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# A Preliminary Exploration of the Stability of Music- and Photo-Evoked Autobiographical Memories in People with Alzheimer's and Behavioral Variant Frontotemporal Dementia

**Amee Baird, Rebecca Gelding, Olivia Brancatisano and William Forde Thompson**

**Abstract**

Music evoked autobiographical memories (MEAMs) occur in people with Alzheimer's dementia (AD), but there is limited study of such memories in people with other dementia types such as behavioral variant frontotemporal dementia (Bv-FTD). Furthermore, there has been no study of the integrity of such memories over time, and scarce comparison with other memory cues such as photos. Our aim was to address this current gap in our knowledge and to characterize MEAMs and photo-evoked autobiographical memories (PEAMs) in healthy elderly people and people with AD and Bv-FTD on two occasions, 6 months apart. Twenty-two participants (7 with AD, 6 with Bv-FTD, and 9 healthy elderly people) reported memories following exposure to two famous songs and two famous event photographs from each decade from 1930–2010 on two occasions. All people with AD and all healthy elderly controls reported at least one MEAM or PEAM at both times. In contrast, two people with Bv-FTD reported no memories at either time. The percentage of memories over time for songs and photos remained stable for the Healthy Elderly and AD groups, whilst the percentage of memories to songs increased over time for people with Bv-FTD. Songs elicited more positive memories than photos. The specific music and photo stimuli that triggered memories, and the topic of the memories that were evoked, remained stable over a 6-month period across all groups. Our results suggest that music and photos are efficient memory cues in people with AD and Bv-FTD. Future large-scale studies of people with different dementia types over a longer time period will provide insights into the integrity of music- and photo-evoked autobiographical memories as dementia progresses.

**Keywords**

Alzheimer's dementia, autobiographical memory, behavioral variant frontotemporal dementia, music

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## Introduction

Dementia affects roughly 50 million people worldwide, with patients and caregivers experiencing considerable physical, emotional, and economic burden (World Health Organization, 2019). Memory impairment is the hallmark feature of the most common type of dementia, Alzheimer's dementia (AD). This can include reduced ability to recall autobiographical or personal memories. Autobiographical memory comprises personal information that is both semantic (general knowledge about oneself) and episodic (relating to specific personal events), and is considered crucial for maintaining our sense of self and identity (Conway, 2005). Research studies of autobiographical memory

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in people with dementia have typically used verbal tasks. Recent literature has explored how other stimuli, such as music, can cue personal memories. Spontaneous episodic memories are commonly elicited after or during music listening, and are referred to as music-evoked autobiographical memories (MEAMs), a term coined by Janata and colleagues, who first characterized the phenomenon in healthy university students (Janata et al., 2007). The links between music, emotion, and autobiographical memory have also been addressed by Juslin (2013) in his framework outlining mechanisms that underpin emotional responses to music. "Episodic memory" is an identified mechanism in his model, and he highlights that when a MEAM is triggered, so too is the emotion associated with that memory.

The aim of "reminiscence therapies" for people with dementia is to improve autobiographical recall and enhance psychological wellbeing (Elfrink et al., 2018; McKeown et al., 2006). Various stimuli are utilized in such therapies, including music and photos. For example, *Life Story Books* include personally meaningful photographs (Clarke, 2000; Clarke et al., 2003) and *Music Mirrors* use personally selected music and sounds (Edwards, 2015). There is accumulating evidence that music is a particularly effective memory cue for people with AD. Various types of musical memory can remain relatively preserved in late stages of AD. The ability to recall familiar tunes and lyrics (semantic music memory, e.g., Cuddy & Duffin, 2005), play a musical instrument (procedural music memory, see Baird & Samson, 2015 for a review) and in some cases learn and recall new music has been documented in people with AD (Baird et al., 2017). The preservation of MEAMs in this population is well established (El Haj et al., 2013; El Haj, Fasotti, & Allain, 2012; El Haj, Postal, & Allain, 2012; Cuddy et al., 2017; Baird et al., 2018).

