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ADVANCED REVIEW

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The cognitive characteristics of music-evoked autobiographical memories: Evidence from a systematic review of clinical investigations

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Abstract

In healthy adults, autobiographical memories (AMs) evoked by music appear to have unique cognitive characteristics that set them apart from AMs evoked by other cues. If this is the case, we might expect music cues to alleviate AM deficits in clinical disorders. This systematic review examines music-evoked autobiographical memories (MEAMs) in clinical populations, focusing on cognitive characteristics, and whether MEAMs differ from AMs evoked by other stimuli. We identified 15 studies featuring participants with Alzheimer's disease (AD), behavioral variant — Frontotemporal dementia (bv-FTD), acquired brain damage, and depression. We found that music evokes AMs in these disorders, and that familiar music was more likely to evoke AMs. Compared with healthy controls, AD participants had a relative advantage for MEAMs over picture-evoked AMs. People with damage to the medial prefrontal cortex showed preserved access to MEAMs in terms of frequency, but a relative disadvantage regarding the episodic richness for MEAMs, but not for memories cued by pictures, compared to controls. Participants with bv-FTD had fewer AMs evoked after both music and pictures than healthy controls. Across conditions, MEAMs were generally specific and retrieved fast, suggesting little retrieval effort. MEAMs were also positive, except in depression, where as many negative as positive AMs were produced. These findings suggest several underlying cognitive and affective mechanisms of MEAMs, including anxiety reduction, increased fluency, music-evoked emotions, reminiscence, and involuntary retrieval, and that these might be moderated by musical abilities and memory for music. In conclusion, MEAMs appear to be relatively well preserved, especially in AD.

This article is categorized under:

Psychology > Memory

KEYWORDS

Alzheimer's disease, autobiographical memory, episodic memory, music, music-evoked autobiographical memories

1 | INTRODUCTION

1.1 | Cognitive characteristics of music-evoked autobiographical memories in healthy adults

Music-evoked autobiographical memories (MEAMs) refer to autobiographical memories (AMs) that come to mind during music listening (Janata et al., 2007). MEAMs are thought to play an important part in music appreciation (Thompson et al., 2022), music preferences (Schäfer & Sedlmeier, 2010), and music-evoked emotions (Juslin et al., 2008). The ability of music to evoke autobiographical memories is also a main motivation behind music listening (North et al., 2004).

In healthy adults, MEAMS have been found to have unique cognitive characteristics that seem to set them apart from other mnemonic cues. MEAMs are evoked frequently, both experimentally (Cady et al., 2008; Janata et al., 2007) and in everyday life (Jakubowski & Ghosh, 2021) and appear to be more vivid and specific compared to memories evoked by pictures of famous faces (Belfi et al., 2016, 2022) and TV shows (Jakubowski et al., 2021). MEAMs are also associated with strong, predominately positive, emotions (Janata et al., 2007), even when playing sad music (Schulkind & Woldorf, 2005). The most common emotions elicited by MEAMs are happiness, youthfulness, and nostalgia (Janata et al., 2007), and the most common themes are social in nature, predominately featuring family, friends, and significant others (Cady et al., 2008; Jakubowski & Ghosh, 2021; Janata et al., 2007). MEAMs have also been found to be retrieved faster than memories following word cues (Zator & Katz, 2017), and tend to demand relatively little retrieval effort (Jakubowski & Ghosh, 2021).

Familiar music is most likely to trigger a MEAM, but unfamiliar music can also do this, albeit to a significantly lesser degree (Ford et al., 2014; Janata et al., 2007). For older participants, music released during the time of their adolescence and young adulthood — that is, the period covered by the reminiscence bump (Rubin et al., 1986) — appears to be most effective at evoking AMs (Jakubowski et al., 2021; Platz et al., 2015; Schulkind et al., 1999; Schulkind & Woldorf, 2005), while younger participants appear to show an advantage for recent memories (Cady et al., 2008; Krumhansl & Zupnick, 2013), and an increase in response to music released when their parents were young (Krumhansl & Zupnick, 2013). In general, older participants appear to retrieve less specific MEAMs than young adults (Ford et al., 2014; Schulkind et al., 1999).

Taken together, the evidence from healthy adults points toward music cues being unique compared to other AM retrieval cues. However, so far relatively few studies have compared music to other cues, and little is still known about the specific cognitive processes involved in MEAMs. No overall theoretical model currently exists, but music has many unique characteristics that could facilitate AM retrieval to which we now turn.

1.2 | Facets of music cognition that could facilitate autobiographical memory

The following is a preliminary, theoretical proposal of aspects of music cognition that could make music especially powerful as a mnemonic cue. Listening to music activates a broad spectrum of brain areas and associated cognitive functions, including, but not limited to, areas associated with motor, auditory, emotion, memory, and reward processing (Särkämö et al., 2013; Vuust et al., 2022). Activations of these domains, and their interactions, can contribute to facilitate MEAMs.

The finding that music listening in itself can facilitate AM, regardless of whether the participant is familiar with the music (Janata et al., 2007; Schulkind & Woldorf, 2005), could be related to several aspects of music listening in general, such as a reduction of anxiety or stress (de Witte et al., 2022; Irish et al., 2006; Lam et al., 2020), the pleasant experience of listening to music (Elvers, 2016; Zentner et al., 2008), or general improvements in cognition and/or fluency, related to music listening (Demarin et al., 2016; Ferreri et al., 2019).

Music can also evoke strong emotions, which could also be a key factor in how music facilitates memory (Juslin et al., 2008; Zentner et al., 2008). Music-evoked emotions can facilitate AM retrieval, for instance when the emotional state evoked by music can act as a cue to previous occasions when this emotion was felt. Music-evoked emotions can also make the memories more accessible through mood-congruent memory (Ellis & Moore, 1999; Schulkind & Woldorf, 2005) as well as strengthen the encoding of the memories, as more emotional memories tend to be remembered better (Buchanan, 2007). In support of the importance of music-evoked emotions for MEAMs, Salakka et al. (2021) found that the experienced emotional intensity and valence when listening to a song was strongly related to the evocation of MEAMs.

Juslin and colleagues (Juslin, 2013; Juslin et al., 2008) propose eight psychological mechanisms of how music evokes emotions: (1) Brain stem reflex (sudden, loud or dissonant sounds causing arousal or surprise), (2) rhythmic entrainment (increased arousal or social connectedness through synchronization with the music's rhythm), (3) evaluative conditioning (pairing of music with other stimuli), (4) emotional contagion (induction of the emotion expressed in the music), (5) visual imagery (feelings of pleasure or deep relaxation evoked by the imagery), (6) evocation of episodic memories (MEAMs), (7) aesthetic judgment of the music (e.g., awe or wonder), and (8) musical expectancy and predictions. The latter is discussed separately here, as musical expectancy and predictions can evoke strong emotions, but also plays a central role in music processing in general. When we listen to music we have expectations about the progression of melody, harmony, and rhythm based on our previous listening experiences. When these expectations are confirmed or violated, it brings action tendencies, (e.g., wanting to move to a rhythm), emotional reactions (e.g., pleasure or surprise), and musical learning (Vuust et al., 2022). Several of the above music cognition processes could also facilitate AM retrieval in themselves. For instance, visual imagery might act as an AM cue.

Music can also evoke memories through specific individual associations. An example of an associative factor can be when a specific song can become connected with for instance a specific event (e.g., a party or a concert), a period of life (e.g., in high school), or a relationship (e.g., couple-defining songs; Harris et al., 2020). This effect could be reinforced by the fact that preferred music is revisited more than other cultural products (Janssen et al., 2007). In general, the reason why familiar music is significantly more likely to evoke a memory could be that this music would be more likely to activate an associative AM network, causing spreading activation (Clark & Warren, 2015) which facilitates memory retrieval.

Lastly, music has been found to contribute to both social and personal identity formation (DeNora, 1999; Hargreaves & North, 1999; Peck & Grealey, 2020). Thus, some music may become strongly associated with important elements of identity and facilitate AM retrieval through increased self-reference (Belfi et al., 2022; Penaud et al., 2022) or trigger specific memories central to identity.

1.3 | The potential of examining MEAMs in clinical populations

An approach to further examining the basic cognitive characteristics and processes of MEAMs, as well as its relation to possibly related mechanisms in music cognition, is to look at the evidence from clinical populations. If music cues have a special ability to activate memories, we might expect MEAMs to be able to reduce AM deficits in several clinical populations when exposed to music cues, relative to the effects of other types of cues. AM is often impaired in clinical populations (Watson & Berntsen, 2015; Williams et al., 2007). Most notably in Alzheimer's disease (AD) AM impairment has been found to be related to deficits regarding sense of self (Fargeau et al., 2010), personal identity (El Haj et al., 2015a), and interactions with significant others (Baird & Thompson, 2018).

Music might be a particularly appropriate tool for facilitating and investigating AM, especially in AD, as musical abilities (e.g., music enjoyment, perception, playing), and memory for music are often well-preserved in dementias (Cuddy et al., 2012). This means that people with AD are able to recognize familiar songs, perceive melody, harmony, and rhythm, as well as enjoy the listening experience (Golden et al., 2017; Johnson & Chow, 2015). Because these cognitive abilities are often intact, people with dementia as well as other clinical populations may benefit from the majority of the above-mentioned possible mechanisms of MEAMs.

