by the clips) differed as a function of music condition. Participants gave binary responses (yes/no) to indicate whether each clip spontaneously evoked a memory. We estimated the proportion of clips evoking spontaneous recall in each condition using a logistic regression model with random effects of condition for each participant:

spontaneous_recall ~ music_condition + (music_condition | id)

From this model we examined the following contrasts: 1) likelihood of spontaneous recall in the familiar music condition > unfamiliar music condition, and 2) likelihood of spontaneous recall for both music conditions > the no-music condition. If 97.5% of draws from the posterior distribution had the same sign for either contrast, we interpreted this as evidence for an effect of music condition on spontaneous recall.

Manipulation check for coincidence between spontaneous and prompted recall

It is possible that memories that are spontaneously evoked by a clip overlap to some degree with the randomly selected event prompt. We expected such coincidence between spontaneous and prompted memories to be rare. However, to ensure that this possibility did not play a confounding role, we examined the proportion of total trials for which these memories coincided. We defined 'coincide' as participants giving a rating ≥4 (on a scale from 1-5) for how closely related the prompted and spontaneous memories were for a given trial. We used a logistic regression model to estimate, for each condition, the proportion of clips evoking a coinciding memory. This model included random intercepts and effects of condition for each participant.

coincidence ~ music_condition + (music_condition | id)

From this model we examined the following contrasts: 1) likelihood of coincidence in the familiar music condition > unfamiliar music condition, and 2) likelihood of coincidence for both music conditions > the no-music condition. If 97.5% of draws from the posterior distribution had the same sign for either contrast, we interpreted this as evidence for an effect of music condition on coincidence between spontaneous and prompted memories. We planned that if there was such an effect, then we would include an additional fork for all specification curve analyses in which we added an additional trial-level binary covariate for degree of coincidence (see Supplemental Table 6). This covariate was coded as 0 if participants did not report a spontaneous memory or if coincidence did not occur (using the same coding as above) and coded as 1 if coincidence did occur.

Primary Planned Analyses

1. Effects of familiar vs. unfamiliar music on memory retrieval

Primary analysis: This analysis was conducted only after confirming that the music familiarity manipulation was successful (see *Music familiarity manipulation check)*. We fit a Bayesian multilevel linear regression model to estimate effects of exposure to familiar music on retrieval of both internal and external details, as well as the proportion of internal details (see Table 1 Question 1). In this model, we included both fixed and random (varying by participant) terms for detail type, music condition, developmental time period, and the interactions of music condition and developmental time period with detail type. While regressors for developmental time period were included in all models to help explain variance, such effects were not the focus of the current study (see Fig. 5). Detail type was effect-coded such that main effects of music condition represented ANOVA-like grand mean differences in number of details recalled (averaging across internal and external details). The model syntax in R was as follows:

*num_details ~ detail_type*music_condition + detail_type*time_period +*
*(detail_type*music_condition + detail_type*time_period | id)*

Our model structure allowed us to estimate effects of music exposure on both internal and external details individually, and with respect to each other. From the model, we examined the following contrasts: 1) internal details in the familiar > unfamiliar music condition, 2) external details in the familiar > unfamiliar music condition, 3) proportion of details that are internal (i.e., $\frac{internal}{internal+external}$) in the familiar > unfamiliar music condition, and 4) details in the familiar > unfamiliar music condition, averaged across external and internal details. Effect estimates for all contrasts were calculated through extracting 4000 draws from the model's posterior predictive distribution for the linear predictor. Highest density intervals (HDI) were calculated for each contrast. Such intervals are roughly analogous to confidence intervals (Turkkan & Pham-Gia, 1993).

The primary analysis included data from the 75 participants meeting the main inclusion criteria for the study, and included summed internal and external details, respectively, across both the recall and general probe phases. Trials in which participants reported no memories in response to probes were excluded from analysis, though trials for which participants reported memories with no internal details (and >0 external details) were included (Supplemental Fig. 2). Thus, all reported memories contributed to the analyses, irrespective of their content.

Specification curves: In addition to the primary analyses, we considered additional analyses that were theoretically motivated. This allowed us to determine whether our observed results were robust to different analysis decisions that were equally valid. To that end, we conducted specification curve analysis to determine the robustness of observed results (Orben & Przybylski, 2019; Steegen et al., 2016). We reran the model described above under all possible combinations of the analysis specifications detailed in Supplemental Table 6, resulting in a total of 24 analysis specifications. For each contrast, we tested whether the median effect of the specification curve significantly differed from that expected in the absence of a true effect through permutation testing. Specifically, we shuffled the music condition labels randomly for each participant, then re-calculated the specification curve and the corresponding median effect estimate 100 times (Simonsohn et al., 2015). This procedure tested the statistical significance of the specification curve as a whole, and we considered any results for individual specifications (other than the primary analyses) exploratory. We set an alpha level $\alpha = 0.05$ as the criterion for significance for these analyses. See specification curves at https://pbloom.shinyapps.io/music_memory_specification_curves/.

2. Associations between ratings of song familiarity and memory retrieval

Primary analyses: We also used similar Bayesian multilevel linear regression models to those outlined for analyses #1 (see Table 1 Question 1) to estimate associations between participants' ratings of familiarity for each song and retrieval of internal and external details following exposure to that song (see Table 1 Question 2). We included random effects terms for familiarity rating and time period (and their interactions with detail type) for each participant. Familiarity rating was treated as a continuous variable, with effect coding for detail type and dummy coding for time period (see Supplemental Table 8). The syntax will be as follows:

*num_details ~ detail_type*familiarity_rating + detail_type*time_period + (detail_type* familiarity_rating + detail_type*time_period | id)*

We examined the following four contrasts from the model: 1) the average expected increase in internal details associated with a 1-unit increase in familiarity, 2) the average expected increase in external details associated with a 1-unit increase in familiarity, 3) the average expected increase in the proportion of details that are internal associated with a 1-unit increase in familiarity, and 4) the average increase in all details (averaged across internal and external) associated with a 1-unit increase in familiarity.

3. Effects of music vs. non-music clips on memory retrieval

Primary analysis: To estimate effects of music on memory recall more generally (see Table 1 Question 3), we examined an additional 4 contrasts from the model described in planned analysis #1 (see Table 1 Question 1 and Supplemental Table 7). The contrasts we examined here were: 1) internal details in both music conditions > no-music condition, 2) external details in both music conditions > no-music condition, 3) the proportion of details that are internal in both music conditions > no-music condition, and 4) all details in both music conditions > no-music condition, averaged across external and internal details. Effect estimates were calculated through draws from the model's posterior predictive distribution for the linear predictor as previously detailed.

Corrections for multiple comparisons

To account for the multiple comparisons introduced by making inferences for several contrasts from the same model, we implemented a modified Holm-Bonferroni procedure (Holm, 1979). For each model, contrasts were ordered from greatest to least by the proportion of posterior draws with the same sign (a rough equivalent of frequentist confidence intervals; Ludbrook, 2000). With a maximum family-wise error rate of $\alpha = 0.05$, contrasts were interpreted as showing evidence for an effect if a proportion greater than $1 - \frac{\alpha/2}{m}$ of posterior draws had the same sign for each contrast, where m is initially the total number of contrasts tested (4 for each model), then is reduced by 1 for each subsequently tested contrast (thereby relaxing the criteria). If for any contrast, this multiple comparisons-corrected criterion was not met, we interpreted such a result as absence of consistent evidence for that contrast, and any following contrasts.

We applied this correction for multiple comparisons to all models used in primary analyses. However, such procedures were unnecessary, as no primary analyses met our planned criteria for an effect even without such corrections. Because specification curve analyses were considered in combination with the primary analysis, we did not apply additional corrections for multiple comparisons to specification curves.

Secondary Planned Analyses

Question	Analysis	Interpretation	Result
1. Effects of music condition on mood: Is there an effect of music condition on participant-rated mood?	Bayesian multilevel ordinal regression model with mood ratings as outcome	Results will inform the degree to which our music manipulation impacts affect.	Familiar music clips evoked the most positive affect compared to unfamiliar music or non-music clips. Unfamiliar clips also evoked more positive affect compared to non-music clips.
2. Associations between mood and retrieval of internal and external details: Is participant-rated mood associated with voluntary retrieval of internal details, external details, or the proportion of internal details?	Bayesian multilevel linear regression model with number of details as outcome, contrasts for a 1-unit increase in mood rating	Results will inform interpretations of whether music effects on memory retrieval may be related to changes in mood.	We did not find associations between affect and retrieval of internal or external details.
3. Associations between spontaneous recall and voluntary retrieval of internal and external details: Is the occurrence of a spontaneous memory associated with subsequent voluntary retrieval of internal details, external details, or the proportion of internal details?	Bayesian multilevel linear regression model with number of details as outcome, including only participants who reported spontaneous recall on at least one trial	Results will inform whether spontaneous recall is associated with subsequent enhanced deliberate recall. If so, this might indicate a potential mechanism by which music could boost voluntary recall.	We did not find associations between spontaneous recall and voluntary (prompted) recall of internal or external details.
4. Associations between self-reported music exposure during the time period of music release and voluntary memory retrieval: Is higher self-reported exposure during the time period of music release (vs. during different time periods) associated with retrieval of internal details, external details, or the proportion of internal details?	Bayesian multilevel linear regression model with number of details as outcome, including only trials from the familiar music condition	Results will inform whether exposure to music during the time period of music release (versus other times in life) is associated with retrieval of memories from the same time period. Such an association might suggest temporally specific effects of music on memory recall.	While preregistered analyses found an association between exposure during the time period of release and prompted recall of internal details, such analyses were likely confounded by the time periods of the prompted events. In follow-up analyses controlling for the time period of events, we did not find associations between exposure during the time period of music release and recall of internal or external details (see Supplemental Results).

Table 3: Questions, analysis methods, interpretations, and results, for secondary planned analyses.

Effects of music condition on mood

Although our music manipulation was not designed to affect participants' mood, we analyzed mood as a function of music condition (Jakubowski et al., 2018; Nineuil et al., 2020; Schulkind et al., 1999). Mood (affect) ratings were ordinal responses on a 7-point scale, so we used a cumulative ordinal regression model (as we proposed for the music familiarity manipulation check). We estimated effects of familiar relative to unfamiliar music clips, and music relative to non-music clips, on self-reported mood. This model included a regressor for developmental time period to help the model explain more variance. This model also had participant-specific random effects of music condition and time period as follows:

mood ~ music_condition + time_period + (music_condition + time_period | id)

From this model we examined the following contrasts: 1) mood ratings in the familiar music condition > unfamiliar music condition, and 2) mood ratings in both music conditions > the no-music condition. If 97.5% of draws from the posterior distribution had the same sign for either contrast, we interpreted this as evidence for an effect of music condition on mood.

Associations between mood and memory retrieval

To ask whether mood and remote memory retrieval were associated, we will model both internal and external details as a function of mood (Palombo et al., 2020; Sheldon et al., 2020; Sheldon & Donahue, 2017; Simpson & Sheldon, 2019; Wardell, Madan, et al., 2020). Detail type was effect-coded such that the main effect of mood represented the mean association of mood with retrieval averaged across internal and external details. Number of details and mood were treated as continuous variables, and mood was z-scored within participants. The model syntax in R included participant-level random effects for all terms as follows:

*num_details ~ detail_type*mood + (detail_type*mood| id)*

From this model we examined the following contrasts: 1) the average expected increase in internal details associated with a 1-unit increase in mood, 2) the average expected increase in external details associated with a 1-unit increase in mood, 3) the average expected increase in the proportion of details that are internal associated with a 1-unit increase in mood, and 4) the average increase in all details (averaged across internal and external) associated with a 1-unit increase in mood. Multiple comparisons corrections were applied across all contrasts as described previously (see *Corrections for Multiple Comparisons*). No other analyses were contingent on these results.

Associations between spontaneous and voluntary recall

We fit an additional Bayesian multilevel model to ask whether involuntary recall was associated with voluntary (prompted) recall on a trial-by-trial basis. Recall measures included internal details and external details, and the model included random effects of spontaneous_recall, detail type, and their interaction for each participant.

*num_details ~ spontaneous_recall*detail_type + (spontaneous_recall*detail_type | id)*

From this model we examined the following contrasts: 1) number of internal details recalled in trials with spontaneous recall > trials without spontaneous recall, 2) number of external details recalled in trials with spontaneous recall > trials without spontaneous recall, 3) the total number of details (across internal and external) in trials with spontaneous recall > trials without spontaneous recall, and 4) the proportion of recalled details that are internal in trials with spontaneous recall > trials without spontaneous recall.

Associations between self-reported music exposure during the time period of music release and voluntary memory retrieval

For the familiar music condition only, we also asked whether self-reported music exposure during the time period of the music's release (childhood, adolescence, or early adulthood) was associated with deliberate recall of memories from that same time period. To accomplish this, we constructed a Bayesian multilevel linear regression to estimate associations between reported exposure to music clips and deliberate recall of internal or external details. The preregistered model had terms for both music exposure during the time period of the music's release (music_exposure_matching) and average music exposure during all other time periods (music_exposure_nonmatching). The preregistered model included both music exposure terms, detail type (internal vs. external), and interactions of the music exposure terms with detail type, with participant-varying random effects for all parameters.