Studies of MEAMs in people with AD have typically used self-chosen personally preferred music (El Haj et al., 2013; El Haj, Fasotti, & Allain, 2012; El Haj, Postal, & Allain, 2012) or familiar researcher-selected music, with or without lyrics (Cuddy et al., 2017; El Haj, Postal, & Allain, 2012), and compared memories evoked after listening to the music excerpts or a period of silence. They have demonstrated a memory-enhancing effect for music, and that the frequency of MEAMs in people with AD is similar to that of healthy elderly people (Baird et al., 2018; Cuddy et al., 2015, 2017), suggesting a striking maintenance of function in the presence of music. Further, various characteristics of MEAMs of people with AD were consistent with the characteristics of MEAMs among healthy elderly individuals, including the length (word count) of these memories and ratings of their vividness (Cuddy et al., 2017). The phenomenon of the "reminiscence bump," or a peak in autobiographical memories from the period when someone was 10–30 years of age (Rubin & Schulkind, 1997), has also been observed in studies of MEAMs in people with AD. Song stimuli dating from when participants were aged 10–30 years are more likely to trigger MEAMs in this population (Baird et al., 2018), and when MEAMs are dated by participants, they are typically from this period of life (Cuddy et al., 2015).

In a series of studies in people with mild AD, El Haj and colleagues (2012, 2013) compared memories evoked after a period of silence versus hearing self- or researcher-chosen music. They found that memories evoked while listening to self-chosen music were more specific, were recalled more quickly, and had higher emotional content than memories evoked following a period of silence. Verbal descriptions of MEAMs also had higher grammatical complexity (El Haj et al., 2013) and contained more "self-defining" references—defined by the authors as how the person saw themselves or events related to personality construction, concerns or unresolved conflicts—compared with memories evoked after silence (El Haj, Fasotti, & Allain, 2012; El Haj, Postal, & Allain, 2012).

The majority of research on the topic of music and memory in dementia has been conducted in people with AD, with scarce attention to other types of dementia such as frontotemporal dementia (FTD). FTD is the second most common type of younger-onset dementia (at 45–60 years compared with over 65 years in AD), but far less common than AD. Preserved or even enhanced artistic skills, including music skills, have been observed in people with FTD. There are two main variants of FTD, each with their own diagnostic criteria; (1) behavioral variant FTD (Bv-FTD) which causes prominent changes in social and emotional functions, such as disinhibition (Rascovsky et al., 2011), and (2) primary progressive aphasia (PPA), which has three subtypes with different language features, namely semantic dementia (Hodges & Patterson, 2007), non-fluent/agrammatic PPA and logopenic PPA (Gorno-Tempini et al., 2011). The predominant cognitive impairment in Bv-FTD is frontal executive dysfunction, including deficits in social cognition and emotional processing, but there is also evidence that memory difficulties can occur, including autobiographical memory impairment (see review by Hodges & Piguet, 2018).

There are several case studies of people with Bv-FTD who developed novel musical skills, such as whistling and composing, post dementia onset (Miller et al., 2000), and preserved musical instrument playing during the progression of their dementia (piano in the case of Hsieh et al., 2009). Novel learning of a musical instrument after the onset of dementia has also been documented (saxophone in the case of Cho et al., 2015; ukulele in the case of Baird & Thompson, 2019). Recent research has documented "musicophilia" or a strong desire to engage in music listening or other forms of music engagement in people with FTD. This phenomenon involves music craving or seeking, with some patients "demanding to listen to a narrow repertoire of songs for up to many hours each day but sometimes also engaging in more organized behaviors such as taking up a musical instrument or buying music equipment" (Fletcher et al., 2015, p. 99). This symptom was reported by carers of nearly half (48%) of Fletcher and colleagues'

(2015) sample of people with FTD and was more frequently observed in people with semantic dementia compared with Bv-FTD.

To our knowledge there has only been one study to date that has explored MEAMs in people with Bv-FTD (Baird et al., 2020). In this case series of six men with Bv-FTD, Baird and colleagues observed reduced frequency and specificity of MEAMs compared with people with AD and healthy elderly people. Some cases with Bv-FTD had a complete absence of MEAMs. These observations are consistent with previous research demonstrating reduced autobiographical memory function in people with FTD (Hornberger & Piguet, 2012), and suggests that the striking preservation of MEAMs in AD may not be evident in all types of dementia. Reduced MEAMs in people with Bv-FTD is predicted as a sequela to progressive damage to medial frontal regions of the brain, which have been shown in neuroimaging research to be critical for MEAM retrieval (Janata, 2009). Overall, these findings suggest that people with different types of dementia respond differently to music, and the mnemonic effect of music may not be consistent across dementia types.