MEAMs in clinical populations have been investigated with promising results, but no systematic review exists of this research area. The present review focuses on cognitive characteristics of MEAMs in four clinical conditions for which we have been able to identify published studies on this topic: AD, behavioral variant — Frontotemporal dementia (bv-FTD), major depressive disorder, and acquired brain damage, respectively. All these disorders are characterized by general cognitive, and specifically executive dysfunction, making it an interesting case for examining how this affects the efficacy of music as a cue in itself and compared to other cues. All four clinical conditions are characterized by distinct disturbances to AM to be briefly delineated in the following.

1.4 | Alzheimer's disease and AM

AD is a neurodegenerative disorder characterized by progressive cognitive and behavioral impairments (McKhann et al., 2011). The AM impairment in AD is characterized by significantly fewer episodic AMs, while the memories recalled are less specific and detailed, that is, include fewer internal details and are more frequently about generic events, compared to healthy controls (El Haj et al., 2015a; Seidl et al., 2011). Patients with AD generally experience less mental reliving related to their AMs, likely reflecting more semanticized memories (El Haj et al., 2015a). Although AM is generally impaired in AD, a number of studies have found that memories from the remote past (i.e., childhood and young adulthood) are better preserved than memories from later life periods as well as recent memories (De Simone et al., 2016; Kirk & Berntsen, 2018a; Leyhe et al., 2009). Semantic AM for older memories appears to be relatively preserved, at least in the early phases of the disease, while more recent memories are more impaired (Berntsen et al., 2022; El Haj et al., 2015a). A number of studies have shown that AM retrieval in AD benefits from prompts, such as objects or film material, that pertain specifically to the periods covered by childhood and young adulthood (e.g., Kirk & Berntsen, 2018b; Rasmussen et al., 2021).

1.5 | Behavioral variant — Frontotemporal dementia and AM

Bv-FTD is characterized by atrophy of the frontal lobes and causes behavioral changes in terms of social and emotional functions. Patients with bv-FTD also show impairments in executive functions (Rascovsky et al., 2011). AM in bv-FTD is also impaired, as patients generally retrieve fewer memories than healthy controls, and their AM retrieval does not seem to favor memories from earlier life periods (Hou et al., 2005; Irish et al., 2011, 2018; Piolino et al., 2003; Thomas-Antérion et al., 2000). In addition, memories in bv-FTD are less specific compared with healthy controls, suggesting more semantization (Irish et al., 2011; Piolino et al., 2003; Thomas-Antérion et al., 2000).

1.6 | Major depressive disorder and AM

Major depressive disorder is defined by persistent negative and depressed mood and reduced positive affect (American Psychiatric Association, 2013). AM in depression is characterized by a bias toward negatively valenced memories and diminished access to positively valenced memories (Köhler et al., 2015). Patients with depression retrieve negative memories faster than positive memories (Dalgleish & Werner-Seidler, 2014; Gupta & Kar, 2012) and have more intrusive memories (Newby & Moulds, 2011). Another key AM impairment in depression is overgeneral memory, where memories recalled are less specific in terms of perceptual and spatiotemporal details (Hallford et al., 2021; Williams et al., 2007). Positive memories are also likely to be recalled less vividly and with less emotional intensity (Werner-Seidler & Moulds, 2011, 2012). Evidence from memory specificity training in depression shows that the ability to retrieve AM details can be improved through repeated practice (Barry et al., 2019; Hitchcock et al., 2017; Raes et al., 2009).

1.7 | Acquired brain damage and AM

The type of AM deficit following acquired brain damage depends largely on the type, location, and extent of the injury. We will focus on damage to prefrontal areas. Damage to the prefrontal cortex seems to cause a significant deficit in recalling episodic AMs from across all life periods, with fewer memories reported and with fewer internal details (Kopelman et al., 1999; Piolino et al., 2007; Rasmussen & Berntsen, 2018), compared with healthy controls.

1.8 | Aim

In this review, we aim to provide an overview of the state of the art of clinical research pertaining to MEAMs, with a focus on (1) describing the cognitive characteristics of MEAMs in clinical populations, (2) whether these differ from other ways of evoking autobiographical memories, and (3) what these findings can tell us about the basic cognitive processes of MEAMs. Lastly, we will also discuss possible clinical applications.

2 | METHODS

For quality and transparency, the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines were followed when applicable (Moher et al., 2009; Page et al., 2021).

2.1 | Search strategy

Studies were identified through searching the databases PubMed, PsycINFO, Scopus, and Web of Science, and through backwards search of the references of related articles and reviews in the area. The search used variants, synonyms as well as relevant index terms of the search words "music" and "autobiographical memory," as well as the standalone "music-evoked autobiographical memory." Supporting Information S1 features the specific search strings in each database. This was part of a larger search intended to identify all literature in the area, after which the clinical literature was extracted for this review. The PubMed and PsycINFO search was carried out on the 10th of February 2022, whereas Scopus and Web of Science were searched on the 14th of February 2022.

2.2 | Inclusion and exclusion criteria

The inclusion criteria were the study must (1) report original empirical data, (2) be reported in English, (3) in a peer-reviewed publication, (4) provide demographic and clinical information on participants, (5) focus on memory about personal information evoked directly by music, meaning that music must be played immediately before or during the memory studied, (6) provide information on methods and measures regarding AM, and (7) feature a clinical population, defined as either neurological or psychiatric conditions. The exclusion criteria were (1) Intervention studies (e.g., music therapies), (2) Memories not directly evoked by music, for example, mood induction studies, and (3) Investigate only episodic (nonautobiographical) memories, for example, memorization of lists of words.

2.3 | Selection process and risk of bias

Two independent researchers performed the title and abstract screening and full-text selection to increase validity and reliability. This process was done using the review tool Covidence (Covidence systematic review software, 2022). Discrepancies were discussed following title-abstract screening with a "substantial" interrater reliability of Cohen's kappa = 0.62 and after the full-text selection with an "almost perfect" interrater reliability of Cohen's kappa = 0.86, following the guidelines of Landis and Koch (1977). Data extraction was performed by the first author and included all outcomes relating to the evoked memories. Effect sizes and correlations are reported when the authors disclose them.

Risk of bias was assessed qualitatively and focused on publication bias, study design, reporting, and analysis in the individual studies (Page et al., 2021).

3 | RESULTS

3.1 | Study selection

In total, 2053 records were identified. After duplicates were removed, 1505 remained. Titles and abstracts of these records were screened, which led to the exclusion of 1435. The remaining 69 records were full-text assessed for eligibility. This led to 54 records being excluded. These are listed in Supporting Information S2 alongside the reason for exclusion. This assessment led to 15 studies being included in the review (see Figure 1 for an overview).

3.2 | Participant characteristics

The range of included clinical subjects in the studies was 5–28 and 4–30 for controls. One study had depressed participants, defined as ≥14 on Beck Depression Inventory-II (BDI-II), 15/18 with a depression diagnosis (Sakka & Saarikallio, 2020), two studies had participants with acquired brain damage, with either specific damage to Medial Prefrontal Cortex (mPFC; Belfi et al., 2018) or "severe acquired brain damage" (Baird & Samson, 2014). The remaining studies had participants with dementia. One study included participants diagnosed with bv-FTD (Baird, Brancatisano, et al., 2020), 11 studies with participants diagnosed with AD (Baird et al., 2018; Cuddy et al., 2017; El Haj et al., 2013, 2015b, 2017; El Haj, Fasotti, & Allain, 2012; El Haj, Postal, & Allain, 2012; Foster & Valentine, 2001; Fraile et al., 2019;