*Num_details ~ music_exposure_matching*detail_type + music_exposure_nonmatching*detail_type + (music_exposure_matching*detail_type + music_exposure_nonmatching*detail_type | id)*

After data collection, we realized that associations of time-windowed music exposure in the preregistered model were likely confounded by the developmental time windows of the prompted event memories. Within the familiar music condition, the time period of the event prompt was matched to the time period of song release, and time-windowed music exposure was higher for songs released in adolescence and young adulthood compared to childhood (Supplemental Fig. 13). Thus, effects of the time period of the recalled events—more internal details for adolescent and young adulthood memories vs. those from childhood—may have driven apparent effects of music exposure in the preregistered model. To explore this possibility, we fit an additional (not preregistered) model with added covariates for the time period of the events as follows:

*num_details ~ music_exposure_matching*detail_type + music_exposure_nonmatching*detail_type + time_period*detail_type + (music_exposure_matching*detail_type + music_exposure_nonmatching*detail_type + time_period*detail_type | id)*

From these models we examined the following contrasts: 1) the average expected increase in internal details associated with a 1-unit increase in music exposure in the matching time period, 2) the average expected increase in external details associated with a 1-unit increase in music exposure in the matching time period, 3) the average expected increase in internal details associated with a 1-unit increase in music exposure in the non-matching time periods, and 4) the average expected increase in external details associated with a 1-unit increase in music exposure in the non-matching time periods. Multiple comparisons corrections were applied across contrasts (see *Corrections for Multiple Comparisons).* See Supplemental Results and Supplemental Fig. 10 for all results of this analysis.

Model-fitting

We fit all models using Hamiltonian Monte Carlo No-U-Turn sampling as implemented by the brms package in the R computing environment (Bürkner, 2019). We chose to use fully Bayesian estimation for all models to improve estimation of hierarchical regression models with many parameters, as well as to address the practical concern that maximum likelihood-based approaches are often prone to model convergence issues or underestimation of coefficient uncertainty (Chung et al., 2015). All linear models were fit using weakly informative priors, namely package-default student's t distributions centered at 0 with 3 degrees of freedom and a scale parameter of 10 (units are standard deviations of the predictor variable) for both fixed effects and the standard deviation of participant-level random effect distributions (priors for standard deviations were censored to only include values 0 and above). Additionally, a package-default LJK prior with shape $\eta = 1$ was used for the covariance matrix of participant-level coefficients. For all models, we fit 4 chains of 2000 sampling iterations (1000 warmup) each for a total of 4000 post-warmup samples. In cases where the tail effective sample size was low (as indicated by Stan warning messages), we added 1000 more sampling iterations for each chain until sufficient tail effective sample size was achieved. For all primary analysis models, the $\hat{R}$ statistic for all fixed effects was below a threshold of 1.1 (Gelman et al., 2013). We computed full posterior distributions for all contrasts of interest, and plotted these along with corresponding highest density intervals for each primary analysis (Kruschke, 2021; van de Schoot et al., 2021). Extraction and transformation of posterior draws after models were fit was done using the tidybayes package and the tidyverse collection of packages in R (Kay, 2022; Wickham et al., 2019). All results figures were created using ggplot2.

Exploratory Analyses

Differences in prompted recall as a function of age at the time of the prompted event

Using the model previously fit for primary planned analysis #1, we examined whether prompted recall of internal or external details differed as a function of age at the time of the prompted event. This served as an additional (not preregistered) manipulation check, given that autobiographical memories tend to be less detailed for childhood events (Bauer, 2012). Between each of the time periods (childhood, adolescence, or young adulthood), we calculated posterior contrasts for differences in internal details, external details, all details (the sum of internal + external), and the proportion of details that were internal. Multiple comparisons corrections were not applied to these analyses, as our goal was to explore estimated differences in recall between time periods, rather than to test specific hypotheses.

Differences in prompted recall as a function of event prompts

We used a Bayesian multilevel linear regression model to explore whether different event prompts evoked differing recall of internal or external details. Because not all participants recalled memories for all prompts, we included only event prompts for which ≥10 participants recalled memories, and included random intercepts and effects of detail type for each participant as follows:

*num_details ~ event*detail_type + (detail_type | id)*

We then extracted posterior predictions for the average internal details, external details, all details (the sum of internal + external), and proportion of internal details recalled for each event. We grouped events by their time period of occurrence to help visualization of differences in recall between events within each time period. As the goal of this exploratory analysis was to estimate differences in recall among event prompts, we did not compute contrasts between specific pairs of events or apply corrections for multiple comparisons.

Deviations from preregistered methods

Although we largely followed all preregistered methods (see https://osf.io/kjnwd/), we note several small changes from the registered protocol. First, we used an additional recruitment method of paper flyers posted in several locations in New York City, and we did not recruit any participants through shared institutional participant lists. In addition, while the preregistered protocol stated that we would play participants a sample audio clip at the end of the prescreening session, we played this audio at the beginning of each study session to ensure that audio quality was sufficient for each call.

Although preregistered methods stated that participants would be given 4 minutes to recall a memory in response to each prompt, in practice it was difficult to interrupt participants if they were continuing to recall a memory beyond the designated time. This was particularly true because participants could not always hear on Zoom if an experimenter interjected while they were simultaneously speaking. Thus, for some trials (10.3%), recall continued after 4 minutes before the experimenter was able to move on to the next item. Experimenters worked to be as consistent as possible for each participant in moving to the next follow-up question as soon as possible after 4 minutes of recall had elapsed.

Preregistered methods also stated that members of the research team correcting automatically generated text transcripts (‘transcribers’) using the Zoom audio would not be those conducting the corresponding study sessions. However, some Zoom transcripts (25 participants) were corrected by the same person who conducted the session, such that transcribers in these cases were aware of the music condition for the text transcripts they corrected. In addition, even when transcribers were not correcting transcripts for sessions they ran themselves, they could have been aware of the condition because the recordings and text transcripts contained the audio of the clips and corresponding text (i.e., the song lyrics or dialogue from non-music clips; transcribers always removed this information from transcripts so that coders would not see it). It is unlikely that this could have been a potential source of bias, as transcribers did not make decisions about how memories were coded and were always distinct from coders making such decisions for each participant.

Lastly, with the permission of the journal editor, we added one questionnaire item at the end of the final study session assessing participants’ liking of each music clip on a numerical scale from 1-5 (see Supplemental Fig. 3). Overall, we believe that the deviations from the preregistered protocol were minor and did not substantially impact the rigor or results of the study.

Results

Manipulation Checks & Preliminary Planned Analyses

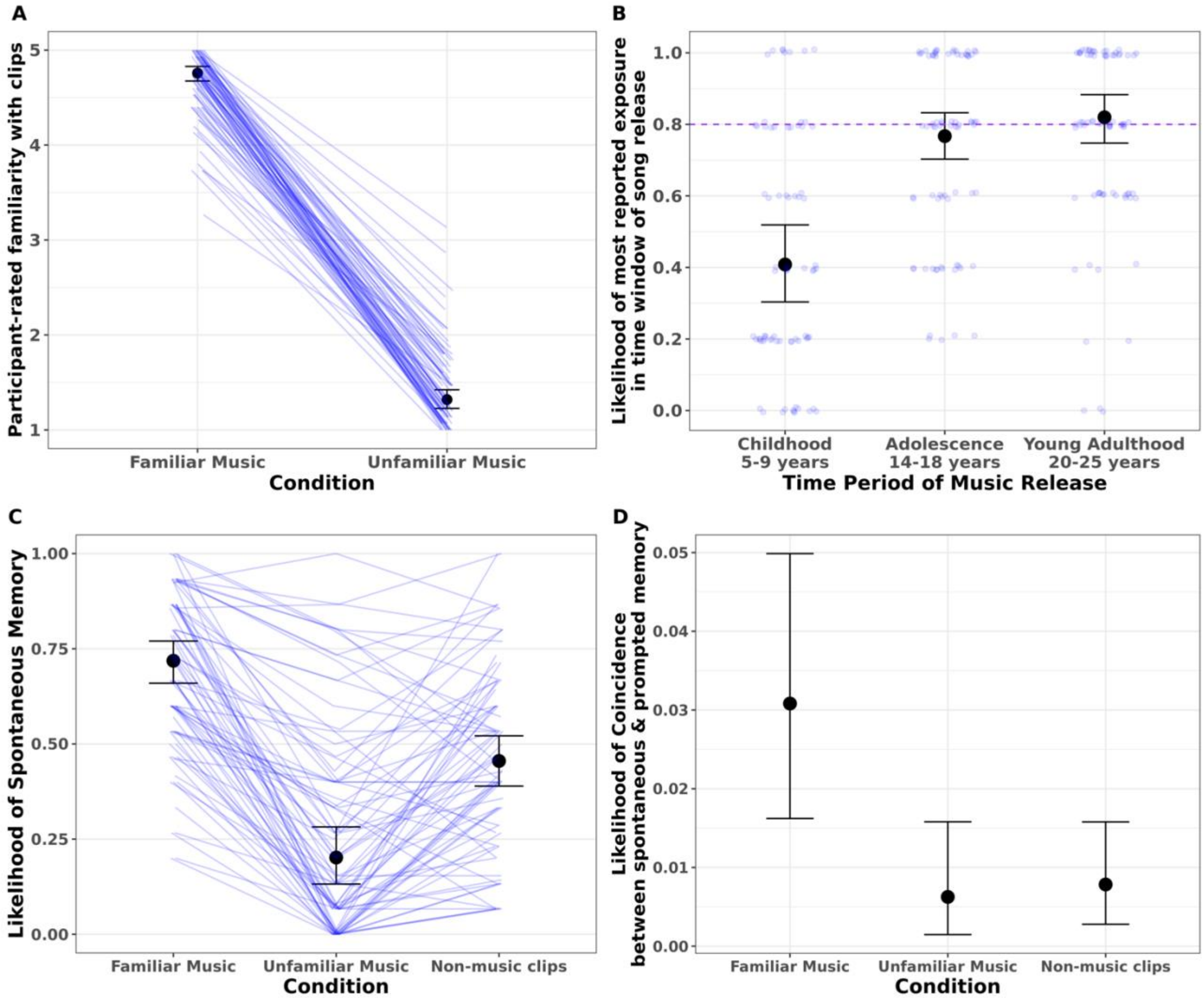

Figure 2: Manipulation checks and preliminary analyses (see Table 2). **A:** Song familiarity manipulation check. Participant-reported familiarity (y-axis) with music clips selected to be familiar and unfamiliar. Note: while familiarity was treated as an ordinal variable in the model, it is plotted as a continuous variable here for ease of visualization. **B:** Likelihood of highest self-reported music clip exposure during the window of each song's release. Y-axis shows the estimated proportion of trials where participants reported the highest (or tied for highest) exposure to each song clip during the developmental window of the song's release (from the options of ages 5-9, 14-18, 20-25, or 26-present). The dashed horizontal line at 0.8 represents the preregistered study criterion for successful manipulation of the time window of music exposure. **C:** Likelihood of participants reporting that a spontaneous memory was evoked during listening of sound clips in each condition. **D:** Likelihood of coincidence between spontaneous memories and prompted memories in each condition. Coincidence was defined by participants giving a rating ≥4 (on a 1-5 numerical scale) for how similar the spontaneous and prompted memories were for each given trial. For all panels, black points and error bars represent group-level model estimates and 95% posterior intervals, and blue points or lines are summaries

(average familiarity in panel A, proportions in panels B & C) of each individual participant's raw data.

Music Familiarity Manipulation Check

A Bayesian multilevel cumulative ordinal regression model indicated that participant-reported familiarity with music clips was higher in the familiar music condition compared to the unfamiliar music condition (β=3.53, 95% HDI [3.26, 3.83]). Further, all individual participants reported numerically higher average familiarity in the familiar music condition compared to the unfamiliar condition (Fig. 2A). We interpret this as a successful manipulation of music familiarity (see Table 1 Q1).

Music Exposure Timing Manipulation Check

Using a Bayesian multilevel logistic regression model, we estimated the proportion of clips in the familiar music condition for which participants reported the highest (or tied for highest) exposure during the time window of the song's release (among the options of childhood [ages 5-9], adolescence [ages 14-18], young adulthood [ages 20-25], and 26-present) (Fig. 2B). Although participants reported highest exposure during the time window of release for the majority of songs released during their adolescence (Median proportion = 0.77, 95% HDI [0.70, 0.83) and young adulthood (Median proportion = 0.82, 95% HDI [0.75, 0.88]), this was true less often for songs released during their childhood (Median proportion = 0.40, 95% HDI [0.30, 0.52). Based on the criteria of a 0.8 likelihood of highest reported exposure during the time window of release, our music exposure timing manipulation did not succeed in temporal specificity (see Table 1 Q2). Thus, any effects of familiar music on memory cannot be ascribed to temporal matching between prompted events and the developmental timing of the release of the songs.

Spontaneous music-evoked recall

Using a Bayesian multilevel logistic regression model, we estimated the proportion of trials in each condition for which participants reported a spontaneous memory coming to mind while listening to the clip (Fig 2C). We found an effect of music familiarity on spontaneous recall, such that participants reported more spontaneous memories in the familiar music condition compared to both the unfamiliar music condition (β=2.31, 95% HDI [1.92, 2.75]) and the non-music clips condition (β=1.11, 95% HDI [0.85, 1.38]). In addition, participants reported more spontaneous memories in the non-music clips condition compared to the unfamiliar music condition (β=1.20, 95% HDI [0.81, 1.63]). This latter effect was not expected, and we explore reasons for why unfamiliar music may have evoked the fewest spontaneous memories in the Discussion.

Coincidence between spontaneous and prompted recall

We used a Bayesian multilevel logistic regression model to estimate the proportion of all trials where participants reported a high degree of coincidence ($\geq$4 on a numerical scale from 1-5) between prompted and spontaneous memories in each condition. Although such coincidence was rare overall (generally fewer than 5% of trials; Fig. 2D), participants reported coincidence more often during the familiar music condition compared to either the unfamiliar music (β=1.61, 95% HDI [0.55, 2.89]) or non-music clips (β=1.37, 95% HDI [0.70, 2.33]). There were no differences in likelihood of coincidence between the unfamiliar music condition and non-music clips (β=-0.20, 95% HDI [-1.61, 0.96]). Thus, we included specifications in our specification curves for primary planned analyses with an additional covariate for coincidence (see Supplemental Table 6).