The research to date has clearly established that music can enhance autobiographical recall memory in people with AD. As discussed, it appears that music is not as effective at triggering such memories in people with Bv-FTD. Nevertheless, research to date has employed small sample sizes, so the existing evidence remains tentative. A current gap in our knowledge is the integrity of MEAMs over time. All the studies to date have been conducted on one occasion only, precluding any understanding of whether MEAMs are preserved over time. Specifically, if a song or piece of music evokes a memory, will it trigger this memory consistently over time? This is a crucial question in the case of AD, which by its nature involves a decline in memory function over time. If music can reliably trigger autobiographical memories, we need to understand if those memories remain stable over time. In neurologically healthy people, we predict that a memory elicited by music would remain stable over time, such that the same memory is elicited by the same music. In other words, the first MEAM that occurs should increase the probability of its reoccurrence. In the case of AD and associated memory decline, it is unknown if the same MEAM occurs in response to the same music over time.

The phenomenon of preserved memory for music including MEAMs in people with AD has received considerable media attention, and there may be an expectation from carers of people with AD that music can reliably and consistently "unlock" personal memories and "bring people back to themselves." Our preliminary case series suggests that people with Bv-FTD may not show the same preservation of MEAMs as those with AD, but it is unclear if this pattern remains stable over time. Understanding the nature of MEAMs over time has potential scientific, and clinical implications. It will contribute to our understanding of autobiographical memory during the progression of AD and Bv-FTD, provide knowledge for carers of people with dementia, and inform expectations about the potential effects of music in these populations.

The main objective of this study was to investigate the stability of MEAMs in people with different types of dementia, namely AD and Bv-FTD. In view of our previous findings, we predicted no difference in the frequency of MEAMs in the AD and Healthy Elderly groups over time, but reduced frequency of MEAMs in Bv-FTD, given that this type of dementia negatively impacts upon the medial frontal regions which are crucial for MEAM retrieval. We also predicted that the topic and stimulus evoking the memories would remain stable.

A secondary aim was to compare memories evoked by music and photos (Baird et al., 2018, 2020). We also hypothesized that people with Bv-FTD would have more PEAMs than MEAMs at both time periods, given the known reliance of MEAM retrieval on medial frontal regions. In the AD group, we predicted that MEAM frequency would remain stable, given the known preservation of these memories, whereas PEAM frequency would decline over time. Our discussion focuses on the stability of MEAMs and PEAMs over time; a more detailed comparison of MEAMs and PEAMs at the first time point is discussed elsewhere (Baird et al., 2018, 2020).

## Methods

### Materials

*Songs and Photo Stimuli.* In order to match the music and photo stimuli we chose famous songs and events from the same time periods. This method of stimuli selection involved dating and matching music and photo stimuli according to time period, which allowed an examination of whether stimuli from the "reminiscence bump" (when participants were aged 10–30 years) were more likely to trigger memories. The findings regarding this specific issue are reported elsewhere (see Baird et al., 2018, for AD participants, and Baird et al., 2020, for Bv-FTD participants) and will not be addressed in the current article. Choosing famous songs and events for photos also ensured a high likelihood that participants had been exposed to these stimuli during their lifetime. In total, 16 famous songs and 16 photos depicting world-famous events across eight decades, from 1930–2010, were chosen (see Baird et al., 2018). Two songs and two photos were selected from each decade (see Appendix A). Song selection was based on those that had spent the longest duration at Number One in the Australian music charts and had the highest music sales according to two sources: The Kent Music Report (for songs from 1930–1989) and Australian Recording Industry Association (for songs from 1990–2010). Songs were purchased via iTunes and played on a laptop through a Phillips BT6000 Bluetooth speaker. Participants initially confirmed

**Table 1.** Demographic characteristics of the AD, Bv-FTD, and healthy elderly participants at Times 1 and 2.

| | AD ($n = 7$) | | Bv-FTD ($n = 6$) | | Healthy elderly ($n = 9$) | |
|---|---|---|---|---|---|---|
| Gender (M/F) | (3/4) | | (6/0) | | (5/4) | |
| MusEQ (*SD*) | 2.88 (0.84) | | 2.45 (0.74) | | 3.01 (0.56) | |
| Time | 1 | 2 | 1 | 2 | 1 | 2 |
| Age (*SD*) | 77.0 (14.3) | 77.8 (14.1) | 71.7 (10.6) | 72 (10.6) | 74.8 (9.0) | 75.0 (9.2) |
| M-ACE (*SD*) | 17.0 (7.0) | 12.4 (5.2) | 19.3 (4.5) | 18.3 (4.3) | 29.2 (0.4) | 29.1 (1.2) |
| FAS (*SD*) | 23.7 (12.1) | 16.4 (9.0) | 24 (16.1) | 19.0 (21.8) | 42.1 (7.2) | 45.2 (5.7) |