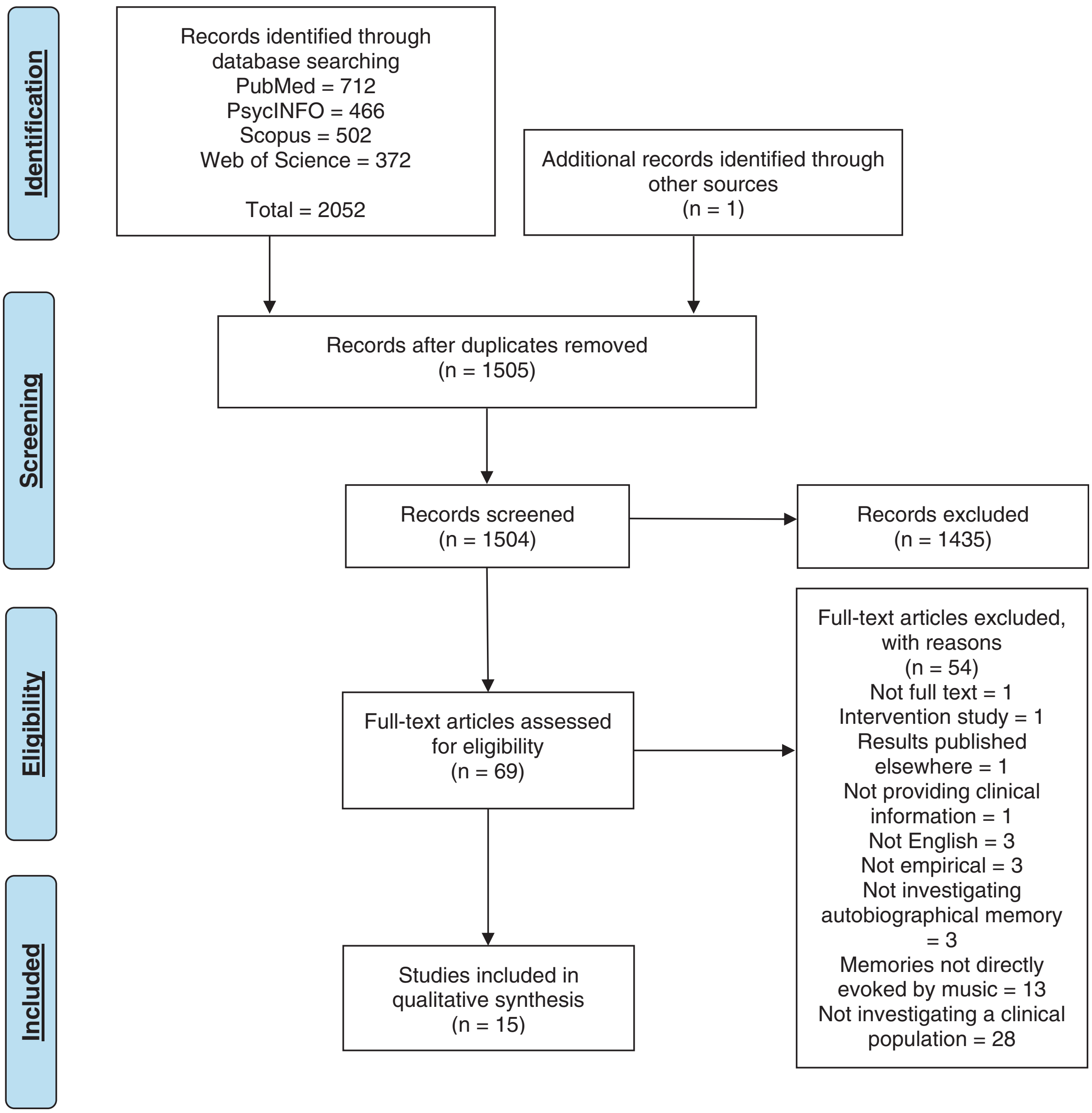

FIGURE 1 Search flow chart

Garćia et al., 2012; Irish et al., 2006), and one study had both populations (Baird, Gelding, et al., 2020). Age range in bv-FTD was 59–81 years, 63–89 years in AD, and 25–76 years in brain damage. Depressed participants had a mean age of 28.5 years.

3.3 | Study design

All studies examined memories reported immediately after exposure to the cue stimuli. A total of 14 studies examined this once, while Baird, Gelding, et al. (2020) examined the responses to the same stimulus on two occasions, 6 months apart. One study was conducted online (Sakka & Saarikallio, 2020), whereas the remaining were conducted in person.

For studies of AD, all but 1 (Cuddy et al., 2017) had a nonmusic comparison condition. Of these, 1 used odors (El Haj et al., 2017), 2 used cafeteria noise (Foster & Valentine, 2001; Garćia et al., 2012), 3 used photographs of prominent "one of" world events from 1930 to 2010 (Baird et al., 2018; Baird, Brancatisano, et al., 2020; Baird, Gelding, et al., 2020), and 8 studies used silence (El Haj et al., 2013, 2015b, 2017; El Haj, Fasotti, & Allain, 2012; El Haj, Postal, & Allain, 2012; Foster & Valentine, 2001; Garćia et al., 2012; Irish et al., 2006). All studies except

2 (Foster & Valentine, 2001; Garćia et al., 2012) had a healthy control group. All of these were matched on age. In addition, Cuddy et al. (2017) and El Haj, Fasotti, and Allain (2012) also included a young adult control group.

Studies of brain damage compared music with verbal cues (Baird & Samson, 2014) and images of famous persons from the participant's youth (Belfi et al., 2018). Both studies included an age-matched healthy control group. The study featuring depressed participants did not have a comparison condition (Sakka & Saarikallio, 2020). They included an age-matched healthy control group.

3.4 | Music characteristics

Regarding the music selection, different stimuli were used, with some studies using more than one type of music. Of these, 1 study used a compilation of preferred and popular music (Sakka & Saarikallio, 2020), 1 study used familiar instrumental pieces (Cuddy et al., 2017), 2 studies used unfamiliar music (Foster & Valentine, 2001; Garćia et al., 2012), 4 studies used the participant's preferred music (El Haj et al., 2013, 2015b; El Haj, Fasotti, & Allain, 2012; El Haj, Postal, & Allain, 2012), 5 studies used chart pop music, with four 4 music from 8 decades (Baird et al., 2018; Baird, Brancatisano, et al., 2020; Baird, Gelding, et al., 2020; Baird & Samson, 2014) and 1 used songs from when the participant was 15–30 years old (Belfi et al., 2018). Six studies used familiar instrumental classical music (El Haj et al., 2015b, 2017; El Haj, Postal, & Allain, 2012; Foster & Valentine, 2001; Irish et al., 2006), with 1 categorizing the pieces by valence (Garćia et al., 2012).

The music is played between 15 and 30 s (Baird et al., 2018; Baird, Brancatisano, et al., 2020; Baird, Gelding, et al., 2020; Belfi et al., 2018; Cuddy et al., 2017) to 2 min (El Haj et al., 2013, 2015b, 2017; El Haj, Fasotti, & Allain, 2012; El Haj, Postal, & Allain, 2012) or 3 min (Sakka & Saarikallio, 2020). Two studies played the music continuously as background music (Foster & Valentine, 2001; Irish et al., 2006).

There were four studies that did not report listening medium (Baird & Samson, 2014; Belfi et al., 2018; El Haj et al., 2013; El Haj, Postal, & Allain, 2012), 1 was online (Sakka & Saarikallio, 2020), while the remaining played music through speakers (Supporting Information S3).

3.5 | Studies comparing music cues with silence

Table 1 provides an overview of the included studies and their main findings. In the following, we review the findings according to the cue-manipulations employed and the clinical populations involved (Supporting Information S3 for a table of outcomes and correlational analyses).

3.5.1 | Alzheimer's disease

El Haj, Fasotti, and Allain (2012) involved 16 participants diagnosed with AD, 16 healthy older controls, and 16 healthy younger controls in a study comparing memories evoked after listening to participants' preferred music for 2 min with memories retrieved following silence. In the silence condition, participants were instructed to recount an event in their life, whereas following music, they were asked if they had any memories during listening.

Specificity was measured on the TEMPau scale (Piolino et al., 2004), where the memory is rated based on the presence of spatiotemporal details (specific event located in time versus repeated or general event) and internal characteristics (e.g., phenomenological details). In AD, specificity was higher after music exposure than in silence, but AD participants still had lower specificity than older and younger controls both in silence and music. MEAMs were retrieved significantly faster following music than silence in all groups, with the greatest improvement in AD. AD participants however still retrieved memories more slowly than older and younger control participants following both music and silence. El Haj, Fasotti, and Allain (2012) also found that older controls reported more positive memories than AD and younger controls, and for all groups, MEAMs were rated more positive than memories after silence.

El Haj, Postal, and Allain (2012) involved 12 participants with AD and 12 healthy older controls in a study comparing AM performance across a preferred music and silence condition, as well as a condition with familiar classical music.

TABLE 1 Overview of included studies organized alphabetically by name of the first author

Author	Clinical condition	Participants n (mean age, SD; range)	Control group n (mean age, SD; range)	Screening	Study procedure	Music stimuli	Nonmusic comparison condition	Main finding
Baird & Samson, 2014	Acquired brain injury	*N*: 5 (37.4 years; 25–60) 3 traumatic, 2 hypoxic	*N*: 4 (40.8 years; 26–59)	*Cognitive*: WAIS-IV[1] (vocabulary, matrix reasoning, digit span), BNT[2], RAVLT[3], RCF[4], Fluency, Trail making A + B *Affectivity*: DASS21[5] *Music perception*: Case 5 only: MBEA[6], FMT[7]	Memories reported immediately after cue	30–60s of Billboard Chart Hot 100 "Number 1 songs of the year" from 1961–2010, but not before the participant was 5 years old	AMI[8] (verbal cues)	Similar frequency of MEAMs[9] for patients and OC[10] In three out of five cases, music elicited a higher frequency of memories than verbal cues from the AMI Only Case 5 had no MEAMs, but showed deficits in pitch perception and song recognition
Baird et al., 2018	Alzheimer's Disease	*N*: 10 (77.7 years, SD: 12.7) 9 AD[11], 1 vascular dementia/AD M-ACE[12]: 18 (SD: 6)	*N*: 10 (76 years, SD: 9.3)	*Cognitive*: M-ACE, Fluency *Music*: MusEQ[13]	Memories reported immediately after cue	30s of 16 number 1 or best-selling songs from 1930 to 2010	16 photographs of prominent "one of" world events from 1930 to 2010	AD participants showed similar frequency of MEAMs and PEAMs[14], whereas OC had higher frequency for PEAMs No difference between groups in frequency of MEAMs, but lower frequency of PEAMs for AD MEAMs were more often less specific than PEAMs in both groups AD had fewer "specific event" PEAMs than OC
Baird, Gelding, et al., 2020	Alzheimer's Disease Behavioral variant—frontotemporal dementia	*N*: 7 (77 years, SD: 14.3) with AD. M-ACE: 17 (SD: 7) *N*: 6 (71.7 years, SD: 10.6) with Bv-FTD[15].	*N*: 9 (74.8 years, SD: 9.0)	*Cognitive*: M-ACE, Fluency *Music*: MusEQ	Two instances of memories reported immediately after cue, 6 months apart	30s of 16 number 1 or best-selling songs from 1930 to 2010	16 photographs of prominent "one of" world events from 1930 to 2010	Songs and photos evoked the same frequency of memories over time for the AD and OC groups