Primary Planned Analyses

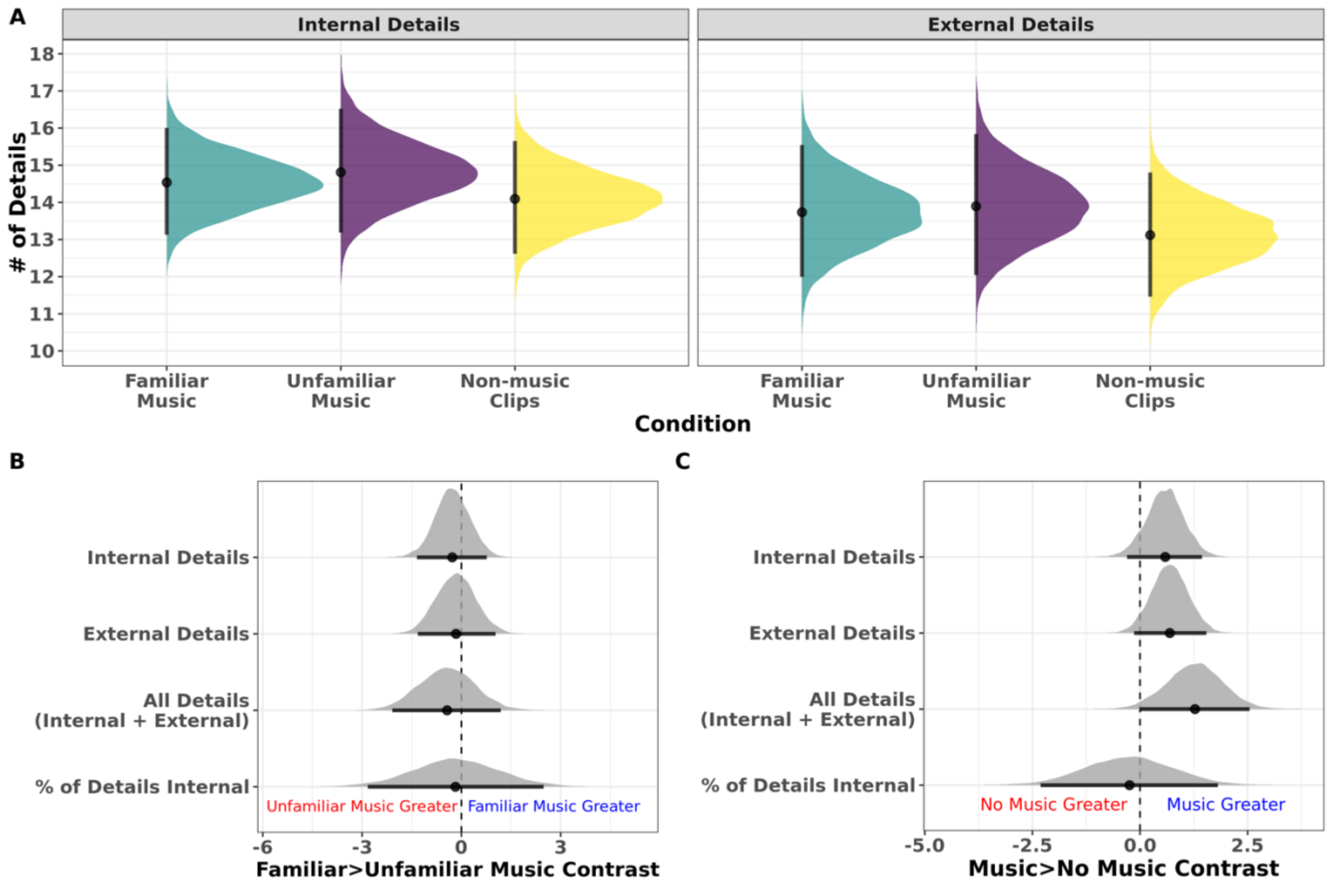

Figure 3: Effects of music manipulation on deliberate recall. Overall, primary analyses found no effects of familiar > unfamiliar music (see Table 1 Q1) or all music > non-music clips (see Table 1 Q3) under preregistered criteria, as 95% posterior intervals for all contrasts included 0. **A:** Model predictions for mean internal (left) and external (right) details recalled in each condition. Shaded distributions are posterior predictive distributions for mean details, and black points and error bars represent posterior medians and 95% intervals. **B:** Posterior distributions for the familiar music > unfamiliar music contrast, representing differences in mean recall between those two conditions. Shaded distributions represent all posterior contrast samples, and error bars represent 95% intervals. **C:** Posterior distributions for the all music > non-music clips contrast, representing differences in mean recall between those two conditions. As all 95% intervals included 0, multiple comparisons-corrected intervals are not displayed.

Effects of familiar vs. unfamiliar music exposure on prompted memory recall

We found no effects of familiar versus unfamiliar music exposure on prompted memory recall under preregistered decision criteria (Fig. 3A-B). Specifically, a Bayesian multilevel regression model did not find differences between the familiar and unfamiliar music conditions in internal details (Familiar > unfamiliar estimate =-0.27, 95% HDI [-1.27, 0.82]), external details

(Familiar > unfamiliar estimate=-0.17, 95% HDI [-1.34, 1.00]), all details (the sum of internal + external) combined (Familiar > unfamiliar estimate=-0.44, 95% HDI [-2.11, 1.16]), or the percentage of details that were internal (Familiar > unfamiliar estimate=-0.17, 95% HDI [-2.90, 2.40]). Specification curves also found no evidence for effects of familiar versus unfamiliar music on prompted recall (see https://pbloom.shinyapps.io/music_memory_specification_curves/). Additional visualizations illustrating summaries of the raw data and between-participant heterogeneity in effects of familiar music can be found in Supplemental Figures 6 & 7.

Associations between ratings of song familiarity and prompted memory recall

We found no associations between participant-reported familiarity with music clips and prompted memory recall under preregistered decision criteria (Fig. 4). Specifically, a Bayesian multilevel linear regression did not find associations between music clip familiarity and internal details (β=-0.02, 95% HDI [-0.30, 0.24]), external details (β=-0.04, 95% HDI [-0.33, 0.25]), all details (sum of internal + external) combined (β=-0.07, 95% HDI [-0.47, 0.33]), or the percentage of details that were internal (β=0.04, 95% HDI [-0.63, 0.73]). Specification curves also found no such associations (see https://pbloom.shinyapps.io/music_memory_specification_curves/).

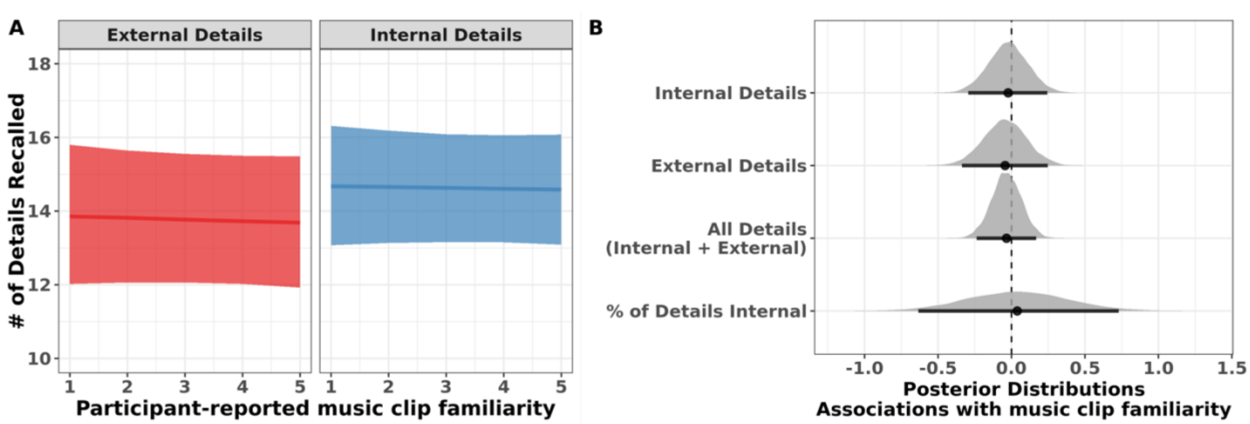

Figure 4: Associations between participant-reported music clip familiarity and deliberate recall. **A:** Model-predicted mean details recalled as a function of participant-reported familiarity (on a numerical scale from 1-5) with each music clip. This analysis included only clips from the familiar and unfamiliar music conditions. Lines represent median posterior predictive estimates for average internal (left) and external (right) details, and shaded regions represent 95% posterior intervals. **B:** Posterior distributions for estimated associations between memory detail type and participant-reported familiarity. For Internal Details, External Details, and All Details, posterior estimates represent the change in number of details recalled with a 1-unit (on a numerical scale from 1-5) increase in clip familiarity. For % of Details Internal, posterior estimates represent the change, with a 1-unit increase in clip familiarity, in the percentage of recalled details that are internal. As all 95% intervals included 0, multiple comparisons-corrected intervals are not displayed.

Effects of music vs. non-music clips on prompted memory recall

Primary analysis did not find any robust effects of exposure to music (both familiar and unfamiliar combined) versus non-music clips on prompted recall under preregistered decision criteria (Fig. 3A & C), although some weak evidence was observed. Specifically, a Bayesian multilevel regression model did not find differences between the music and non-music clips conditions in internal details (Music > no-music estimate=0.58, 95% HDI [-0.29, 1.45]), external details (Music > no-music estimate=0.69, 95% HDI [-0.16, 1.52]), all details (the sum of internal + external) combined (Music > no-music estimate=1.27, 95% HDI [-0.01, 2.53]), or the percentage of details that were internal (Music > no-music estimate=-0.25, 95% HDI [-2.31, 1.80]). For external details and all details combined, however, the 95% HDIs (not adjusted for multiple comparisons) barely overlapped 0, with most posterior draws indicating that more details were recalled in the music compared to no-music condition.

Specification curves allowed us to examine whether effects were present using different analysis choices. However, no specification curves found strong evidence for effects of music versus non-music clips on prompted recall (see https://pbloom.shinyapps.io/music_memory_specification_curves/). While the permutation test for the specification curve for differences in all details (sum of internal + external) resulted in $p = .05$, this p-value did not strictly meet the preregistered $p < .05$ criteria, and only 3 out of 24 individual specifications (not including the primary analysis) indicated an effect such that the 95% highest density interval excluded 0. Because the permutation test of the specification curve was limited to 100 resampling iterations for computational feasibility, and not adjusted for multiple comparisons (though decision criteria for primary analyses were adjusted for multiple comparisons), the result of the specification curve should not be over-interpreted as strong evidence of an effect. The combination of the primary analysis and specification curve indicate that the evidence for an effect of music exposure on prompted recall is not robust, and at best mixed.

Secondary Planned Analyses

Effects of music manipulation on clip-evoked affect

We used a Bayesian multilevel cumulative ordinal regression model to estimate effects of the music manipulation on affect (rated on a 1 [most negative] to 7 [most positive] numerical scale) evoked by the sound clips (Supplemental Fig. 9A). We found differences between all conditions, such that evoked affect was more positive on average for familiar music clips compared to both unfamiliar music (β=1.23, 95% HDI [1.06, 1.38]) and non-music clips (β=1.69, 95% HDI [1.52, 1.87]). Evoked affect was also more positive on average for unfamiliar music clips compared to the non-music clips (β=0.46, 95% HDI [0.30, 0.64]).

Associations between clip-evoked affect and prompted memory recall

We found no associations between clip-evoked affect and prompted memory recall (Supplemental Fig. 9B-C). Specifically, a Bayesian multilevel regression did not find associations between clip-evoked affect and internal details (β=0.01, 95% HDI [-0.23, 0.25]), external details (β=0.11, 95% HDI [-0.09, 0.32]), all details (the sum of internal + external) combined (β=0.06, 95% HDI [-0.10, 0.22]), or the percentage of details that were internal (β=-0.18, 95% HDI [-0.74, 0.37]).

Associations between spontaneous and prompted memory recall

We found no differences in prompted memory recall as a function of whether a spontaneous memory occurred during listening to the sound clip on the same trial (Supplemental Fig. 11). Specifically, a Bayesian multilevel regression did not find differences in internal details (β=-0.15, 95% HDI [-0.80, 0.46]), external details (β=0.56, 95% HDI [-1.18, 0.08]), all details (the sum of internal + external) combined (β=-0.71, 95% HDI [-1.54, 0.31]), or the percentage of details that were internal (β=0.78, 95% HDI [-0.77, 2.36]) as a function of whether a spontaneous memory had occurred.