Note: A M-ACE score $\leq 25$ is 5 times more likely to have come from a person with dementia than without, and a score $\leq 21$ is almost always associated with a diagnosis of dementia (Hsieh et al., 2015). The mean score on the FAS (Verbal fluency task - Letters F, A and S; Tombaugh et al., 1999) for people aged 60–79 years with 9–12 years of education is 35.6; MusEQ raw score (Music Experience Questionnaire; Vanstone et al., 2016).

they could hear the stimuli, and the volume was not adjusted once the experiment was underway. Photos of prominent world events were based on famous events for each decade listed in Wikipedia and verified using online news resources. We aimed to choose specific "one off" events (e.g., "victory over Japan day") rather than events that spanned a long period of time (e.g., WWII). Each photo was individually printed on A5 paper and laminated.

*Standardized Cognitive Tasks.* The *Mini-Addenbrooke's Cognitive Examination* (M-ACE; Hsieh et al., 2015) was used to assess cognitive functioning. It comprises 5 items which assess attention (/4), memory (/7), animal fluency (/7), clock drawing (/5) and memory recall (/7), with a maximum score of 30. There are two recommended cut-offs; 25/30 (a score at or below this value is five times more likely to have come from a person with dementia than without) and 21/30 (a score at or below this value is almost always associated with a diagnosis of dementia). The M-ACE has been deemed more sensitive than the Mini Mental State Examination (MMSE) and less likely to have ceiling effects (Hsieh et al., 2015). Lower scores indicate greater cognitive impairment.

Verbal fluency in the letter form was also assessed (FAS; *Controlled Oral Word Association Test*; Strauss et al., 2006). This task requires the participant to say as many words as possible for one minute that start with the letter provided (F, A and S, each in turn). Proper nouns, repetitions, and variations of a word are to be avoided. It is considered a measure of "generative" ability and a test of both language and executive function (Strauss et al., 2006).

## Participants

Of the 26 participants who completed the first assessment (Time 1 (T1)), four participants were not able to complete the 6-month follow-up visit (Time 2 (T2); due to death $n = 2$ or illness $n = 2$) leaving a total of 22 participants. The sample comprised 7 participants with probable AD (3 males, 4 females, mean age at T1 = 77 years, age range: 55–96 years), 6 participants with probable Bv-FTD (all male, mean age at T1 = 71.7 years, age range: 59–82 years) and 9 healthy elderly participants (5 males, 4 females, mean age at T1 = 74.8 years, age range: 57–88 years). All participants received a clinical diagnosis of dementia (AD or Bv-FTD) by a geriatrician or neurologist with the support of a clinical neuropsychologist's assessment, using diagnostic criteria outlined by McKhann et al. (2011) and Rascovsky et al. (2011), respectively. These participants were recruited via a local health service ($n = 5$) and an aged care facility ($n = 2$). The healthy elderly participants were recruited via the university participant registry ($n = 8$) and one family member of an AD participant.

Inclusion criteria were native English-speaking and residing in Australia since aged 10 years (to ensure familiarity with stimuli). Exclusion criteria were a comorbid neurological condition (e.g., Parkinson's disease) or severe psychiatric disorder (e.g., schizophrenia), and any visual, hearing, or language impairments that would prevent communication or ability to hear music and engage with the stimuli. One participant with AD and one with Bv-FTD still played a musical instrument, while the remaining participants had no music training. No healthy elderly participants had any formal music training. Participants also completed a *Music Experience Questionnaire* (Vanstone et al., 2016).

Demographic details of the sample are shown in Table 1. As expected, the M-ACE total score and FAS score of the AD and Bv-FTD participants were significantly lower than those of the healthy elderly participants ($p < 0.05$) at both time points. Furthermore, the AD participants had significantly lower M-ACE scores than the Bv-FTD participants at T2, but not T1 ($p = .028$). The AD participants showed a decline in cognition (mean total M-ACE score) from T1 to T2 [$t(6) = 2.597$, $p = .041$], but no change in their FAS scores at T1 and T2. There was no change in the M-ACE or FAS scores from T1 to T2 in the Bv-FTD or healthy elderly participants. See Appendix C Figure C.1. for a plot of individual M-ACE and FAS scores over time for all participants.