TABLE 1 (Continued)

Author	Clinical condition	Participants n (mean age, SD; range)	Control group n (mean age, SD; range)	Screening	Study procedure	Music stimuli	Nonmusic comparison condition	Main finding
		M-ACE: 19.3 (SD: 4.5, for T1)						In bv-FTD, the frequency of MEAMs increased over time In addition, the same stimuli tended to evoke memories across T1 and T2
Baird, Brancatisano, et al., 2020	Behavioral variant—frontotemporal dementia	*N*: 6 (71.7 years, SD: 10.6; 59–81) M-ACE: 19.3 (SD: 4.5)	*N*: 10 (76 years, SD: 9.3)	*Cognitive*: M-ACE, Fluency *Music*: MusEQ	Memories reported immediately after cue	30s of 16 number 1 or best-selling songs from 1930 to 2010	16 photographs of prominent "one of" world events from 1930 to 2010	Reduced frequency and specificity of MEAMs and PEAMs in bv-FTD compared to OC Lower frequency of MEAMs for bv-FTD compared to PEAMs
Belfi et al., 2018	Acquired brain damage in Medial Prefrontal Cortex	*N*: 9 (62.3 years, SD: 9.9; 42–76) (5 stroke, 4 meningioma resection)	*N*: 20 (57.9 years, SD: 10.4; 34–72)	*Cognitive*: Neuro-psychological assessment *Music*: MBEA, BMRQ[16]	Memories reported immediately after cue	15 s of 30 Billboard chart songs from when the participant was between the ages of 15 and 30 years	30 images of famous persons from when the participants were between 15–30 years old	The mPFC[17] group had a significantly lower internal-to-total details (episodic richness) compared to controls in the music, but not the face condition No group difference for frequency
Cuddy et al., 2017	Alzheimer's disease	*N*: 20 (Mdn: 77.5 years; 63–89) MMSE mdn: 21 (8–29) + 4 nonresponders	YC[18]: *N*: 20 (21.2 years, SD: 1.2; 19–24) OC: *N*: 20 (73.1 years, SD: 5.2; 66–83)	*Cognitive*: MMSE[19], fluency, DSRS[20], MoCA[21] *Affectivity*: GDS[22], PANAS[23] *Music*: MusEQ, FDT[24]	Memories reported immediately after cue	30 s of 12 instrumental, familiar tunes	N/A	AD performed similar to OC regarding MEAM frequency, word count, topics, vividness, and positivity Difference in self-rated memory specificity between AD (10%) and OC (50%) Higher self-rated and categorized specificity for YC

(Continues)

TABLE 1 (Continued)

Author	Clinical condition	Participants n (mean age, SD; range)	Control group n (mean age, SD; range)	Screening	Study procedure	Music stimuli	Nonmusic comparison condition	Main finding
								compared to AD+OC OC + AD > YC in memories categorized as positive and self-reported present and past positive feelings attached to the memory
El Haj, Fasotti, & Allain, 2012	Alzheimer's disease	*N*: 16 (75.9 years, SD: 6.2) MMSE: 21.9 (SD: 1.6)	YC: *N*: 16 (21.2 years, SD: 2.9) OC: *N*: 16 (73.8 years, SD: 6.5)	*Cognitive*: MMSE, Plus-Minus task, 2-back task, Stroop task, fluency	Memories reported immediately after cue	2 min of participant's preferred music	2 min of silence	MEAMs were less specific and retrieved more slowly for AD compared to YC and OC For AD patients only, MEAMs were more specific than memories evoked in silence MEAMs were evoked faster than memories after silence. This reduction was largest for AD OC rated memories more positive than AD and YC, but MEAMs were overall rated more positive than memories after silence
El Haj, Postal, & Allain, 2012	Alzheimer's disease	*N*: 12 (76.2 years, SD: 5.8; 67–87) MMSE: 23.1 (21–26)	*N*: 12 (73.2 years, SD: 4.7; 68–86)	*Cognitive*: MMSE, fluency	Memories reported immediately after cue	2 min of familiar classical music and preferred music	Silence	Lower memory specificity for AD compared to OC in all conditions Higher specificity and amount of positive emotional words in AD for preferred > familiar > silence

TABLE 1 (Continued)

Author	Clinical condition	Participants n (mean age, SD; range)	Control group n (mean age, SD; range)	Screening	Study procedure	Music stimuli	Nonmusic comparison condition	Main finding
								AD produced more positive words than OC in preferred and familiar music, but fewer in silence
El Haj et al., 2013	Alzheimer's disease	*N*: 18 (75.8 years, SD: 5.9) MMSE: 23 (1.6)	*N*: 18 (73.6 years, SD: 6.3)	*Cognitive*: MMSE, fluency	Memories reported immediately after cue	2 min of participant's preferred music	Silence	Lower specificity for AD compared to OC, and increased specificity for music over silence in AD only AD produced more empty words, had lower grammatical complexity and propositional density compared to OC. Both groups improved on all measures after music compared to silence, with greatest improvement for AD
El Haj et al., 2015b	Alzheimer's disease	*N*: 22 (71.7 years, SD: 7) MMSE: 21.9 (1.5)	*N*: 24 (72.9 years, SD: 7.3)	*Cognitive*: MMSE, Forwards and backwards digit span, Plus-minus task, Stroop task, Grober and Buschke episodic memory task *Affectivity*: HADS[25]	Memories reported immediately after cue	Participant's preferred music and familiar popular music	Silence	Lower specificity for AD compared to OC in familiar music and silence, but no difference in preferred music Higher specificity in AD for preferred > familiar > silence AD had the same percentage of self-defining memories as OC when exposed to preferred music, and produced more self-defining

(Continues)

TABLE 1 (Continued)

Author	Clinical condition	Participants n (mean age, SD; range)	Control group n (mean age, SD; range)	Screening	Study procedure	Music stimuli	Nonmusic comparison condition	Main finding
								memories than personal semantics or autobiographical episodes
El Haj et al., 2017	Alzheimer's disease	*N*: 28 (73.3 years, SD: 6.7) MMSE: 22.5 (1.6)	*N*: 30 (71.8 years, SD: 8.1)	*Cognitive*: MMSE, Forwards and backwards digit span, Plus-minus task, Stroop task, Grober and Buschke episodic memory task, fluency *Affectivity*: HADS	Memories reported immediately after cue	Familiar classical and popular music	Two odors: coffee and vanilla Silence	For AD participants, music and odor exposure improved specificity, emotional valence, mental time travel, and retrieval time compared to silence Lower specificity for AD compared to OC in all conditions Only retrieval time differed between music and odor, with faster time for odor
Foster & Valentine, 2001	Alzheimer's disease	*N*: 23 (78.7 years; 68–90; 7 high ability MEAMS[26]: >5; 16 low, MEAMS: <5)	N/A	*Cognitive*: MEAMS	Memories reported immediately after cue (background music)	2 min of familiar, classical music and novel music	Cafeteria noise Silence	Recall was significantly better for music > cafeteria noise > quiet No difference between novel and familiar music There was better recall for remote and medium-remote memories but not recent, in music compared to cafeteria noise
Garćia et al., 2012	Alzheimer's disease	*N*: 25 (80.7 years, SD: 5.8) MMSE: 14.6 (8.3)	N/A	*Cognitive*: MMSE *Affectivity*: GDS, PANAS	Memories reported immediately after cue (background music)	Happy and sad classical music and new music, lacking emotion	Cafeteria noise Silence	Recall was significantly better for sad and happy music > cafeteria sounds and

TABLE 1 (Continued)

Author	Clinical condition	Participants n (mean age, SD; range)	Control group n (mean age, SD; range)	Screening	Study procedure	Music stimuli	Nonmusic comparison condition	Main finding
								nonemotional music > quiet Remote memories only showed effect of music: Sad > happy > cafeteria noise and nonemotional music
Irish et al., 2006	Alzheimer's disease	*N*: 10 (76.3 years, SD: 7.5) MMSE: 21.6 (3.7)	N: 10 (76.5 years, SD: 5.2)	*Cognitive*: MMSE, CDT[27], SART[28] *Affectivity*: GDS, STAI[29] *Physiological*: GSR[30]	Memories reported immediately after cue (background music)	Familiar classical music	Silence	Semantic and episodic recall was better for music than silence in AD OC performed better than AD in both music and silence Recall of recent semantic memories were enhanced in music condition, whereas episodic memories were improved in all life periods Reduction in state anxiety in AD for music compared to silence. With state anxiety as covariate, the effect of music disappeared
Sakka & Saarikallio, 2020	Depressed ("high levels" on BDI-II[31])	*N*: 18 (28.5 years, SD: 9.3) 15 with depression diagnosis BDI-II: 32.4 (SD: 9.3)	*N*: 21 (31.4 years, SD: 11.5)	*Affectivity*: BDI-II	Memories reported immediately after cue (Online)	Compilation of approximately 3 min of preferred and pop music from when they were 10–25 years old	N/A	Depressed reported more negative valence and induced emotion of MEAMs. They had memories across the whole valence spectrum, whereas controls were skewed toward positive

(Continues)

TABLE 1 (Continued)