Exploratory Analysis Results

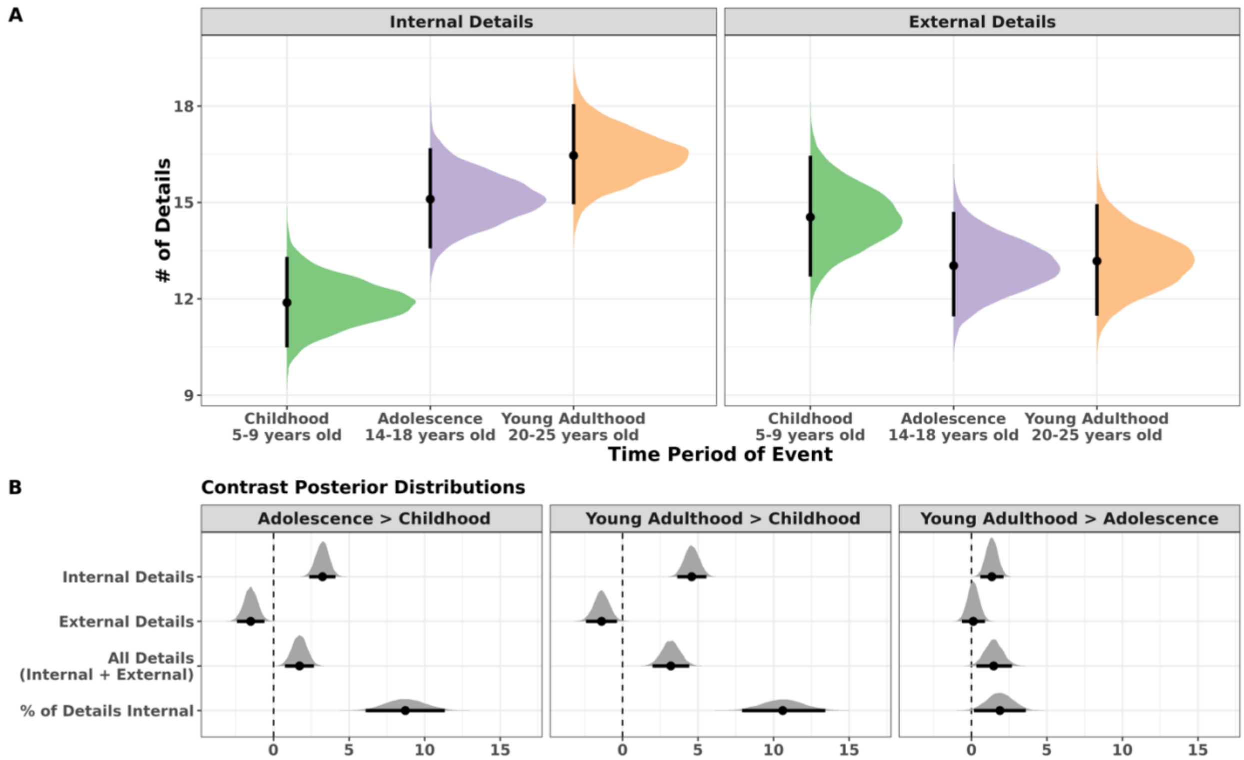

Figure 5: Exploratory analysis of differences in deliberate recall as a function of age at the time of the prompted event. **A:** Model predictions for mean internal (left) and external (right) details recalled as a function of the time period of the prompts. Shaded distributions are posterior predictive distributions for mean details, and black points and error bars represent posterior medians and 95% intervals. **B:** Posterior distributions representing differences in mean recall for each pair of time periods (adolescence > childhood, young adulthood > childhood, and young adulthood > adolescence). Shaded distributions represent all posterior contrast samples, and error bars represent 95% intervals.

Differences in prompted recall as a function of age at the time of the prompted event

To probe factors impacting prompted recall, we explored differences in recalled details as a function of the developmental time period of the prompted event (these exploratory analyses were not adjusted for multiple comparisons). Prior studies of autobiographical memory have found worse memory (e.g., fewer internal details) for memories from early childhood vs. other time periods (Bauer, 2007; Newcombe et al., 2000; Rubin & Schulkind, 1997). This analysis therefore offered a post-hoc manipulation check that our memory scoring procedures were sensitive to these reported effects.

Using the Bayesian multilevel linear regression model previously fit to test the music condition manipulation, we found that participants recalled more internal details on average for events in adolescence ($\beta=3.26$, 95% HDI [2.41, 4.11]) and young adulthood ($\beta=4.61$, 95% HDI [3.63, 5.56]) compared to childhood (Fig. 5). Participants also recalled more internal details for events in young adulthood compared to adolescence ($\beta=1.35$, 95% HDI [0.57, 2.12]). Participants recalled more external details for events in childhood compared to adolescence ($\beta=1.54$, 95% HDI [0.57, 2.39]) and young adulthood ($\beta=1.41$, 95% HDI [0.40, 2.41]), though there were no differences in external details between young adulthood and adolescence ($\beta=0.13$, 95% HDI [-0.63, 0.95]). Recall of all details (internal + external) was greater for events in both adolescence ($\beta=1.72$, 95% HDI [0.78, 2.74]) and young adulthood ($\beta=3.20$, 95% HDI [2.02, 4.45]) compared to childhood, and also greater for young adulthood compared to adolescence ($\beta=1.49$, 95% HDI [0.31, 2.67]). In addition, the percentage of details recalled that were internal was greater for events in both adolescence ($\beta=8.81$, 95% HDI [6.31, 11.51]) and young adulthood ($\beta=10.69$, 95% HDI [8.00, 13.45]) compared to childhood, and also greater for young adulthood compared to adolescence ($\beta=1.88$, 95% HDI [0.09, 3.62]). In general, effect sizes were larger for differences in internal details compared to external details, and for childhood compared to other developmental periods (e.g. smaller for comparisons between adolescence and young adulthood). These results therefore concord with prior work in showing worse autobiographical recall for events from early childhood (Newcombe et al., 2000; Pillemer & White, 1989; Rubin & Schulkind, 1997).

Differences in prompted recall as a function of event prompts

We explored whether different event prompts influenced recall of internal or external details. Visualization of the estimated proportion of internal details recalled for each prompt revealed substantial variability among prompts, even those within the same time window (Fig. 6). We also found substantial variability between prompts in the total number of details recalled (see Supplemental Fig. 14). These large differences may have made it more difficult to find more subtle memory differences due to music condition, a topic we return to in the Discussion.

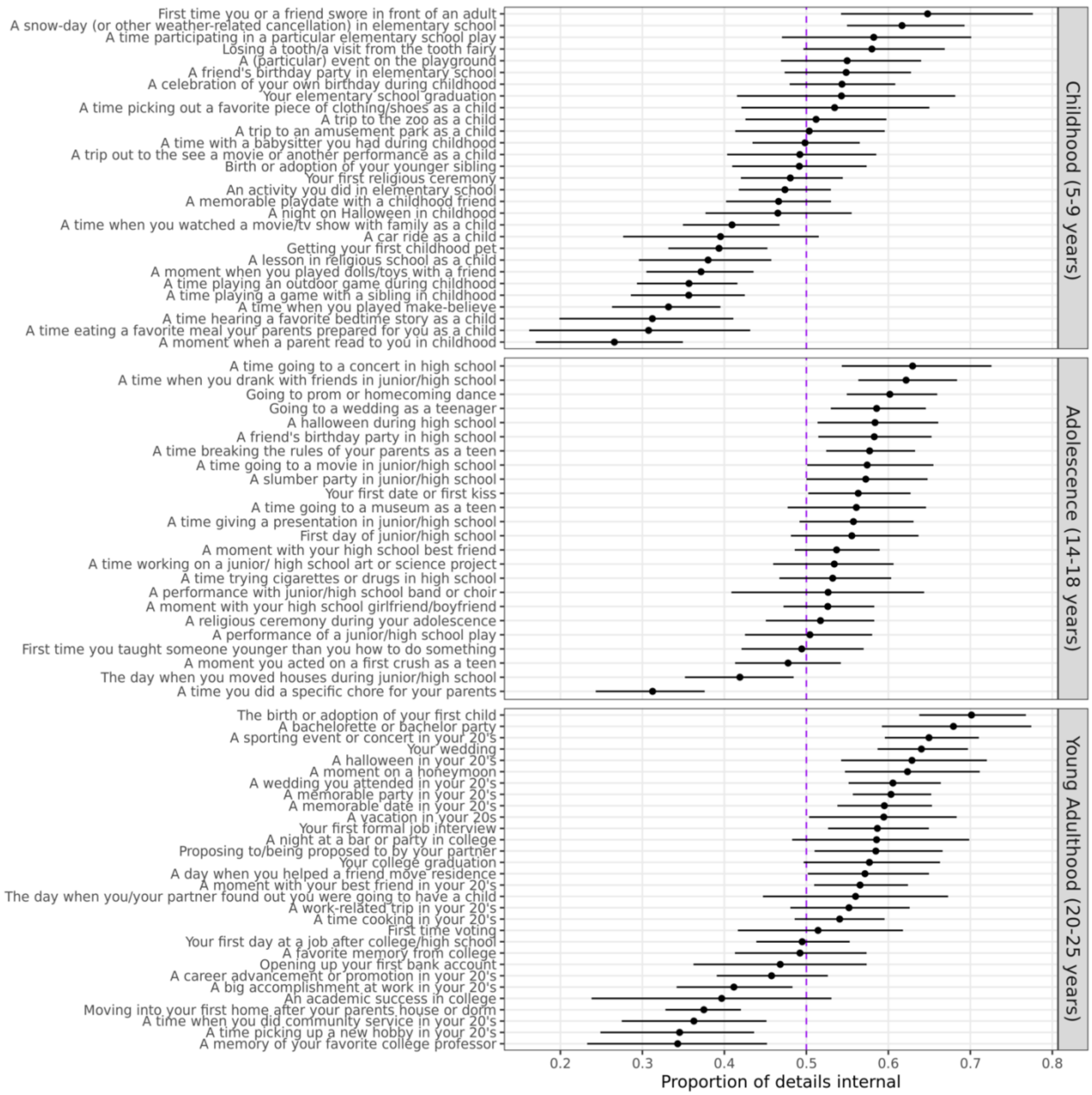

Figure 6: Exploratory analysis of differences in deliberate recall as a function of prompt. X-axis shows the estimated average proportion of details that are internal for responses to each prompt. Points are posterior medians and error bars are 95% posterior intervals. The y-axis indicates each specific prompt grouped by each time period. Only prompts that ≥10 participants responded to are included in this visualization. Prompts are sorted by highest to lowest proportion of internal details, separately for each time period.

Discussion

We examined whether hearing familiar music (vs. unfamiliar music or non-music audio) impacted autobiographical memory recall for prompted events in healthy adults ages 65-80 years. We created customized music lists for each participant to manipulate music familiarity, overcoming limitations of prior work that assumes which music may have been unfamiliar (Foster & Valentine, 1998; Irish et al., 2006; Salakka et al., 2021). Our manipulation of participants' familiarity with the music clips was successful, yielding robust differences in familiarity between familiar and unfamiliar music conditions. Nevertheless, we observed no differences across music conditions in deliberate autobiographical memory recall in response to pre-selected event prompts. According to preregistered criteria, we found no effects of exposure to familiar music versus unfamiliar music, nor music versus non-music clips, on prompted episodic or non-episodic recall. Further, participant-reported familiarity with music clips was not associated with deliberate autobiographical recall. At the same time, the music exposure manipulation influenced both spontaneous recall and affect, such that hearing familiar music clips (compared to both unfamiliar music and non-music clips) evoked more spontaneous memories and more positive affect on average. Overall, our results provide evidence that, among healthy aging adults and within the context of the current paradigm, effects of hearing familiar music on autobiographical recall may be specific to memories directly triggered by the music, rather than extending to more deliberate recall of distinct memories.

Specificity of music exposure effects on memory recall

The current investigation did not find effects of music exposure on recall of pre-selected prompted events. Although prompted recall of all details (episodic and non-episodic) was numerically higher following hearing music compared to non-music clips, this effect did not meet preregistered criteria. However, our results were concordant with prior findings that familiar music evokes *spontaneous* memories more often in comparison to unfamiliar music (Janata et al., 2007; Salakka et al., 2021). Thus, the absence of effects of music exposure on prompted autobiographical recall helps to distinguish which aspects of memory retrieval can be influenced by listening to music.

Unlike most prior work, voluntarily recalled memories in the present study were nearly always distinct from any memories spontaneously evoked by the music (see Fig. 2D). Although recent work has investigated both involuntary and voluntary music-evoked autobiographical memories, in most studies participants were instructed to retrieve a memory *in response* to each music cue (Belfi et al., 2020, 2022; Sheldon et al., 2020; Sheldon & Donahue, 2017) or describe memories that came to mind during music exposure (Baird et al., 2018; Belfi et al., 2016; El Haj, Fasotti, et al., 2012; Jakubowski & Eerola, 2021). Therefore, even voluntary (as opposed to memory spontaneously evoked by music) retrieval in most prior studies consisted of responses directly to the music, rather than recall of separate memories. Because the current paradigm specifically examined recall for events distinct from those that came to mind during music exposure, our findings suggest that music effects on autobiographical recall may be limited to memories recalled specifically in response to music clips.

The presence of effects of familiar music on spontaneous, but not prompted, recall in the current study suggests that while familiar music may serve as a cue for specific events or semantic information, it may not induce a ‘retrieval mode’ of broadly enhanced recall. Though multiple lines of evidence indicate that exposure to familiar stimuli can evoke a state of enhanced retrieval (Tarder-Stoll, Jayakumar, et al., 2020), such effects may last only seconds (Patil & Duncan, 2018) which potentially explains why music familiarity did not impact prompted recall in the current study. More broadly, if encoding and retrieval modes only persist for several seconds after the offset of familiar stimuli (Meeter et al., 2004), free autobiographical recall paradigms allowing participants minutes to recall memories may not be well-suited to examine such states.

We emphasize that the absence of effects of music on deliberate recall does not contradict prior work showing that exposure to familiar music can facilitate retrieval of information encoded during (or very close in time to) prior listening through associative, or context-dependent, mechanisms (Balch et al., 1992; Janata, 2009; Kubit & Janata, 2022). In the current study prior music exposure was not precisely synchronized in time (within a 5-year window at best) with the prompted events; thus, the music clips were likely only weakly associated with most prompted memories. In particular, participants reported lower exposure to music released during childhood within the time window of its release (see Supplemental Fig. 13), yet high familiarity for this music overall (see Supplemental Fig. 15A); this suggests that familiarity may have come from listening at later times. It is therefore unlikely that the music clips had strong associative links to the prompted events, unlike the links that may exist in prior studies that play music concurrently or in close proximity to to-be-remembered information.