## Procedure

Participants were filmed using a small digital camera on a tripod and all participants were asked for their consent

before filming proceeded. The order of the presentation of songs or photos was counterbalanced between T1 and T2 for each participant to reduce order effects. Participants were seen individually and completed the standardized cognitive tasks first, followed by the MEAM/PEAM task. The 16 songs and 16 photos were individually presented in random order. This was done by pressing "shuffle" on iTunes for the songs, and manually shuffling the photos. Each song was played from the beginning, as would be in a real-life music listening scenario. After approximately 30 seconds of listening to the song the researcher asked the participant the questions on the MEAM task sheet (Appendix B) and recorded their answers; firstly, "are you familiar with this song?" and "do you like this song?" followed by "does this song bring to mind a memory?" If the participant answered "yes" to this latter question, the researcher moved onto the next series of questions on the MEAM task sheet. If the participant responded with "no," the researcher skipped to the questions at the bottom of the MEAM task sheet specifying the factual details about the song and artist, then moved onto playing the next song. Some participants reported a memory within seconds of the song commencing, before they were formally asked the MEAM questions. If this occurred, then the order of the questions was rearranged to start with those related to the memory.

For the PEAM task, each photo was handed to the participant to look at for as long as they required while they responded to the PEAM task questions. These questions were asked in the same manner by the researcher as those in the MEAM task. Participants were asked at the initial presentation of the first song and photo as to whether or not they were able to hear/see the stimulus. Participants were also asked to rate their familiarity verbally with each stimulus on a 3-point scale (1 = not familiar, 2 = somewhat familiar, and 3 = extremely familiar ("I know it almost perfectly")) and to rate the valence of the memory on a 3-point scale (1 = very negative, 2 = neutral, and 3 = very positive).

## Data Analysis

*Coding of Memories.* A MEAM/PEAM was either elicited (score = 1) or was not (score = 0) for each stimulus. When participants were asked "does this song/photo bring to mind a memory?," the maximum score of 1 was assigned if a memory was described. Only responses that referred to personal experience were counted as an autobiographical memory. For example, if participants reported that a song was "in a movie" but did not recall a memory of seeing the movie, this was not classified as an autobiographical memory, and therefore was not coded as a memory. In contrast, if they reported "I remember seeing this song in a movie" or "I watched this on TV" it was classified as a MEAM or PEAM. If several memories were elicited, only the first was scored. All elicited memories were then coded for topic (see below).

Three raters reviewed audio transcripts of the MEAM/PEAM task and coded each reported memory. Scoring of the full set of transcripts was divided equally between two raters. A third independent rater double scored half of the transcripts scored by each original rater. There was a high interrater agreement (95.3%) between the third rater's scoring and those of the first two raters. Any discrepancies were discussed by all three raters and the majority decision was taken.

*Measures of memories elicited.* Three measures were calculated to describe general changes over time in the memories elicited. Firstly, the "percentage of memories evoked" was calculated as the number of memories elicited divided by the number of stimuli presented (i.e., /16). This provided a straightforward measure of the amount of memories for each person, at each time point per stimulus type. Secondly, mean familiarity ratings were obtained; one for how familiar participants were with all of the stimuli, and a second subset of this, a familiarity rating for just the stimuli that elicited a memory. We were most interested in the latter ("familiarity of stimuli evoking a memory"). Finally, the mean "valence of the memory evoked" was measured for each memory. In addition, to capture the stability of the memories over time, two additional measures were calculated: "stability of the stimuli in evoking a memory" and "stability of the topic of the memories."

*Stimuli Evoking a Memory.* To calculate the stability of the stimuli in evoking a memory, we determined the number of songs/photos that evoked a memory at both time points (i.e., number of stable songs/photos), and divided by the total number of unique songs/photos that evoked a memory. For example, if a participant had 4 MEAMs at T1 (from songs A, B, C, and D) and 3 at T2 (from songs A, B, and E), then we recorded that 2 songs (i.e., A and B) elicited a memory at both time points, out of the 5 songs that elicited a memory (i.e., A, B, C, D, E). The "stability score" for this participant would be calculated as 2/5 = 0.4. Dividing by the total number of songs/photos that evoked a memory provides a comparable measure of stability of stimuli evoking a memory that is not biased towards overall percentage of memories elicited.

*Topic of Memories.* The topic content of MEAMs and PEAMs were coded according to the following four categories: person/people, period of life (e.g., high-school days), place, or specific event. These categories were used because they are distinguishable and collectively captured all memories reported. Memories were coded for their primary topic content and expressed as a percentage of the total number of memories.