Author	Clinical condition	Participants n (mean age, SD; range)	Control group n (mean age, SD; range)	Screening	Study procedure	Music stimuli	Nonmusic comparison condition	Main finding
								Depressed peoples MEAMs contained themes of dysfunctional relationships and negative mental states, whereas controls' MEAMs were most often about activities

Note: [1]Wechsler Adult Intelligence Scale; [2]Boston Naming Test; [3]Rey Auditory and Verbal Learning Test; [4]Rey Complex Figure Test; [5]Depression, Anxiety and Stress Scales; [6]Montreal Battery for Evaluation of Amusia; [7]Famous Melodies Test; [8]Autobiographical Memory Interview; [9]Music-Evoked Autobiographical Memories; [10]Older Controls; [11]Alzheimer's Disease; [12]Mini-Addenbrooke's Cognitive Examination; [13]Music Experience Questionnaire; [14]Photo-Evoked Autobiographical Memories; [15]Behavioral-Variant Frontotemporal Dementia; [16]Barcelona Music Reward Questionnaire; [17]Medial Prefrontal Cortex; [18]Younger Controls; [19]Mini-Mental State Examination; [20]Dementia Severity Rating Scale; [21]Montreal Cognitive Assessment; [22]Geriatric Depression Scale; [23]Positive and Negative Affective Schedule; [24]Familiarity Decision Test; [25]Hospital Anxiety and Depression Scale; [26]Middlesex Elderly Assessment of Mental State; [27]Clock Drawing Test; [28]Sustained Attention to Response Task; [29]State Trait Anxiety Inventory; [30]Galvanic Skin Response; [31]Beck Depression Inventory-II.

After each stimulus, participants were asked to recount an event from their life. AD participants generally had lower specificity (on TEMPau) than controls in all conditions, but had a significantly better performance regarding specificity after music than silence, with preferred music causing greater improvements than familiar classical music. El Haj, Postal, and Allain (2012) also found that AD participants produced more positive words than controls after both preferred music and familiar classical music, with most after preferred music, while producing fewer in silence. They also found a reduction in negative words following preferred music compared to silence.

El Haj et al. (2013) had 18 participants with AD and 18 healthy older controls listen to 2 min of participants' preferred music in comparison with a period of silence. Following the stimulus, participants were asked to recount an event from their life. Similar to El Haj, Postal, and Allain (2012) and El Haj, Postal, and Allain (2012), they found lower specificity of MEAMs for AD participants compared to older controls and increased specificity in music over silence conditions in AD only.

In contrast to these previous studies, El Haj et al. (2013) focused on language characteristics in MEAM descriptions. Compared to controls, AD participants generally produced more empty, indefinite words (i.e., "it", "thing"), had a lower propositional density (the amount of information in a sentence compared to its length), and lower grammatical complexity. However, when comparing memories produced after exposure to music and silence, both groups improved, with the greatest improvement in AD on all three measures.

El Haj, Antoine, Nandrino, and Kapogiannis (2015) involved 22 participants with AD and 24 healthy older controls in a study exposing participants to 2 min of their preferred music, familiar popular music, and silence. After the stimulus, they were asked to recount an event from their life. They found that AD participants generated the same amount of self-defining memories as controls during exposure to their self-chosen music, but not during silence and familiar music. Self-defining memories were defined as an event that "contributed to the way the participants saw herself or himself, and/or if the event was related to personality construction, concerns, or unresolved conflicts" (p. 1723). AD participants produced more of these memories than personal semantics and autobiographical episodes after listening to self-chosen music. After silence and familiar music, this pattern was reversed with more personal semantics and autobiographical episodes.

Three studies assessed the effect of music on autobiographical semantic recall. The first was Foster and Valentine (2001) who tested 23 participants with AD across four conditions of background stimuli: (1) familiar classical music, (2) novel music, (3) cafeteria noise, and (4) silence. There was no control group. They measured semantic recall using questions developed from the Mini-Mental State Examination (MMSE; Folstein et al., 1975) and found that recall was significantly better in both music conditions compared to cafeteria noise, which was in turn better than silence. Compared with cafeteria sounds, Foster and Valentine (2001) found better recall for remote and medium-remote, but not recent memories for both music conditions.

Garćia et al. (2012) tested 25 participants with AD across five conditions: (1) happy, familiar classical music, (2) sad, familiar classical music, (3) novel, "nonemotional" music, (4) Cafeteria noise, and (5) Silence. They measured semantic recall on the same adapted questions from MMSE as in Foster and Valentine (2001) and did not feature a control group. They found better recall for remote memories with music than with cafeteria sounds and nonemotional music. The same effect was found for sad music compared to happy music.

Irish et al. (2006) involved 10 participants with AD and 10 age-matched healthy controls in a study with two conditions: familiar classical music and silence. They measured AM using the Autobiographical Memory Interview (AMI), which includes measures of both semantic and episodic recall (Kopelman et al., 1989, 1990). The control group generally performed better than AD participants in both music and silence for both semantic and episodic recall. Within the AD group, Irish et al. (2006) only found an effect on semantic recall for recent memories in music compared to silence, an effect that disappeared when controlling for reduction in state anxiety. On episodic incidents, music improved recall across all time periods. They also investigated galvanic skin response as a measure of arousal but found no significant differences between conditions or groups.

In summary, studies comparing music cues with silence generally found that MEAMs had higher specificity than memories following silence for AD participants. In addition, the AD participants' preferred music evoked more specific memories than familiar music. Improvements were not found for the control participants, but this is likely due to a ceiling effect of the TEMPau scale. For all groups, MEAMs were generally retrieved faster and were more positive than memories after silence. Lastly, music was also found to improve semantic recall compared to silence or cafeteria sounds, with conflicting results on whether remote or recent memory was improved.

3.6 | Studies comparing music cues with pictures

3.6.1 | Alzheimer's disease

Baird et al. (2018) involved 10 participants diagnosed with dementia (9 with AD and 1 with vascular dementia) and 10 healthy age-matched controls in a study using top chart or best-selling songs from 1930 to 2010 in comparison with photographs of significant "one of" world events from the same periods. In the music condition, participants listened for about 15 s, after which they completed a questionnaire about potential memories evoked. In the picture condition, participants were handed the photograph until they had responded to a similar questionnaire.

Baird et al. (2018) found no difference between AD and controls regarding MEAM frequency but did find fewer Photo-Evoked Autobiographical Memories (PEAMs) for AD compared with controls ($d = 1.51$). The AD group had a similar frequency for MEAMs and PEAMs, whereas controls had more PEAMs than MEAMs. Thus, a relative advantage was found for music versus picture cues in the AD group when compared to the control group. In the AD group, music that was popular during the participant's early lifetime period (10–30 years old) was significantly more likely to evoke MEAMs than music from when participants were 31–50 years of age ($d = 1.6$) and over 50 years of age ($d = 2.8$). For controls, only 10–30 years of age versus over 50 years of age showed a significant difference regarding MEAMs ($d = 1.88$). This effect was not seen for PEAMs. Baird et al. (2018) also found that songs that were more familiar evoked more memories for both AD participants and controls. Importantly, Baird et al. (2018) did not find a difference between groups in MEAM specificity (on an adapted TEMPau), whereas they did find that controls had more "specific event" PEAMs than AD. Thus, compared with the controls, the AD group showed a relative advantage for MEAM specificity.

3.6.2 | Behavioral variant — Frontotemporal dementia

Baird, Brancatisano, et al. (2020) involved six participants diagnosed with bv-FTD and 10 healthy age-matched controls in a study using the same stimuli and instructions as Baird et al. (2018). They found that bv-FTD participants reported significantly fewer MEAMs and PEAMs than controls. Only the bv-FTD group showed more PEAMs than MEAMs, and thus a relative advantage for PEAMs compared with controls. Regarding the age of memories, the control group showed more MEAMs from stimuli from the reminiscence bump period (10–30 years) compared to later life (+50 years), but this was not evident in bv-FTD. Participants with bv-FTD also had fewer PEAMs from later life than both earlier periods and fewer memories than controls in early and later decades. For the bv-FTD group, no MEAMs or PEAMs about specific events were reported, and they generally had more semantic-personal and repeated event memories than controls.

3.6.3 | Alzheimer's disease and behavioral variant — Frontotemporal dementia

Baird, Gelding, et al. (2020) had a similar design to Baird et al. (2018), and investigated the stability of the performance 6 months apart in seven participants with AD, six participants with bv-FTD, and nine healthy age-matched controls. They found that the same stimuli tended to evoke memories at both points, with no differences in controls and AD. Participants with bv-FTD, however, had a significant increase in their frequency of MEAMs over the 6 months period. The valence of memories in both AD and bv-FTD was generally stable across 6 months. For both AD, bv-FTD, and controls, MEAMs were more often about a period of life, whereas PEAMs were more often about a specific event (Baird et al., 2018; Baird, Brancatisano, et al., 2020; Baird, Gelding, et al., 2020).

3.6.4 | Acquired brain damage

Belfi et al. (2018) involved nine participants with damage to the mPFC and 20 healthy controls in a study playing excerpts of pop songs from when the participant was between 15 and 30 years old. They compared this with memories evoked by pictures of famous faces from the same time periods. After each stimulus, the participants were asked to rate their autobiographical association with it and asked to provide a verbal description if they had any. They found that pictures of famous faces evoked more memories than music in both groups, with no differences in memory frequency between groups. Belfi et al. (2018) also investigated the episodic richness of the evoked memories, defined as the ratio of internal-to-total details in the memory description (Levine et al., 2002). They found significantly lower episodic richness for participants with damage to the mPFC compared to controls when exposed to music, but not faces. Thus, participants with damage to the mPFC demonstrated a relative disadvantage regarding episodic richness in response to music cues, compared with the control group.