Potential methodological explanations for the absence of music effects on deliberate recall

Our primary findings indicate an absence of evidence for effects of music exposure on prompted autobiographical recall. Here, we consider several reasons—beyond a true null effect—that may have contributed to this lack of a difference. First, one concern may be that high within-participant variance for deliberate recall measures (internal and external details), even within music conditions and time periods, may have lowered the statistical power of the current study to identify music exposure effects (Baker et al., 2021). Such variance in recall was likely due to the fact that prompted events varied in autobiographical salience (see Fig. 6). However, observed within-participant variance was roughly consistent with that used to perform sample size calculations, indicating that the current study was powered appropriately to detect true effects of approximately 2 details or larger (see Supplemental Fig. 12).

In the current study, participants heard music immediately before memory prompts were given, but not during recall. Although prompted recall began only seconds after the end of each music clip, it is possible that the temporal separation of the music listening and recall processes may have diminished true music effects that would have been observed had the music been played during recall. Indeed, some studies of music-evoked memory in patients with Alzheimer's or other forms of dementia have found effects of playing music clips softly in the background during memory retrieval (El Haj et al., 2015; Foster & Valentine, 1998; Irish et al., 2006). Yet, several studies have found that music can enhance autobiographical memory retrieval for patients with Alzheimer's disease for at least several minutes after listening (El Haj et al., 2012; García et al., 2012). It is possible that the duration of effects differs for direct memory cues (i.e., spontaneous memory recall) versus retrieval mode induction (i.e., for deliberate memory recall). Future work will be needed to test this possibility. In the present study, the use of Zoom videoconferencing prevented playing music during recall as it is difficult to listen to audio and speak at the same time using this platform. Subsequent studies could explore whether simultaneous versus preceding music presentation impacts prompted or spontaneous memory retrieval.

In addition, unlike some previous work, the familiar music stimuli were chosen by the experimenters (not directly by the participants), and unfamiliar music stimuli were matched in sound quality. We consider both design choices to be strengths of the study for mitigating potential confounds (i.e., differences in sonic features, or if participants were able to choose the familiar, but not unfamiliar music clips). However, it is possible that some mnemonic effects of familiar music observed in the literature are driven by participants' preference for their chosen music, or because unfamiliar music clips were a different (or entirely unfamiliar) genre of music. Here, because unfamiliar music clips were selected by the research team to be stylistically similar to the familiar music clips, any potential effects of *familiarity with the music genre* (as opposed to familiarity with specific songs) would not have been observed.

Music-evoked affect was not sufficient to impact deliberate autobiographical recall

Consistent with prior work indicating that more familiar music evokes more positive emotions (Belfi et al., 2022; Gabard-Durnam et al., 2018; Kathios et al., 2022; Salakka et al., 2021) and that music generally induces pleasure and reward processes in most people (Belfi et al., 2021; Belfi & Loui, 2020; Peretz, 2006), our music manipulation induced changes in affect. Participants reported feeling most positive after listening to familiar music compared to unfamiliar music or non-music clips, and more positive after listening to unfamiliar music compared to non-music clips (Supplemental Fig. 9A).

However, music-evoked affect was not associated with recall of prompted memories (Supplemental Fig. 9B-C). While previous work has found that pleasure evoked by music can boost associative memory for non-musical information encoded during listening (in particular, through dopaminergic modulation of memory consolidation; see Ferreri & Rodriguez-Fornells, 2022), the present results indicate that such mood induction may not be sufficient to impact deliberate autobiographical recall. Alternatively, because hearing music may most strongly influence emotionally congruent memories (i.e., positively valenced music impacts positively valenced memories), it is possible that mismatch between music-evoked emotions and the emotional content of prompted memories diminished such effects (Sheldon et al., 2020; Talamini et al., 2022). Additionally, it is possible that participants' music-evoked emotions in the current study were influenced by their expectations for the study paradigm. Although participants were informed that some audio clips played in the study would not be music, some expressed surprise and disappointment not to be hearing music while listening to the non-music clips. The lower affect ratings in the non-music condition then may have been due to violated expectations rather than more negative emotions evoked by the content of the clips.

Age-related and prompt-specific effects on deliberate autobiographical recall

After observing that music exposure did not impact deliberate autobiographical recall, we sought to explore whether other factors impacted retrieval of internal or external details. Exploratory analyses indicated that participants retrieved more episodic information and less non-episodic information for prompted events that occurred in young adulthood (20-25 years) relative to adolescence (14-18 years) or childhood (5-9 years), and for adolescence relative to childhood. In particular, memories in the childhood time window contained the least episodic detail related to the prompted events, consistent with age-related increases in episodic memory from middle childhood through adolescence (Bauer & Larkina, 2014; Ghetti & Angelini, 2008; Ghetti & Bunge, 2012; Nelson, 2018; Usher & Neisser, 1993; Willoughby et al., 2012).This finding further aligns with previous findings of 'reminiscence bumps' of enhanced memory among older adults for events in adolescence and young adulthood, compared to other time periods (Jakubowski et al., 2020; Krumhansl & Zupnick, 2013; Schlagman et al., 2007). In addition, participants recalled the most non-episodic information (or information for non-prompted episodes) in response to prompts from childhood, indicating potential compensatory mechanisms for the lack of episodic retrieval (Lalla et al., 2022). While differences in recall among developmental time periods cannot be fully distinguished from impacts of recency (Moreton & Ward, 2010), that all prompted events were remote (≥ 40 years before the study) may have reduced the magnitude of potential recency effects.

Even within each time window, recall of episodic information varied substantially as a function of the specific event prompted (see Fig. 6). Event prompts were randomly assigned to a music condition for each participant to avoid prompt-induced confounds. However, as previously discussed, high within-participant variance in deliberate recall due to prompt effects may have made it more difficult to detect recall differences due to music exposure. In future investigations, researchers may consider selecting prompts that are relatively well-matched in average evoked memory content (Fig. 6) to minimize unwanted sources of variability in recall.

Non-music clips evoked spontaneous memories more often than unfamiliar music

Familiar music clips evoked spontaneous memories most often, but we also found that non-music clips evoked spontaneous memories more often than unfamiliar music (see Fig. 2C). In line with these findings, some prior work has found that unfamiliar music elicits fewer autobiographical memories compared to environmental sounds or word cues, suggesting that unfamiliar music may not be a strong retrieval cue for many memories (Jakubowski & Eerola, 2021). Unfamiliar clips may shift focus away from retrieval and towards an “encoding mode” in which participants attend to sonic features, lyrics, or musical event structures (Janata, 2005; Janata et al., 2002; Williams et al., 2022). Further, participants in the current study may have focused their attention on trying to identify the unfamiliar music clips; this could have suppressed memory retrieval. Alternatively, the non-music clips played in the current study may have cued comparatively more specific associations based on their semantic content (news, weather, traffic).

It is noteworthy that this difference between unfamiliar music and non-music clips was specific to spontaneous memory recall and did not extend to deliberate recall. Thus, the cognitive variables that may have suppressed spontaneous memories in response to unfamiliar music did not similarly affect the ability to deliberately search for a distinct memory.

Limitations and Future Directions

Several limitations to the current study may be addressed with further research. First, while the Autobiographical Interview allowed us to measure what types of details were recalled, the internal versus external designations of details represent extremely broad categorizations. Future work could also take a more fine-grained approach to understand whether recall of subcategories of details (for example, perceptual, emotion/thought, place, or time details) are impacted by music exposure. Furthermore, the current study only investigated remote autobiographical recall; future investigations could explore whether music exposure impacts recall of more recent events. Further studies may also benefit from using additional measurements of autobiographical recall that allow for verifying the accuracy of participants' memories (Barclay & Wellman, 1986; Cabeza & St Jacques, 2007) or rely less on manual experimenter scoring of recalled details (for example via automated software, see Genugten & Schacter, 2022).

Our measurements of spontaneous memory were also limited to binary responses indicating the presence versus absence of a memory evoked by each clip. We did not ask participants to elaborate or share further details on spontaneously evoked memories in efforts to avoid burdening participants with longer study sessions and because the main hypotheses of the study concerned prompted memory. Because we only measured the presence or absence of evoked memories, our work does not speak to the quality of music-evoked autobiographical memories (i.e. MEAMs; see Belfi et al., 2020; Janata et al., 2007). Although there is much reason, based on prior literature, to expect reports of detailed autobiographical memories in response to music, there is also the possibility that such memories may be relatively weak or gist-like. In particular, familiar stimuli associated with many events are weaker associative cues for episodic recall compared to stimuli only associated with one specific event (i.e. 'fan effects'; Badham et al., 2016; Tulving & Thomson, 1973). In the current study, if the familiar music clips were broadly associated with many events, it is possible that the spontaneous memories these clips elicited were gist-like, rather than strongly episodic. Broad associative links of familiar music may have also interfered with the ability to deliberately access other memories not directly associated with the music; however, such an explanation may lead to the prediction of worse deliberate recall following familiar versus unfamiliar music, which we did not observe.

Nevertheless, discussion of such fan effects is purely speculative based on the current paradigm; future research aiming to investigate relationships between spontaneous and prompted retrieval would benefit from allowing participants to freely recall both types of memories.

The current study was conducted via Zoom videocalls so as not to increase participants' risk of COVID-19 infection. This format may have had unintended effects on both the experience of music listening and memory recall. Although participants were instructed to choose a consistent and comfortable volume for music listening at the beginning of each session, we were not able to ensure that the quality and volume of audio were constant across sessions. In addition, it is possible that participants felt less energetic (i.e., through "Zoom fatigue" mechanisms) or less comfortable sharing memories with an experimenter over Zoom than they would have been in person. Although the video call format allowed this study to be conducted given the circumstances, impacts of music on memory may be explored with more experimental control within in-person lab environments.

An additional limitation of the study design is that experimenters were aware of the goals of the study and music condition during each session. Therefore, it is possible that experimenters may have unintentionally altered their interactions with participants based on knowledge of the study condition (Schulz & Grimes, 2002). While we do not believe such biases likely gave rise to the current results (given the absence of hypothesized effects on deliberate recall), further work could eliminate such potential biases by computerizing experimental procedures or otherwise ensuring that experimenters are unaware of the condition while interacting with participants. Relatedly, while participants did not know the goals, hypothesis, or manipulations of the study, the fact that different sound clips were played in each session was necessarily transparent to them. Thus, participants may have been able to guess aspects of the study design, which could have introduced demand characteristics (Gillihan et al., 2007). For example, participants may have thought experimenters expected them to recall more in the music conditions compared to the non-music clips.

We also note several limitations to the generalizability of the current findings. The studied cohort was a highly educated majority-White sample recruited mostly from the United States. Moreover, that participants self-selected for a study involving Zoom videoconferencing and listening to popular music likely yielded a non-representative sample among healthy adults ages 65-80 years. Further, the study inclusion criteria selected for a cohort that probably was more familiar with popular music and higher in memory function compared to other adults in the same age range. Finally, the music stimuli themselves only represented a small subset of styles, and the vast majority of lyrics were in English. It is possible that impacts of music on autobiographical memory differ for different populations (for example, participants of different ages or cultural backgrounds) or styles of music.

In particular, individuals with dementia or other memory disorders may experience effects of music on autobiographical memory not observed among the healthy participants in the current study. Several prior studies have found evidence for effects of music on autobiographical memory in Alzheimer's patients but not healthy control individuals (El Haj et al., 2013, 2015; Irish et al., 2006). Thus, different processes may underlie music-induced effects on memory in memory-impaired patients compared to healthy individuals. Future work examining impacts of music exposure on memory for both healthy participants and patients with memory disorders—while avoiding ceiling effects in healthy participants—will be important in understanding whether common mechanisms exist.

Crucially, lack of music-evoked effects on recall of distinct prompted memories does not preclude the usefulness of music-based therapies (Taylor, 1997). That music can provoke spontaneous recall and induce positive affect is sufficient motivation for further development of music-based techniques in a variety of treatment settings. Indeed, music-based therapies may be powerful even if effects are somewhat general and not limited to memory. For example, for patients with Alzheimer's disease, music therapies have been shown to act through non-mnemonic mechanisms (e.g., arousal, affect, self-consciousness, linguistic function; see Peck et al., 2016 for review). Recent work has also highlighted potential music-based interventions targeting auditory and reward systems for healthy aging adults (Quinci et al., 2022).

Conclusions

The results of the current study indicate that among healthy adults ages 65-80 years, exposure to familiar music (vs. unfamiliar music or non-music audio), evoked spontaneous memories more often. Familiar music did not, however, impact voluntary recall of distinct prompted events. If translated to clinical populations, these findings may be able to help optimize methods and target outcomes for music-based therapies (Loui, 2020; Thaut & Hoemberg, 2014). As there is much need to develop and refine non-pharmacological treatments for dementia and other memory disorders (Baird et al., 2019), it will be important for further research to explore how music can influence memory, and what types of memories are impacted.

Data Availability Statement

Deidentified data are available at https://osf.io/56khe/.

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Acknowledgments

We thank the participants for contributing their time and energy to this study. We also thank Amaesha Durazi, Nicolas Camacho, Monica Thieu, Carina Fan, R.B., and the DANLAB and Alyssano groups for their contributions and feedback.

Funding

This work was supported by a National Science Foundation Graduate Fellowship to PAB (DGE 1644869) and a National Science Foundation CAREER Award to MA (BCS-1844241).

Conflicts of Interest

We have no known conflicts of interest to disclose.