In summary, studies comparing music cues with pictures generally found preserved frequencies of MEAMs for AD and mPFC-damage groups compared to healthy controls, but not for bv-FTD participants. Compared to controls, there was a relative advantage for music cues compared to picture cues for the AD group, but not for participants with bv-FTD or damage to the mPFC. MEAM specificity/episodic richness was impaired for the brain-damaged and bv-FTD participants, but not in AD. PEAM specificity was impaired in AD and bv-FTD, but not in mPFC brain damage.

3.7 | Studies comparing music cues with odor

3.7.1 | Alzheimer's disease

El Haj et al. (2017) exposed 28 AD participants and 30 healthy age-matched healthy controls to 2 min of one familiar classical piece and one popular song, two odors (coffee and vanilla), and silence. After exposure to the stimuli, participants were asked to recount an event in their life. In the AD group, both music and odor improved specificity (on TEMPau) compared to silence. Controls did not show any significant changes, but this is likely due to a ceiling effect. In spite of this improvement, controls showed higher specificity than the AD group across all conditions. El Haj et al. (2017) also found that both music and odor produced more positive emotions. AD participants and controls produced similar emotional ratings of their memories after music and odor exposure, but AD participants rated their memories more emotionally negative following silence. AD participants reported less mental time travel than controls after silence, but after being exposed to music or odors, they improved to the level of controls.

The only measure where music and odor cues differed was retrieval time. While MEAMs were retrieved quicker following music than silence in both groups, with the greatest improvement in AD, memories following odor were retrieved most quickly. Nonetheless, AD participants still retrieved memories more slowly than the control group in all conditions.

3.8 | Studies comparing with verbal cues

3.8.1 | Acquired brain damage

Baird and Samson (2014) involved five participants with acquired brain injury and four healthy controls in a study comparing memories following exposure to excerpts of “Number 1” pop songs from 1961 to 2010 (but not before the participant was 5 years old) with participants' responses to the incident schedule of the AMI. After listening to the music, the participants completed the same questionnaire as in Baird et al. (2018). Music was more efficient at evoking memories than the AMI in three out of five cases and compared with controls, no differences were found in the frequency of MEAMs. For both participants with brain damage and controls, MEAMs were most often about people or a life period. Songs that were more familiar and more liked evoked more memories for participants with brain damage and controls.

Participants with brain damage generally experienced MEAMs as vivid and positive, which did not differ from controls. Baird and Samson (2014) also investigated the specificity for one case and found that even though they had a similar frequency of MEAMs compared to controls, the participant with brain damage had memories that were less often about a specific event than the control participant.

3.9 | Studies with no nonmusic comparison

3.9.1 | Alzheimer's disease

Cuddy et al. (2017) involved 20 adults with AD, 20 healthy older controls, and 20 healthy younger controls. They played 12 short familiar instrumental tunes to the participants and instructed them to report if a memory “came to mind spontaneously" during listening. They found no difference in memory frequency between AD participants, older controls, and younger controls, but participants with AD tended to retrieve earlier memories than older controls. Cuddy et al. (2017) also found that older controls and the AD group had more memories about going out than younger controls, whereas the young controls had more memories of stressful events.

Regarding the characteristics of the memories, older controls and participants with AD had more vivid MEAMs than younger controls. Older controls and AD participants also had more categorized and self-reported positive memories, and more positive and less negative emotions when rating how they felt about the memory at the time of the event. Compared with older controls, AD rated their own memories as less often about specific events, but this difference did not replicate in experimenter-rated specificity level. However, there was a difference between the combined older controls and AD group, and the younger controls when specificity was rated by the experimenters.

3.9.2 | Major depressive disorder

Sakka and Saarikallio (2020) exposed 18 participants with depression and 21 age-matched controls to a three-minute compilation of preferred and popular music from when they were 10–25 years old, online. Participants were only instructed to listen to the music and afterward asked if the music had evoked personal memories. They found no significant difference in frequency of MEAMs among participants with depression compared to controls, but the memory content differed. The themes of the MEAMs in the depression group were mostly related to loss and dysfunctional relationships and personal negative mental states, whereas controls reported MEAMs primarily pertained to positive activities. The valence was also significantly different. While controls almost only reported positive MEAMs, the depressed participants reported memories across the emotion spectrum, with a significantly lower median rating for both valence and induced emotion.

In summary, studies with no comparison condition find that both participants with AD and depression have an intact frequency of MEAMs. Depressed participants reported both negative and positive memories, whereas all other groups predominantly reported positive memories.

3.10 | Assessment measures and their relation to autobiographical memories

3.10.1 | Cognitive functions

All studies except Sakka and Saarikallio (2020) included a cognitive screening measure. Below is reported when the studies examined relationships between these and MEAMs.

In bv-FTD, Baird, Brancatisano, et al. (2020) found that frequency of MEAMs and PEAMs had a positive correlation with fluency in the patient group, whereas there was no relationship with scores of the Mini-Addenbrooke's Cognitive Examination (M-ACE; Hsieh et al., 2015). For controls, fluency was not correlated, but M-ACE and PEAMs were.

In AD, Foster and Valentine (2001) found that the group with "high ability" on the MMSE had better personal semantic recall than the group with "low ability". Regarding episodic recall, Baird et al. (2018) found no significant correlation between cognitive function, as measured by the M-ACE, and frequency of MEAMs. They did find a positive correlation between PEAMs and M-ACE, though. However, Cuddy et al. (2017) did find that the AD participants that reported no MEAMs had a higher impairment on the Dementia Severity Scale (Clark & Ewbank, 1996).

Regarding executive functions, Baird et al. (2018) found no correlation between MEAM frequency and fluency. El Haj et al. (2017) also found that executive function only predicted specificity and retrieval time after silence, but not after music or odor for both patient and control groups. In addition, El Haj, Fasotti, and Allain (2012) found that performance on executive function tasks (pooled across groups) explained less variance in the music condition (21%–35%) than in the silence condition (39.6%–55.9%). Baird, Gelding, et al. (2020) found that cognitive decline in M-ACE was not related to frequency of MEAMs, but was related to fewer PEAMs in AD.

There is also some evidence that cognitive function in general improved after music exposure, as El Haj et al. (2013) found better performance in fluency for both groups and Irish et al. (2006) found higher reaction time in the Sustained Attention to Response Task (Robertson et al., 1997) after exposure to music in AD.

In summary, the results are mixed but tend to show that general cognitive or executive function is not correlated with frequency or specificity of MEAMs, but that there could be a relationship between PEAMs and semantic recall with cognitive function. In addition, there might be a general cognitive improvement related to music listening. However, all these findings should be taken with a grain of salt due to the small sample sizes reducing the robustness of correlational analyses.

3.10.2 | Affectivity

There were seven studies that included a measure of affectivity (Baird & Samson, 2014; Cuddy et al., 2017; El Haj et al., 2015b, 2017; Garćia et al., 2012; Irish et al., 2006; Sakka & Saarikallio, 2020). Only Cuddy et al. (2017) found a correlation between scores on the Positive and Negative Affect Schedule (Watson et al., 1988) and the valence rating of MEAMs in AD. Regarding the effect of music on mood, El Haj, Fasotti, and Allain (2012) found a greater improvement of mood in AD following music than silence, when compared to older controls. Irish et al. (2006) found a reduction in state anxiety in AD for the music condition, and when they added state anxiety as a covariate, the effect of music on recent semantic recall became nonsignificant.

3.10.3 | Music experience and perception

Five studies included questionnaires about the participant's experience with music. The majority of studies did not examine relationships between this and MEAMs (Baird et al., 2018; Baird, Gelding, et al., 2020; Belfi et al., 2018), and 1 study did not report the results of the questionnaire (Cuddy et al., 2017). Baird, Brancatisano, et al. (2020) found that participants with bv-FTD with a higher score on an item pertaining to listening to familiar music and recalling events from their past had a higher frequency of MEAMs. Otherwise, music experience was not correlated to MEAM frequency.

Three studies investigated music perception in terms of pitch perception and song recognition. Baird and Samson (2014) had one case that did not produce any MEAMs and found deficits in both pitch perception and song recognition for this participant. Belfi et al. (2018) found no correlations between pitch perception and MEAMs and Cuddy et al. (2017) found that song recognition could not predict which participants would not produce MEAMs.

3.11 | Risk of bias

Publication bias was assessed following previous work (Gehrt et al., 2018) by examining the distribution of p-values for group × condition interaction effects. When following common cutoffs, the following distribution were found: 2 had $p < 0.005$, 4 had $p < 0.01$, 5 had $p < 0.05$, and 1 did not meet the threshold of statistical significance ($p > 0.05$). This suggests no publication bias, as we found no clear indication of an overrepresentation of values just over the $p < 0.05$ boundary.

Risk of bias in the studies' methodology includes some issues in terms of reporting. Most are unclear about the information that participants received prior to the experiment. Thus, it is hard to assess whether they were instructed to pay attention to evoked memories or not.