References

Aalbers, S., Fusar-Poli, L., Freeman, R. E., Spreen, M., Ket, J. C., Vink, A. C., Maratos, A., Crawford, M., Chen, X.-J., & Gold, C. (2017). Music therapy for depression. *Cochrane Database of Systematic Reviews*, *11*. https://doi.org/10.1002/14651858.CD004517.pub3

Acevedo-Molina, M. C., Matijevic, S., & Grilli, M. D. (2020). Beyond episodic remembering: Elaborative retrieval of lifetime periods in young and older adults. *Memory*, *28*(1), 83–93. https://doi.org/10.1080/09658211.2019.1686152

Alonso, I., Davachi, L., Valabrègue, R., Lambrecq, V., Dupont, S., & Samson, S. (2016). Neural correlates of binding lyrics and melodies for the encoding of new songs. *NeuroImage*, *127*, 333–345. https://doi.org/10.1016/j.neuroimage.2015.12.018

Arroyo-Anlló, E. M., Díaz, J. P., & Gil, R. (2013). Familiar Music as an Enhancer of Self-Consciousness in Patients with Alzheimer's Disease. *BioMed Research International*, *2013*. https://doi.org/10.1155/2013/752965

Badham, S. P., Poirier, M., Gandhi, N., Hadjivassiliou, A., & Maylor, E. A. (2016). Aging and memory as discrimination: Influences of encoding specificity, cue overload, and prior knowledge. *Psychology and Aging*, *31*(7), 758–770. https://doi.org/10.1037/pag0000126

Baird, A., Brancatisano, O., Gelding, R., & Thompson, W. F. (2018). Characterization of Music and Photograph Evoked Autobiographical Memories in People with Alzheimer's Disease. *Journal of Alzheimer's Disease*, *66*(2), 693–706. https://doi.org/10.3233/JAD-180627

Baird, A., Brancatisano, O., Gelding, R., & Thompson, W. F. (2020). Music evoked autobiographical memories in people with behavioural variant frontotemporal dementia. *Memory*, *28*(3), 323–336. https://doi.org/10.1080/09658211.2020.1713379

Baird, A., Garrido, S., & Tamplin, J. (2019). *Music and Dementia: From Cognition to Therapy*. Oxford University Press.

Baird, A., Gelding, R., Brancatisano, O., & Thompson, W. F. (2020). A Preliminary Exploration of the Stability of Music- and Photo-Evoked Autobiographical Memories in People with Alzheimer’s and Behavioral Variant Frontotemporal Dementia. *Music & Science*, *3*, 2059204320957273. https://doi.org/10.1177/2059204320957273

Baird, A., & Samson, S. (2009). Memory for Music in Alzheimer’s Disease: Unforgettable? *Neuropsychology Review*, *19*(1), 85–101. https://doi.org/10.1007/s11065-009-9085-2

Baird, A., & Samson, S. (2014). Music evoked autobiographical memory after severe acquired brain injury: Preliminary findings from a case series. *Neuropsychological Rehabilitation*, *24*(1), 125–143. https://doi.org/10.1080/09602011.2013.858642

Baird, A., & Samson, S. (2015). Chapter 11—Music and dementia. In E. Altenmüller, S. Finger, & F. Boller (Eds.), *Progress in Brain Research* (Vol. 217, pp. 207–235). Elsevier. https://doi.org/10.1016/bs.pbr.2014.11.028

Baker, D. H., Vilidaite, G., Lygo, F. A., Smith, A. K., Flack, T. R., Gouws, A. D., & Andrews, T. J. (2021). Power contours: Optimising sample size and precision in experimental psychology and human neuroscience. *Psychological Methods*, *26*(3), 295–314. https://doi.org/10.1037/met0000337

Baker, F. (2001). Rationale for the Effects of Familiar Music on Agitation and Orientation Levels of People in Posttraumatic Amnesia. *Nordic Journal of Music Therapy*, *10*(1), 32–41. https://doi.org/10.1080/08098130109478015

Baker, F. (2009). *Post traumatic amnesia and music: Managing behavior through song*. VDM Verlag Dr. Müller. http://espace.library.uq.edu.au/view/UQ:189580

Balch, W. R., Bowman, K., & Mohler, L. A. (1992). Music-dependent memory in immediate and delayed word recall. *Memory & Cognition*, *20*(1), 21–28. https://doi.org/10.3758/BF03208250

Balteş, F. R., Avram, J., Miclea, M., & Miu, A. C. (2011). Emotions induced by operatic music: Psychophysiological effects of music, plot, and acting: A scientist's tribute to Maria Callas. *Brain and Cognition*, *76*(1), 146–157. https://doi.org/10.1016/j.bandc.2011.01.012

Barclay, C. R., & Wellman, H. M. (1986). Accuracies and inaccuracies in autobiographical memories. *Journal of Memory and Language*, *25*(1), 93–103. https://doi.org/10.1016/0749-596X(86)90023-9

Bartlett, J. C., & Snelus, P. (1980). Lifespan Memory for Popular Songs. *The American Journal of Psychology*, *93*(3), 551–560. https://doi.org/10.2307/1422730

Basaglia-Pappas, S., Laterza, M., Borg, C., Richard-Mornas, A., Favre, E., & Thomas-Antérion, C. (2013). Exploration of verbal and non-verbal semantic knowledge and autobiographical memories starting from popular songs in Alzheimer's disease. *International Psychogeriatrics*, *25*(5), 785–795. https://doi.org/10.1017/S1041610212002359

Bauer, P. J. (2007). Recall in Infancy: A Neurodevelopmental Account. *Current Directions in Psychological Science*, *16*(3), 142–146. https://doi.org/10.1111/j.1467-8721.2007.00492.x

Bauer, P. J. (2012). The life I once remembered: The waxing and waning of early memories. In D. C. Rubin & D. Berntsen (Eds.), *Understanding Autobiographical Memory: Theories and Approaches* (pp. 205–225). Cambridge University Press. https://doi.org/10.1017/CBO9781139021937.016

Bauer, P. J., & Larkina, M. (2014). Childhood amnesia in the making: Different distributions of autobiographical memories in children and adults. *Journal of Experimental Psychology. General*, *143*(2), 597–611. https://doi.org/10.1037/a0033307

Baur, B., Uttner, I., Ilmberger, J., Fesl, G., & Mai, N. (2000). Music memory provides access to verbal knowledge in a patient with global amnesia. *Neurocase*, *6*(5), 415–421. https://doi.org/10.1080/13554790008402712

Belfi, A. M., Bai, E., & Stroud, A. (2020). Comparing Methods for Analyzing Music-Evoked Autobiographical Memories. *Music Perception*, *37*(5), 392–402. https://doi.org/10.1525/mp.2020.37.5.392

Belfi, A. M., Bai, E., Stroud, A., Twohy, R., & Beadle, J. N. (2022). Investigating the role of involuntary retrieval in music-evoked autobiographical memories. *Consciousness and Cognition*, *100*, 103305. https://doi.org/10.1016/j.concog.2022.103305

Belfi, A. M., Karlan, B., & Tranel, D. (2016). Music evokes vivid autobiographical memories. *Memory*, *24*(7), 979–989. https://doi.org/10.1080/09658211.2015.1061012

Belfi, A. M., & Loui, P. (2020). Musical anhedonia and rewards of music listening: Current advances and a proposed model. *Annals of the New York Academy of Sciences*, *1464*(1), 99–114. https://doi.org/10.1111/nyas.14241

Belfi, A. M., Moreno, G. L., Gugliano, M., & Neill, C. (2021). Musical reward across the lifespan. *Aging & Mental Health*, *0*(0), 1–8. https://doi.org/10.1080/13607863.2021.1871881

Blackburn, R., & Bradshaw, T. (2014). Music therapy for service users with dementia: A critical review of the literature. *Journal of Psychiatric and Mental Health Nursing*, *21*(10), 879–888. https://doi.org/10.1111/jpm.12165

Blais-Rochette, C., & Miranda, D. (2016). Music-evoked autobiographical memories, emotion regulation, time perspective, and mental health. *Musicae Scientiae*, *20*(1), 26–52. https://doi.org/10.1177/1029864915626967

Bower, J., & Shoemark, H. (2012). Music Therapy for the Pediatric Patient Experiencing Agitation During Posttraumatic Amnesia: Constructing a Foundation From Theory. *Music and Medicine*, *4*(3), Article 3. https://doi.org/10.47513/mmd.v4i3.318

Brotons, M., & Koger, S. M. (2000). The Impact of Music Therapy on Language Functioning in Dementia. *Journal of Music Therapy*, *37*(3), 183–195. https://doi.org/10.1093/jmt/37.3.183

Brotons, M., Koger, S. M., & Pickett-Cooper, P. (1997). Music and Dementias: A Review of Literature. *Journal of Music Therapy*, *34*(4), 204–245. https://doi.org/10.1093/jmt/34.4.204

Bürkner, P.-C. (2019). *brms: Bayesian Regression Models using "Stan"* (2.10.0). https://CRAN.R-project.org/package=brms

Bürkner, P.-C., & Vuorre, M. (2019). Ordinal Regression Models in Psychology: A Tutorial. *Advances in Methods and Practices in Psychological Science*, *2*(1), 77–101. https://doi.org/10.1177/2515245918823199

Cabeza, R., & St Jacques, P. (2007). Functional neuroimaging of autobiographical memory. *Trends in Cognitive Sciences*, *11*(5), 219–227. https://doi.org/10.1016/j.tics.2007.02.005

Cady, E. T., Harris, R. J., & Knappenberger, J. B. (2008). Using music to cue autobiographical memories of different lifetime periods. *Psychology of Music*, *36*(2), 157–177. https://doi.org/10.1177/0305735607085010

census.gov. (2019). *U.S. Census Bureau QuickFacts: United States*. https://www.census.gov/quickfacts/fact/table/US/PST045219

Chung, Y., Gelman, A., Rabe-Hesketh, S., Liu, J., & Dorie, V. (2015). Weakly Informative Prior for Point Estimation of Covariance Matrices in Hierarchical Models. *Journal of Educational and Behavioral Statistics*, *40*(2), 136–157. https://doi.org/10.3102/1076998615570945

Cross, K., Flores, R., Butterfield, J., Blackman, M., & Lee, S. (2012). The Effect of Passive Listening versus Active Observation of Music and Dance Performances on Memory Recognition and Mild to Moderate Depression in Cognitively Impaired Older Adults. *Psychological Reports*, *111*(2), 413–423. https://doi.org/10.2466/10.02.13.PR0.111.5.413-423

Decker, A. L., & Duncan, K. (2020). Acetylcholine and the complex interdependence of memory and attention. *Current Opinion in Behavioral Sciences*, *32*, 21–28. https://doi.org/10.1016/j.cobeha.2020.01.013

Duncan, K. D., & Shohamy, D. (2016). Memory states influence value-based decisions. *Journal of Experimental Psychology. General*, *145*(11), 1420–1426. https://doi.org/10.1037/xge0000231

Duncan, K., Semmler, A., & Shohamy, D. (2019). Modulating the Use of Multiple Memory Systems in Value-based Decisions with Contextual Novelty. *Journal of Cognitive Neuroscience*, *31*(10), 1455–1467. https://doi.org/10.1162/jocn_a_01447

El Haj, M., Antoine, P., Nandrino, J. L., Gély-Nargeot, M.-C., & Raffard, S. (2015). Self-defining memories during exposure to music in Alzheimer's disease. *International Psychogeriatrics*, *27*(10), 1719–1730. https://doi.org/10.1017/S1041610215000812

El Haj, M., Clément, S., Fasotti, L., & Allain, P. (2013). Effects of music on autobiographical verbal narration in Alzheimer's disease. *Journal of Neurolinguistics*, *26*(6), 691–700. https://doi.org/10.1016/j.jneuroling.2013.06.001

El Haj, M., Fasotti, L., & Allain, P. (2012). The involuntary nature of music-evoked autobiographical memories in Alzheimer's disease. *Consciousness and Cognition*, *21*(1), 238–246. https://doi.org/10.1016/j.concog.2011.12.005

El Haj, M., Postal, V., & Allain, P. (2012). Music Enhances Autobiographical Memory in Mild Alzheimer's Disease. *Educational Gerontology*, *38*(1), 30–41. https://doi.org/10.1080/03601277.2010.515897

Fan, C., Romero, K., & Levine, B. (2019). *Older adults with lower autobiographical memory abilities report less age-related decline in everyday cognitive function*. https://doi.org/10.31234/osf.io/zqs78

Fang, R., Ye, S., Huangfu, J., & Calimag, D. P. (2017). Music therapy is a potential intervention for cognition of Alzheimers Disease: A mini-review. *Translational Neurodegeneration; London*, *6*. http://dx.doi.org.ezproxy.cul.columbia.edu/10.1186/s40035-017-0073-9

Ferreri, L., Bigand, E., Perrey, S., Muthalib, M., Bard, P., & Bugaiska, A. (2014). Less Effort, Better Results: How Does Music Act on Prefrontal Cortex in Older Adults during Verbal Encoding? An fNIRS Study. *Frontiers in Human Neuroscience*, *8*. https://doi.org/10.3389/fnhum.2014.00301

Ferreri, L., & Rodriguez-Fornells, A. (2022). Memory modulations through musical pleasure. *Annals of the New York Academy of Sciences*, *n/a*(n/a). https://doi.org/10.1111/nyas.14867

Folstein, M., Folstein, S., & McHugh, P. (1975). “Mini-mental state”. A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research*, *12*(3), 189–198. https://doi.org/10.1016/0022-3956(75)90026-6

Ford, J. H., Addis, D. R., & Giovanello, K. S. (2011). Differential neural activity during search of specific and general autobiographical memories elicited by musical cues. *Neuropsychologia*, *49*(9), 2514–2526. https://doi.org/10.1016/j.neuropsychologia.2011.04.032

Foster, N. A., & Valentine, E. R. (1998). The Effect of Concurrent Music on Autobiographical Recall in Dementia Clients. *Musicae Scientiae*, *2*(2), 143–155. https://doi.org/10.1177/102986499800200203

Foster, N. A., & Valentine, E. R. (2001). The Effect of Auditory Stimulation on Autobiographical Recall in Dementia. *Experimental Aging Research*, *27*(3), 215–228. https://doi.org/10.1080/036107301300208664

Gabard-Durnam, L. J., Hensch, T. K., & Tottenham, N. (2018). Music Reveals Medial Prefrontal Cortex Sensitive Period in Childhood. *BioRxiv*, 412007. https://doi.org/10.1101/412007

García, J. J. M., Iodice, R., Carro, J., Sánchez, J. A., Palmero, F., & Mateos, A. M. (2012). Improvement of autobiographic memory recovery by means of sad music in Alzheimer's Disease type dementia. *Aging Clinical and Experimental Research*, *24*(3), 227–232. https://doi.org/10.3275/7874

Gelman, A., Carlin, J. B., Stern, H. S., Dunson, D. B., Vehtari, A., & Rubin, D. B. (2013). *Bayesian Data Analysis, Third Edition*. CRC Press.