The study designs employed seem appropriate for studying the phenomenon, as the clinical participants were generally able to take part in the task and describe their memories. When comparing the effects of music on clinical and healthy participants, there is however the issue of a possible ceiling effect, particularly when using the TEMPau scoring. Often, the control group consistently scored at ceiling, even in the control (silence) condition. This may lead to underestimating the effect of music on the healthy controls and render the interpretation of group × condition interactions less clear. The largest risk of bias comes from the low statistical power in many of the included studies, which will be discussed further below.

4 | DISCUSSION

4.1 | Summary of findings

The aim of this review so far was to investigate the cognitive characteristics of MEAMs in clinical populations and whether these are unique compared to other types of cues. The literature search identified 15 studies for inclusion, with one study investigating depressed participants, two studies with participants with acquired brain damage, and 13 studies investigating dementia, with 12 including participants with AD, one including participants with bv-FTD, and one including both participants with AD and bv-FTD.

The results show that music evokes AMs in AD, bv-FTD, brain damage, and depression, and is more efficacious than silence in AD. The more familiar the music was, the more likely it was to produce MEAMs. MEAMs were generally specific and retrieved fast. They were also experienced as positive, except for the group with depression who reported as many negative as positive memories.

When it comes to whether these cognitive characteristics are unique to MEAMs, the results are more mixed. In AD, there was a relative advantage of music cues, as only memories evoked by pictures showed a decline in frequency and specificity compared to healthy controls. There were, however, similar specificity ratings when comparing with odors. For people with damage to the mPFC, the frequency of MEAMs was comparable to the control group, but the episodic richness of MEAMs was specifically impaired, while the specificity of memories following pictures of faces was similar to controls. However, another study involving people with brain damage revealed a relative advantage for MEAMs in comparison with verbal cues. Compared with control participants, bv-FTD participants produced fewer memories after both music and pictures but produced more memories after pictures than after music. In the following, we will further discuss the findings regarding the cognitive characteristics of MEAMs from each clinical condition.

4.2 | Cognitive characteristics of MEAMs by disorder

4.2.1 | Alzheimer's disease

The studies indicate a preserved ability to have MEAMs in AD. The participants were generally able to retrieve memories following music, and the two studies that examined a larger selection of songs (Baird et al., 2018; Cuddy et al., 2017) found no difference between AD and the healthy control groups in frequency of MEAMs. Baird et al. (2018) did, however, find fewer memories evoked by photographs of world events for AD compared to controls. Thus, access to MEAMs appeared to be preserved in AD, while access to PEAMs had declined. Music was also shown to improve semantic autobiographical recall (Foster & Valentine, 2001; Garćia et al., 2012; Irish et al., 2006), but not to the level of healthy controls (Irish et al., 2006).

Regarding the age of memories, AD participants differed from controls by retrieving AMs in which they were younger (Cuddy et al., 2017). In addition, music from when the AD participants were 10–30 years old (consistent with the reminiscence bump period) evoked more MEAMs than music from when they were above 30 years of age, whereas controls only had significantly more memories for the 10 to 30-year period compared to when they were older than 50 (Baird et al., 2018). This bump was not shown for photo-evoked AMs. Thus, music from the period of the reminiscence bump appeared to be more efficient at evoking AMs, which is consistent with the finding that people generally prefer, and better remember, music from their reminiscence bump period (Janssen et al., 2007; Schulkind et al., 1999). Whether the distribution of the participants' age in the MEAMs also follows the reminiscence bump in AD cannot be inferred from the present evidence, as no study investigated the connection between the age of the remembered events and the music. However, studies using other methodologies generally find that the reminiscence bump is intact in AD (Berntsen et al., 2022; Kirk & Berntsen, 2018a).

Several studies investigated the specificity of the AMs in AD and generally found this to be reduced compared to healthy controls, but significantly improved by music. Especially the participants' preferred music was more effective than familiar music at increasing specificity and evoked more self-defining memories. This finding is consistent with the fact that AMs in AD generally become semanticized (El Haj et al., 2015a), but also shows that this might be alleviated with music cues. While there seems to be a relative advantage for music over pictures in AM frequency, whether music provides greater improvements in specificity compared to other ways of cuing is still unclear, as the present studies failed to find more specific memories following music compared to odors. Studies also generally find that other types of cues can improve access to and specificity of AMs in AD, such as objects (Kirk & Berntsen, 2018b), nostalgia films (Rasmussen et al., 2021), or historical environments (Miles et al., 2013).

Baird, Gelding, et al. (2020) found that MEAMs were relatively stable in terms of frequency, specificity, and valence 6 months apart in AD and found that the same stimuli tended to evoke AMs at both points, with no differences in controls and AD. However, they did not report if it was the same memories that were evoked.

4.2.2 | Other disorders

For participants with bv-FTD, MEAMs were generally impaired, with reduced specificity and frequency. They were also more impaired than PEAMs (Baird, Brancatisano, et al., 2020). Interestingly, though, when tested 6 months apart with the same stimuli, participants' MEAM frequency improved significantly, indicating that they benefitted from re-exposure (Baird, Gelding, et al., 2020). Thus, MEAM studies seem to replicate the general findings of fewer and less specific AMs in bv-FTD (Hou et al., 2005; Irish et al., 2011, 2018; Piolino et al., 2003; Thomas-Antérion et al., 2000), although these results are very preliminary.

Sakka and Saarikallio (2020) found that depressed individuals had fewer positive and more negative AMs evoked by music compared to controls. This is in line with the general finding showing more negative and less positive memories in depression (Köhler et al., 2015), but stands out because MEAMs were predominately positive for all other clinical and control groups.

Studies featuring participants with acquired brain damage generally found comparable MEAM frequency with healthy controls if song recognition and pitch perception was intact. Music also appeared to be better than verbal cues at evoking memories. Interestingly, Belfi et al. (2018) found intact episodic richness for AMs evoked by pictures, but not MEAMs for participants with specific damage to the mPFC. This may suggest that this brain area plays a special role in MEAM specificity.

4.3 | Methodological considerations

One of the biggest methodological concerns regarding MEAMs is what constitutes a good control condition. When looking at daily life for many dementia patients and whether interventions can be meaningful, comparisons such as silence can be valid. However, for research purposes or when designing possible interventions, it is important to compare alternative cue stimuli to determine the advantage of music relative to other types of cues.

Regarding pictures, knowledge of famous faces and events has been found to deteriorate faster than AM in AD (Greene & Hodges, 1996), while song recognition is relatively preserved (Cuddy et al., 2012). Thus, pictures of events or faces might be less efficient memory cues, especially at later stages of the disease. In support of this, Baird et al. (2018) only found a reduction in frequency of PEAMs, and not MEAMs, compared to healthy controls. Another advantage of music is that MEAMs appear to be less cognitively demanding, as several studies in this review find a correlation between cognitive function and PEAMs, but not between cognitive functions and MEAMs.

Another issue, at least with using prominent public events, is that the material is very likely to cue semantic memories, or simply trigger recognition of the event pictured rather than accessing personal memories. Such memories would then have less personal significance and serve as a problematic control condition for music cues, at least when examining internal details and specificity. For example, Baird et al. (2018) found that the content of PEAMs primarily pertained to the event pictured.

For the comparison between music and odors, the results indicate they are comparable regarding specificity, valence, and mental time travel although it has not yet been investigated in terms of memory frequency. Odor seems to provide a better control than pictures due to the more abstract nature of both types of stimuli, with odors not inherently referencing a single event in contrast to pictures. A possible issue with using odors in AD is the fact that deficits in smell identification are common, especially in the later stages (Velayudhan, 2015), which could limit its effectiveness and general enjoyment for the patients.

A general methodological limitation of the included studies pertains to the relatively small clinical sample sizes ($N = 5$–28), which limits the possible analyses and increases the risks of false negatives. Examples of this problem include nonsignificant trends toward more negative and fewer positive words in depressed compared to healthy participants, with medium-large effect sizes (Sakka & Saarikallio, 2020) and nonsignificant effects regarding stimuli from early versus later life periods for participants with bv-FTD (Baird, Brancatisano, et al., 2020). Analyses of the relationships between music experience and MEAMs and general cognitive function and MEAMs (Belfi et al., 2018; El Haj et al., 2015b, 2017; El Haj, Fasotti, & Allain, 2012; El Haj, Postal, & Allain, 2012; Garćia et al., 2012) are also hampered by small groups sizes, substantially below recommended sample sizes for correlational analyses (Schönbrodt & Perugini, 2013).

4.4 | A model of basic cognitive processes of MEAMs

We now return to our theoretical discussion of possible cognitive processes of MEAMs. The findings of the studies in this review indicate that many cognitive mechanisms may be involved in the way music cues facilitate AM retrieval and that these mechanisms also might depend on musical abilities and memory for music. Figure 2 presents the most important factors that emerge from this review of clinical literature. It should be underscored that the model presented in Figure 2 is not the only possible way to interpret the reviewed findings, nor does the reviewed literature lend direct support to all aspects of the model. Instead, the model serves to provide a plausible conceptual summary of some of the key findings and a possible starting point for the generation of hypotheses for future studies. As illustrated in Figure 2, we posit that the preservation of overall musical abilities and music memory is a condition for the effects music cues may exert. Better preserved music abilities would strengthen the effects while less well-preserved music abilities would diminish them. To the extent a piece of music is appreciated and recognized, this may lead to the activation of music-evoked emotions, increased cognitive fluency, reduced anxiety, and increased reminiscence, which individually or in combination can evoke autobiographical memories. Evidence for these factors is discussed in the following.