Genugten, R. van, & Schacter, D. L. (2022). *Automated Scoring of the Autobiographical Interview with Natural Language Processing*. PsyArXiv. https://doi.org/10.31234/osf.io/nyurm

Gerdner, L. A. (2000). Effects of Individualized Versus Classical "Relaxation" Music on the Frequency of Agitation in Elderly Persons With Alzheimer's Disease and Related Disorders. *International Psychogeriatrics*, *12*(01), 49–65. https://doi.org/10.1017/S1041610200006190

Gerdner, L. A. (2012). Individualized music for dementia: Evolution and application of evidence-based protocol. *World Journal of Psychiatry*, *2*(2), 26–32. https://doi.org/10.5498/wjp.v2.i2.26

Gerdner, L. A., Hartsock, J., & Buckwalter, K. C. (2000). *Assessment of Personal Music Preference (Family Version)*. The University of Iowa Gerontological Nursing Interventions Research Center: Research Development and Dissemination Core. https://www.health.ny.gov/diseases/conditions/dementia/edge/forms/edge_project_indiv_music_assessment.pdf

Ghetti, S., & Angelini, L. (2008). The development of recollection and familiarity in childhood and adolescence: Evidence from the dual-process signal detection model. *Child Development*, *79*(2), 339–358. https://doi.org/10.1111/j.1467-8624.2007.01129.x

Ghetti, S., & Bunge, S. A. (2012). Neural changes underlying the development of episodic memory during middle childhood. *Developmental Cognitive Neuroscience*, *2*(4), 381–395. https://doi.org/10.1016/j.dcn.2012.05.002

Gillihan, S. J., Kessler, J., & Farah, M. J. (2007). Memories affect mood: Evidence from covert experimental assignment to positive, neutral, and negative memory recall. *Acta Psychologica*, *125*(2), 144–154. https://doi.org/10.1016/j.actpsy.2006.07.009

Halpern, A., & O’Connor, M. (2000). Implicit memory for music in Alzheimer’s disease. *Neuropsychology*, *14*(3), 391–397.

Hanser, S. B., & Thompson, L. W. (1994). Effects of a Music Therapy Strategy on Depressed Older Adults. *Journal of Gerontology*, *49*(6), P265–P269. https://doi.org/10.1093/geronj/49.6.P265

Hasselmo, M., & Schnell, E. (1994). Laminar selectivity of the cholinergic suppression of synaptic transmission in rat hippocampal region CA1: Computational modeling and brain slice physiology. *Journal of Neuroscience*, *14*(6), 3898–3914. https://doi.org/10.1523/JNEUROSCI.14-06-03898.1994

Hays, T., Bright, R., & Minichiello, V. (2002). The Contribution of Music to Positive Aging: A Review. *Journal of Aging and Identity*, *7*(3), 165–175. https://doi.org/10.1023/A:1019712522302

Hobeika, L., & Samson, S. (2020). Chapter 13—Why do music-based interventions benefit persons with neurodegenerative disease? In L. L. Cuddy, S. Belleville, & A. Moussard (Eds.), *Music and the Aging Brain* (pp. 333–349). Academic Press. https://doi.org/10.1016/B978-0-12-817422-7.00013-4

Holm, S. (1979). A Simple Sequentially Rejective Multiple Test Procedure. *Scandinavian Journal of Statistics*, *6*(2), 65–70. JSTOR.

Irish, M., Cunningham, C. J., Walsh, J. B., Coakley, D., Lawlor, B. A., Robertson, I. H., & Coen, R. F. (2006). Investigating the Enhancing Effect of Music on Autobiographical Memory in Mild Alzheimer's Disease. *Dementia and Geriatric Cognitive Disorders*, *22*(1), 108–120. https://doi.org/10.1159/000093487

Jakubowski, K., Bashir, Z., Farrugia, N., & Stewart, L. (2018). Involuntary and voluntary recall of musical memories: A comparison of temporal accuracy and emotional responses. *Memory & Cognition*, *46*(5), 741–756. https://doi.org/10.3758/s13421-018-0792-x

Jakubowski, K., & Eerola, T. (2021). Music Evokes Fewer but More Positive Autobiographical Memories Than Emotionally Matched Sound and Word Cues. *Journal of Applied Research in Memory and Cognition*. https://doi.org/10.1016/j.jarmac.2021.09.002

Jakubowski, K., Eerola, T., Tillmann, B., Perrin, F., & Heine, L. (2020). A Cross-Sectional Study of Reminiscence Bumps for Music-Related Memories in Adulthood. *Music & Science*, *3*, 1–3. https://doi.org/10.1177/2059204320965058

Jakubowski, K., & Ghosh, A. (2019). Music-evoked autobiographical memories in everyday life. *Psychology of Music*, 649–666. https://doi.org/10.1177/0305735619888803

Janata, P. (2005). Brain Networks That Track Musical Structure. *Annals of the New York Academy of Sciences*, *1060*(1), 111–124. https://doi.org/10.1196/annals.1360.008

Janata, P. (2009). The Neural Architecture of Music-Evoked Autobiographical Memories. *Cerebral Cortex*, bhp008. https://doi.org/10.1093/cercor/bhp008

Janata, P., Tillmann, B., & Bharucha, J. J. (2002). Listening to polyphonic music recruits domain-general attention and working memory circuits. *Cognitive, Affective, & Behavioral Neuroscience*, *2*(2), 121–140. https://doi.org/10.3758/CABN.2.2.121

Janata, P., Tomic, S. T., & Rakowski, S. K. (2007). Characterisation of music-evoked autobiographical memories. *Memory*, *15*(8), 845–860. https://doi.org/10.1080/09658210701734593

Kasdan, A., & Kiran, S. (2018). Please don’t stop the music: Song completion in patients with aphasia. *Journal of Communication Disorders*, *75*, 72–86. https://doi.org/10.1016/j.jcomdis.2018.06.005

Kathios, N., Sachs, M. E., Zhang, E., Ou, Y., & Loui, P. (2022). *Generating New Musical Preferences from Hierarchical Mapping of Predictions to Reward* (p. 2022.06.17.496615). bioRxiv. https://doi.org/10.1101/2022.06.17.496615

Kay, M. (2022). *tidybayes: Tidy Data and Geoms for Bayesian Models* (v3.0.2). Zenodo. https://doi.org/10.5281/ZENODO.1308151

Koger, S. M., Chapin, K., & Brotons, M. (1999). Is Music Therapy an Effective Intervention for Dementia? A Meta-Analytic Review of Literature. *Journal of Music Therapy*, *36*(1), 2–15. https://doi.org/10.1093/jmt/36.1.2

Kopelman, M. D., Wilson, B. A., & Baddeley, A. D. (1989). The autobiographical memory interview: A new assessment of autobiographical and personal semantic memory in amnesic patients. *Journal of Clinical and Experimental Neuropsychology*, *11*(5), 724–744. https://doi.org/10.1080/01688638908400928

Krumhansl, C. L. (2017). Listening Niches across a Century of Popular Music. *Frontiers in Psychology*, *8*. https://doi.org/10.3389/fpsyg.2017.00431

Krumhansl, C. L., & Zupnick, J. A. (2013). Cascading Reminiscence Bumps in Popular Music. *Psychological Science*, *24*(10), 2057–2068. https://doi.org/10.1177/0956797613486486

Kruschke, J. K. (2021). Bayesian Analysis Reporting Guidelines. *Nature Human Behaviour*, *5*(10), Article 10. https://doi.org/10.1038/s41562-021-01177-7

Kubit, B. M., & Janata, P. (2022). Spontaneous mental replay of music improves memory for incidentally associated event knowledge. *Journal of Experimental Psychology. General*, *151*(1), 1–24. https://doi.org/10.1037/xge0001050

Lalla, A., Tarder-Stoll, H., Hasher, L., & Duncan, K. (2022). Aging shifts the relative contributions of episodic and semantic memory to decision-making. *Psychology and Aging*. https://doi.org/10.1037/pag0000700

Larkin, M. (2001). Music tunes up memory in dementia patients. *The Lancet*, *357*(9249), 47. https://doi.org/10.1016/S0140-6736(05)71549-X

Levine, B., Svoboda, E., Hay, J. F., Winocur, G., & Moscovitch, M. (2002). Aging and autobiographical memory: Dissociating episodic from semantic retrieval. *Psychology and Aging*, *17*(4), 677–689.

Loui, P. (2020). Neuroscientific Insights for Improved Outcomes in Music-based Interventions. *Music & Science*, *3*, 2059204320965065. https://doi.org/10.1177/2059204320965065

Ludbrook, J. (2000). Multiple inferences using confidence intervals. *Clinical and Experimental Pharmacology & Physiology*, *27*(3), 212–215. https://doi.org/10.1046/j.1440-1681.2000.03223.x

Meeter, M., Murre, J. M. J., & Talamini, L. M. (2004). Mode shifting between storage and recall based on novelty detection in oscillating hippocampal circuits. *Hippocampus*, *14*(6), 722–741. https://doi.org/10.1002/hipo.10214

Merrett, D. L., Zumbansen, A., & Peretz, I. (2019). A theoretical and clinical account of music and aphasia. *Aphasiology*, *33*(4), 379–381. https://doi.org/10.1080/02687038.2018.1546468

Michael Rossato-Bennett (Director). (2014). *Alive Inside* [Documentary]. Netflix. http://www.aliveinside.us/

Miranda, D., Blais-Rochette, C., Vaugon, K., Osman, M., & Arias-Valenzuela, M. (2015). Towards a cultural-developmental psychology of music in adolescence. *Psychology of Music*, *43*(2), 197–218. https://doi.org/10.1177/0305735613500700

Moreton, B. J., & Ward, G. (2010). Time scale similarity and long-term memory for autobiographical events. *Psychonomic Bulletin & Review*, *17*(4), 510–515. https://doi.org/10.3758/PBR.17.4.510

Narme, P., Clément, S., Ehrlé, N., Schiaratura, L., Vachez, S., Courtaigne, B., Munsch, F., & Samson, S. (2014). Efficacy of Musical Interventions in Dementia: Evidence from a Randomized Controlled Trial. *Journal of Alzheimer's Disease*, *38*(2), 359–369. https://doi.org/10.3233/JAD-130893

Nasreddine, Z. S., Phillips, N. A., Bédirian, V., Charbonneau, S., Whitehead, V., Collin, I., Cummings, J. L., & Chertkow, H. (2005). The Montreal Cognitive Assessment, MoCA: A Brief Screening Tool For Mild Cognitive Impairment. *Journal of the American Geriatrics Society*, *53*(4), 695–699. https://doi.org/10.1111/j.1532-5415.2005.53221.x

Nelson, K. (2018). The cultural construction of memory in early childhood. *Handbook of Culture and Memory, 2018, ISBN 9780190230821, Págs. 185-208*, 185–208. https://dialnet.unirioja.es/servlet/articulo?codigo=7144589

Newcombe, N. S., Drummey, A. B., Fox, N. A., Lie, E., & Ottinger-Alberts, W. (2000). Remembering Early Childhood: How Much, How, and Why (or Why Not). *Current Directions in Psychological Science*, *9*(2), 55–58. https://doi.org/10.1111/1467-8721.00060

Nineuil, C., Dellacherie, D., & Samson, S. (2020). The Impact of Emotion on Musical Long-Term Memory. *Frontiers in Psychology*, *11*. https://doi.org/10.3389/fpsyg.2020.02110

Orben, A., & Przybylski, A. K. (2019). The association between adolescent well-being and digital technology use. *Nature Human Behaviour*, *3*(2), 173–182. https://doi.org/10.1038/s41562-018-0506-1

Palisson, J., Roussel-Baclet, C., Maillet, D., Belin, C., Ankri, J., & Narme, P. (2015). Music enhances verbal episodic memory in Alzheimer’s disease. *Journal of Clinical and Experimental Neuropsychology*, *37*(5), 503–517. https://doi.org/10.1080/13803395.2015.1026802

Palombo, D., Te, A., Checknita, K., & Madan, C. R. (2020). *Exploring the Facets of Emotional Episodic Memory: Remembering ‘What’, ‘Where’, and ‘When’* [Preprint]. PsyArXiv. https://doi.org/10.31234/osf.io/ru2xz

Patil, A., & Duncan, K. (2018). Lingering Cognitive States Shape Fundamental Mnemonic Abilities. *Psychological Science*, *29*(1), 45–55. https://doi.org/10.1177/0956797617728592

Peck, Katlyn. J., Girard, Todd. A., Russo, Frank. A., & Fiocco, Alexandra. J. (2016). Music and Memory in Alzheimer’s Disease and The Potential Underlying Mechanisms. *Journal of Alzheimer’s Disease : JAD*, *51*(4), 949–959. https://doi.org/10.3233/JAD-150998

Pendlebury, S. T., Welch, S. J. V., Cuthbertson, F. C., Mariz, J., Mehta, Z., & Rothwell, P. M. (2013). Telephone assessment of cognition after transient ischemic attack and stroke: Modified telephone interview of cognitive status and telephone Montreal Cognitive Assessment versus face-to-face Montreal Cognitive Assessment and neuropsychological battery. *Stroke*, *44*(1), 227–229. https://doi.org/10.1161/STROKEAHA.112.673384

Peretz, I. (2006). The nature of music from a biological perspective. *Cognition*, *100*(1), 1–32. https://doi.org/10.1016/j.cognition.2005.11.004

Peretz, I., Gaudreau, D., & Bonnel, A.-M. (1998). Exposure effects on music preference and recognition. *Memory & Cognition*, *26*(5), 884–902. https://doi.org/10.3758/BF03201171

Pillemer, D. B., & White, S. H. (1989). Childhood Events Recalled by Children and Adults. In H. W. Reese (Ed.), *Advances in Child Development and Behavior* (Vol. 21, pp. 297–340). JAI. https://doi.org/10.1016/S0065-2407(08)60291-8

Piolino, P., Desgranges, B., & Eustache, F. (2009). Episodic autobiographical memories over the course of time: Cognitive, neuropsychological and neuroimaging findings. *Neuropsychologia*, *47*(11), 2314–2329. https://doi.org/10.1016/j.neuropsychologia.2009.01.020

Platz, F., Kopiez, R., Hasselhorn, J., & Wolf, A. (2015). The impact of song-specific age and affective qualities of popular songs on music-evoked autobiographical memories (MEAMs). *Musicae Scientiae*, *19*(4), 327–349. https://doi.org/10.1177/1029864915597567

Quinci, M. A., Belden, A., Goutama, V., Gong, D., Hanser, S., Donovan, N. J., Geddes, M., & Loui, P. (2022). Longitudinal changes in auditory and reward systems following receptive music-based intervention in older adults. *Scientific Reports*, *12*(1), Article 1. https://doi.org/10.1038/s41598-022-15687-5

Ratovohery, S., Baudouin, A., Gachet, A., Palisson, J., & Narme, P. (2018). Is music a memory booster in normal aging? The influence of emotion. *Memory*, *26*(10), 1344–1354. https://doi.org/10.1080/09658211.2018.1475571

Ratovohery, S., Baudouin, A., Palisson, J., Maillet, D., Bailon, O., Belin, C., & Narme, P. (2019). Music as a mnemonic strategy to mitigate verbal episodic memory in Alzheimer’s disease: Does musical valence matter? *Journal of Clinical and Experimental Neuropsychology*, *41*(10), 1060–1073. https://doi.org/10.1080/13803395.2019.1650897

Rubin, D. C., & Schulkind, M. D. (1997). The distribution of autobiographical memories across the lifespan. *Memory & Cognition*, *25*(6), 859–866. https://doi.org/10.3758/BF03211330

Salakka, I., Pitkäniemi, A., Pentikäinen, E., Mikkonen, K., Saari, P., Toiviainen, P., & Särkämö, T. (2021). What makes music memorable? Relationships between acoustic musical features and music-evoked emotions and memories in older adults. *PLOS ONE*, *16*(5), e0251692. https://doi.org/10.1371/journal.pone.0251692

Sambandham, M., & Schirm, V. (1995). Music as a nursing intervention for residents with Alzheimer’s Disease in long-term care: Music may be a memory trigger for patients with Alzheimer’s and provide a means of communication. *Geriatric Nursing*, *16*(2), 79–83. https://doi.org/10.1016/S0197-4572(05)80011-4

Samson, S., & Zatorre, R. J. (1991). Recognition memory for text and melody of songs after unilateral temporal lobe excision: Evidence for dual encoding. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 793–804.

Sánchez, A., Maseda, A., Marante-Moar, M. P., de Labra, C., Lorenzo-López, L., & Millán-Calenti, J. C. (2016). Comparing the Effects of Multisensory Stimulation and Individualized Music Sessions on Elderly People with Severe Dementia: A Randomized Controlled Trial. *Journal of Alzheimer’s Disease*, *52*(1), 303–315. https://doi.org/10.3233/JAD-151150

Sartori, G., Snitz, B. E., Sorcinelli, L., & Daum, I. (2004). Remote memory in advanced Alzheimer’s disease. *Archives of Clinical Neuropsychology*, *19*(6), 779–789. https://doi.org/10.1016/j.acn.2003.09.007

Schiller, D., Eichenbaum, H., Buffalo, E. A., Davachi, L., Foster, D. J., Leutgeb, S., & Ranganath, C. (2015). Memory and Space: Towards an Understanding of the Cognitive Map. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience*, *35*(41), 13904–13911. https://doi.org/10.1523/JNEUROSCI.2618-15.2015

Schlagman, S., Kvavilashvili, L., & Schulz, J. (2007). Chapter 5 – Effects of Age on Involuntary Autobiographical Memories. In *Involuntary Memory* (pp. 87–112). John Wiley & Sons, Ltd. https://doi.org/10.1002/9780470774069.ch5

Schlaug, G., Marchina, S., & Norton, A. (2008). From Singing to Speaking: Why Singing May Lead to Recovery of Expressive Language Function in Patients with Broca’s Aphasia. *Music Perception: An Interdisciplinary Journal*, *25*(4), 315–323. https://doi.org/10.1525/mp.2008.25.4.315

Schlaug, G., Norton, A., Marchina, S., Zipse, L., & Wan, C. Y. (2010). From singing to speaking: Facilitating recovery from nonfluent aphasia. *Future Neurology*, *5*(5), 657–665. https://doi.org/10.2217/fnl.10.44

Schubert, E. (2016). Does recall of a past music event invoke a reminiscence bump in young adults? *Memory*, *24*(7), 1007–1014. https://doi.org/10.1080/09658211.2015.1061014

Schulkind, M. D., Hennis, L. K., & Rubin, D. C. (2013). Music, emotion, and autobiographical memory: They’re playing your song. *Memory & Cognition*, *27*(6), 948–955. https://doi.org/10.3758/BF03201225

Schulz, K. F., & Grimes, D. A. (2002). Blinding in randomised trials: Hiding who got what. *Lancet (London, England)*, *359*(9307), 696–700. https://doi.org/10.1016/S0140-6736(02)07816-9

Semkovska, M., Noone, M., Carton, M., & McLoughlin, D. M. (2012). Measuring consistency of autobiographical memory recall in depression. *Psychiatry Research*, *197*(1), 41–48. https://doi.org/10.1016/j.psychres.2011.12.010

Serafine, M. L., Davidson, J., Crowder, R. G., & Repp, B. H. (1986). On the nature of melody-text integration in memory for songs. *Journal of Memory and Language*, *25*(2), 123–135. https://doi.org/10.1016/0749-596X(86)90025-2

Sheldon, S., & Donahue, J. (2017). More than a feeling: Emotional cues impact the access and experience of autobiographical memories. *Memory & Cognition*, *45*(5), 731–744. https://doi.org/10.3758/s13421-017-0691-6

Sheldon, S., Williams, K., Harrington, S., & Otto, A. R. (2020). Emotional cue effects on accessing and elaborating upon autobiographical memories. *Cognition*, *198*, 104217. https://doi.org/10.1016/j.cognition.2020.104217

Simonsohn, U., Simmons, J., & Nelson, L. (2015). Specification Curve: Descriptive and Inferential Statistics on All Reasonable Specifications. *Marketing Papers*. https://doi.org/10.2139/ssrn.2694998

Simpson, S., & Sheldon, S. (2019). Testing the impact of emotional mood and cue characteristics on detailed autobiographical memory retrieval. *Emotion (Washington, D.C.)*, *20*(6), 965–979. https://doi.org/10.1037/emo0000603

Smith, S. M., & Vela, E. (2001). Environmental context-dependent memory: A review and meta-analysis. *Psychonomic Bulletin & Review*, *8*(2), 203–220. https://doi.org/10.3758/BF03196157

Spivack, S., Philibotte, S. J., Spilka, N. H., Passman, I. J., & Wallisch, P. (2019). Who remembers the Beatles? The collective memory for popular music. *PLOS ONE*, *14*(2), e0210066. https://doi.org/10.1371/journal.pone.0210066

St. Jacques, P., & Levine, B. (2007). Ageing and autobiographical memory for emotional and neutral events. *Memory*, *15*(2). https://doi.org/10.1080/09658210601119762

Stalinski, S. M., & Schellenberg, E. G. (2013). Listeners remember music they like. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *39*(3), 700. https://doi.org/10.1037/a0029671

Steegen, S., Tuerlinckx, F., Gelman, A., & Vanpaemel, W. (2016). Increasing Transparency Through a Multiverse Analysis. *Perspectives on Psychological Science*, *11*(5), 702–712. https://doi.org/10.1177/1745691616658637

Stras, L. (Ed.). (2011). *She's So Fine: Reflections on Whiteness, Femininity, Adolescence and Class in 1960s Music* (1st Edition). Routledge.

Talamini, F., Eller, G., Vigl, J., & Zentner, M. (2022). Musical emotions affect memory for emotional pictures. *Scientific Reports*, *12*(1), Article 1. https://doi.org/10.1038/s41598-022-15032-w

Tarder-Stoll, H., Jayakumar, M., Dimsdale-Zucker, H. R., Günseli, E., & Aly, M. (2020). Dynamic internal states shape memory retrieval. *Neuropsychologia*, *138*, 107328. https://doi.org/10.1016/j.neuropsychologia.2019.107328

Taylor, D. B. (1997). *Biomedical Foundations of Music as Therapy*. MMB Music.

Thaut, M., & Hoemberg, V. (2014). *Handbook of Neurologic Music Therapy*. Oxford University Press.

Thomas, K. S., Baier, R., Kosar, C., Ogarek, J., Trepman, A., & Mor, V. (2017). Individualized Music Program is Associated with Improved Outcomes for U.S. Nursing Home Residents with Dementia. *The American Journal of Geriatric Psychiatry*, *25*(9), 931–938. https://doi.org/10.1016/j.jagp.2017.04.008

Tucker, A. M., & Stern, Y. (2011). Cognitive Reserve in Aging. *Current Alzheimer Research*, *8*(4), 354–360. https://doi.org/10.2174/156720511795745320

Tulving, E. (1972). Episodic and semantic memory. In *Organization of memory* (pp. xiii, 423–xiii, 423). Academic Press.

Tulving, E. (1983). *Elements of Episodic Memory*. Oxford University Press.

Tulving, E., & Thomson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review*, *80*, 352–373. https://doi.org/10.1037/h0020071

Turkkan, N., & Pham-Gia, T. (1993). Computation of the highest posterior density interval in bayesian analysis. *Journal of Statistical Computation and Simulation*, *44*(3–4), 243–250. https://doi.org/10.1080/00949659308811461

Usher, J. A., & Neisser, U. (1993). Childhood Amnesia and the Beginnings of Memory for Four Early Life Events. *Journal of Experimental Psychology: General*, *122*(2), 155. https://doi.org/10.1037/0096-3445.122.2.155

van de Schoot, R., Depaoli, S., King, R., Kramer, B., Märtens, K., Tadesse, M. G., Vannucci, M., Gelman, A., Veen, D., Willemsen, J., & Yau, C. (2021). Bayesian statistics and modelling.

Nature Reviews Methods Primers, *1*(1), Article 1. https://doi.org/10.1038/s43586-020-00001-2

Wall, M., & Duffy, A. (2010). The effects of music therapy for older people with dementia. *British Journal of Nursing*, *19*(2), 108–113. https://doi.org/10.12968/bjon.2010.19.2.46295

Wallace, W. T. (1991). Jingles in Advertisements: Can They Improve Recall? *ACR North American Advances*, *18*, 239–24.

Wallace, W. T. (1994). Memory for Music: Effect of Melody on Recall of Text. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *20*(6), 1471–1485.

Wan, C. Y., & Schlaug, G. (2010). Music Making as a Tool for Promoting Brain Plasticity across the Life Span. *The Neuroscientist*, *16*(5), 566–577. https://doi.org/10.1177/1073858410377805

Wardell, V., Esposito, C. L., Madan, C. R., & Palombo, D. J. (2020). Semi-automated transcription and scoring of autobiographical memory narratives. *Behavior Research Methods*, 507–517. https://doi.org/10.3758/s13428-020-01437-w

Wardell, V., Madan, C. R., Jameson, T. J., Cocquyt, C., Checknita, K., Liu, H., & Palombo, D. (2020). *Emotional Autobiographical Recollection: The Devil is in the Details* [Preprint]. PsyArXiv. https://doi.org/10.31234/osf.io/pbdr5

Wickham, H., Averick, M., Bryan, J., Chang, W., McGowan, L. D., François, R., Grolemund, G., Hayes, A., Henry, L., Hester, J., Kuhn, M., Pedersen, T. L., Miller, E., Bache, S. M., Müller, K., Ooms, J., Robinson, D., Seidel, D. P., Spinu, V., … Yutani, H. (2019). Welcome to the

Tidyverse. *Journal of Open Source Software*, *4*(43), 1686. https://doi.org/10.21105/joss.01686

Williams, J. A., Margulis, E. H., Nastase, S. A., Chen, J., Hasson, U., Norman, K. A., & Baldassano, C. (2022). High-Order Areas and Auditory Cortex Both Represent the High-Level Event Structure of Music. *Journal of Cognitive Neuroscience*, *34*(4), 699–714. https://doi.org/10.1162/jocn_a_01815

Willoughby, K., Desrocher, M., Levine, B., & Rovet, J. (2012). Episodic and Semantic Autobiographical Memory and Everyday Memory during Late Childhood and Early Adolescence. *Frontiers in Psychology*, *3*. https://www.frontiersin.org/articles/10.3389/fpsyg.2012.00053