A theoretical explanation for why musical abilities and memory for music could be crucial for the cognitive mechanisms of MEAMs, can be found in a basic systems approach to AM (Rubin, 2005), where the memories associated with music must be understood in the context of the specialized neural networks involved in music cognition. Thus, the MEAMs could be distributed in musical ability networks. Evidence for this comes from an fMRI-study by Janata (2009), which showed similar activation in the dorsal and lateral mPFC by familiar music and MEAMs. Interestingly, this activation was also related to tracking musical structures. Similar areas were activated in studies that manipulate musical structures (Koelsch, 2005). This explanation is especially supported by the findings in AD, due to the relative preservation of memory for music and musical abilities (Cuddy et al., 2012; Leggieri et al., 2019; Peck et al., 2016), with brain structures activated by familiar music being less affected by cortical atrophy than the rest of the brain (Jacobsen et al., 2015). Evidence of a connection between memory for music and musical abilities with MEAMs was found by Baird and Samson (2014), as the one case that did not produce any MEAMs also showed deficits in pitch perception and song recognition. The importance of memory for music in the facilitation of MEAMs is further underlined by the finding that familiarity with the music increases MEAM frequency significantly.

The general factors of music cognition facilitating AM retrieval are consistent with unfamiliar music still evoking more AMs than noise or silence (Foster & Valentine, 2001; Garćia et al., 2012). There is also support for the fact that anxiety reduction could be an underlying mechanism for the activation of memories in response to music, as Irish et al. (2006) found a reduction in state anxiety following music listening that removed the effect of music when entered as a covariate. This suggests that the effects of music on autobiographical memory might be mediated by its ability to reduce

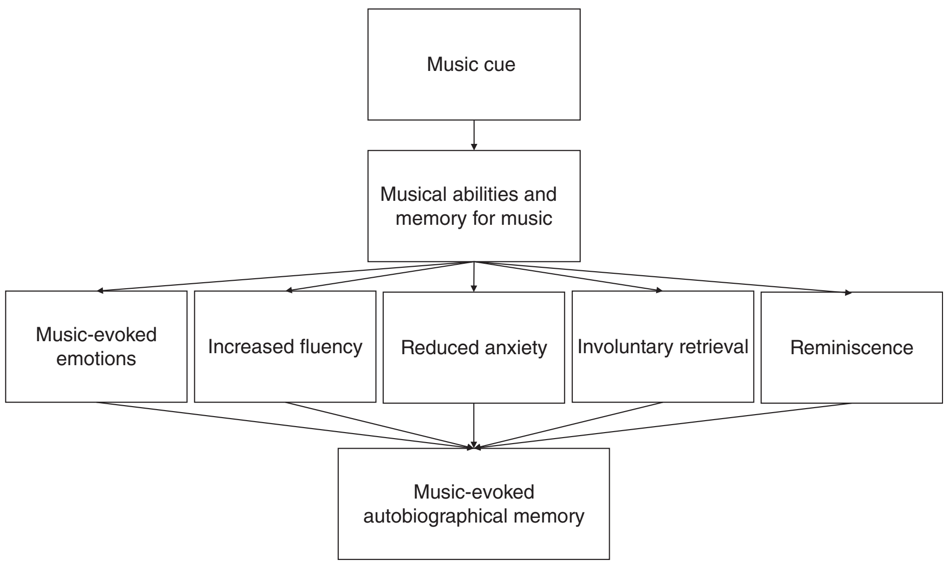

FIGURE 2 Model of cognitive processes of MEAMs

anxiety and stress. El Haj et al. (2013) found improved fluency following music listening, which likewise may ease access to autobiographical memories.

Regarding the role of music-evoked emotions, two studies reported that music induced a change in mood (El Haj, Fasotti, & Allain, 2012; Sakka & Saarikallio, 2020). In addition, as an indirect indication of this, MEAMs were generally positive (Cuddy et al., 2017) and more positive than memories evoked in silence in AD (El Haj et al., 2017; El Haj, Fasotti, & Allain, 2012; El Haj, Postal, & Allain, 2012). In depression, participants had both strong positive and negative emotional reactions (Sakka & Saarikallio, 2020).

This review also suggests the importance of associative music cognition factors for MEAMs. First of all, music associated with the participants' identity seems to be more efficient at evoking MEAMs than music that is not associated. Here, we term this factor "reminiscence." For instance, music released during the participants' reminiscence bump was more effective than music released at other times (Baird et al., 2018). This is the period thought to be very formative in terms of identity formation (Rubin et al., 1998) and role transition (Berntsen & Rubin, 2004). Further support comes from El Haj et al. (2015b), that found that participants with AD had as many self-defining memories as controls when listening to preferred music, but not to music that was just familiar. Thus, there seems to be an association between these memories central to identity and the participants' preferred music.

We also found evidence supporting the role of individual direct associations with the music. Across all studies, familiar music was more effective than unfamiliar music, and preferred music was more effective than familiar music. This indicates that having direct associations with the music aids recall. A possible cognitive mechanism for the preserved accessibility of MEAMs in many clinical groups could be that these memories are evoked through involuntary recall (El Haj, Fasotti, & Allain, 2012). MEAMs have the characteristics of this type of recall, as they are typically specific, positive, and retrieved fast (Berntsen, 2010). In involuntary recall, memories are likely retrieved automatically, through a bottom-up process of spreading activation in the AM network triggered by specific cues in the environment. This contrasts with the intentional route with strategic top-down memory retrieval (Berntsen, 1996, 2010; Conway & Pleydell-Pearce, 2000; Moscovitch, 1995). In AD, the intentional route has been found to be impaired (El Haj et al., 2015a), whereas persons with AD benefit greatly from cues during memory retrieval, especially from their youth (Baird et al., 2018; Kirk & Berntsen, 2018b; Miles et al., 2013; Rasmussen et al., 2021). Further support for this explanation is the fact that involuntary retrieval appears to be less dependent on cognitive and executive function (Hall et al., 2014) and deficits in these did not impact MEAM characteristics significantly in any study.

5 | CONCLUSION AND FUTURE RESEARCH

In this review, we have systematically examined clinical research pertaining to MEAMs and have included 15 studies. We found that music can evoke AMs in people with AD, bv-FTD, acquired brain damage, and depression, and that the more familiar the music was, the more likely it was to evoke AMs. MEAMs were generally characterized as specific and retrieved fast, as well as positive, except for participants with depression. Whether music differs from other cues at evoking AMs is not clear, but MEAMs were better preserved in AD than AMs evoked by pictures. However, MEAMs might be relatively diminished compared to photo-evoked memories in bv-FTD and brain damage involving the mPFC. Based on the reviewed articles, we have also presented a model of possible cognitive processes involved in MEAMs, suggesting these could be moderated by musical abilities and memory for music.

Although clinical MEAM research is very preliminary, the results of this review point toward many promising future research areas. The proposed role of memory for music and musical abilities in MEAMs warrants further investigations, both in terms of dysfunction (e.g., amusia) and variations within normal function (e.g., musicians vs nonmusicians). Another interesting finding in this review is the fact that some characteristics of MEAMs appear to be unrelated. For instance, specificity was found to be impaired, while frequency was intact in both AD and mPFC-brain damage. This could hint at different cognitive characteristics relying on separate relatively independent cognitive processes, but this will require future studies.

Other future research avenues are also pertinent. First, the present studies mostly feature AD participants in early stages, so little is known about how effective music is in later stages of the disease. Second, specificity of MEAMs in depression were not investigated. As overgeneral memory is a common finding in people with depression (Williams et al., 2007), it would be interesting for future studies to examine whether music can improve this, especially in lieu of the improvements in specificity found in AD. Many other clinical disorders such as schizophrenia (Allé et al., 2021), posttraumatic stress disorder (Ono et al., 2016), and Borderline personality disorder (Van den Broeck et al., 2015) also have AM-related issues where it could be relevant to investigate MEAMs.

Relatedly, another possible promising area of research is the long-term effects of music exposure on AM. Music is very easy to personalize, pleasurable, cheap, and easy to administer in large doses, which makes it promising for interventions. As mentioned above, reduced specificity of AM is apparent across many clinical disorders, and AM specificity training has been developed for disorders such as depression (Raes et al., 2009), posttraumatic stress disorder (Moradi et al., 2014), and mild cognitive impairment (Emsaki et al., 2017), with generally promising results (Barry et al., 2019; Hitchcock et al., 2017). While music therapy for depression exists and seems to improve depressive symptoms, anxiety, and functioning (Aalbers et al., 2017), these findings have not been analyzed in terms of their relation to AM. Given that MEAMs are generally specific, music could play a part, either as a separate intervention or as a part of already established methods. Another possibility is as a form of reminiscence therapy in AD. Several music interventions for AD currently exist, but with mixed results for long-term effects, and none explicitly studying effects on AM (Leggieri et al., 2019).

AUTHOR CONTRIBUTIONS

Alexander P. Kaiser: Conceptualization (equal); data curation (lead); investigation (lead); methodology (equal); project administration (equal); writing – original draft (lead); writing – review and editing (equal). **Dorthe Berntsen:** Conceptualization (equal); data curation (supporting); investigation (supporting); methodology (equal); project administration (equal); supervision (lead); writing – original draft (supporting); writing – review and editing (equal).

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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