*Statistical Analyses.* Analyses were conducted using JASP (version 0.11.1.0) and R (version 3.6.1) software. A preliminary examination suggested that the data should be analyzed using Friedman (non-parametric) tests. First, for

each group (AD, Bv-FTD, Healthy Elderly) and stimuli (Photo, Song) combination, Friedman Tests were calculated to compare differences over time points for three measures: (1) percentage of memories evoked; (2) familiarity of stimuli evoking a memory; (3) valence of memory evoked. Second, for each group (AD, Bv-FTD, Healthy Elderly) and time point (T1, T2) combination, Friedman Tests were calculated to compare differences between MEAMs and PEAMs in these same three variables. Third, Kruskal-Wallis tests for each stimuli (Photo, Song) were calculated to examine group differences (AD, Bv-FTD, Healthy Elderly) in the stability of stimuli evoking a memory, and topic of memories across T1 and T2.

## Results

### *Emotional Valence and Arousal of Stimuli*

To determine the equivalence of emotional valence and arousal in the stimuli used, 16 healthy older adults completing a different study were asked to rate on 5-point Likert scales all songs and photos used in this study, where 5 indicated positive emotional valence and high arousal, and 1 indicated negative emotional valence and low arousal. No significant differences between stimuli were found for mean emotional valence (Song: $M = 3.43$, $SD = 0.97$; Photo: $M = 3.25$, $SD = 0.88$; $t(30) = -0.55$, $p = .586$, $d = -0.20$, 95% CI (Confidence Interval) [−0.89, 0.50]) or arousal (Song: $M = 3.48$, $SD = 0.59$; Photo: $M = 3.69$, $SD = 0.57$; $t(30) = 0.99$, $p = .330$, $d = 0.35$, 95% CI [−0.35, 1.05]). A plot of the mean emotional valence and arousal for each stimulus is shown in Appendix C Figure C.2.

### *Percentage of MEAMs and PEAMs Evoked at T1 and T2*

All healthy participants and all participants with AD reported at least one memory in response to songs and photos at both time points. In contrast, two people with Bv-FTD had no MEAMs at T1 (but had 3 PEAMs) and in one case no PEAMs at T2.

At T1, the majority of people with AD (5/7) had more MEAMs than PEAMs, or an equal number of MEAMs than PEAMs. The opposite pattern, with majority of people having more or equal number of PEAMs than MEAMs, was seen in healthy (8/9) and Bv-FTD groups (6/6). In contrast, at T2, all people with AD and the majority of healthy adults (7/9) had more or equal number of PEAMs than MEAMs, whereas all participants with Bv-FTD had more or equal number of MEAMs than PEAMs. Table 2 displays the mean percentage of memories evoked by songs and photos for each group.

To determine any differences over time in the percentage of memories evoked, non-parametric Friedman tests were conducted for each stimuli type (Song, Photo) × group (AD, Bv-FTD, Healthy Elderly) combination separately. No significant differences between T1 and T2 were found in percentage of memories evoked by photos for any group. The AD and Healthy Elderly groups showed no significant difference in the percentage of memories evoked by songs. However, the Bv-FTD group did show a significant difference, with the percentage of memories evoked from songs increasing over time ($\chi^2 = 5.00$, $p = .025$, Kendall's W = .96).

To compare the percentage of memories evoked from songs and photos, Friedman tests were calculated for each time point (T1, T2) × group (AD, Bv-FTD, Healthy Elderly) combination separately. The only significant difference at T1 was in the Healthy Elderly group, with more memories being evoked from photos than songs ($\chi^2 = 5.44$, $p = .020$, Kendall's W = .63). While at T2 the only significant difference was in the AD group, with again more memories being evoked from photos than songs ($\chi^2 = 5.00$, $p = .025$, Kendall's W = .93).

Figure 1 shows the individual data points and distributions of percentage of memories evoked for both time points and stimuli. This figure shows that there is greater variation in percentage of MEAMs and PEAMs in the Bv-FTD group compared with the AD and Healthy Elderly groups. There is a tendency for percentage of MEAMs to increase over time in Bv-FTD participants, but decline in AD and Healthy Elderly groups, whereas PEAM percentage declines over time in all groups.

### *Familiarity and Valence Ratings of Songs and Photos*

To determine any differences over time in the familiarity ratings of songs evoking a memory, Friedman tests were conducted for each stimuli type (Song, Photo) × group (AD, Bv-FTD, Healthy Elderly) combination separately. No significant differences were found for the Bv-FTD or Healthy Elderly groups, however for the AD group, familiarity ratings of photos evoking a memory significantly decreased over time ($M_{T1} = 2.68$, $M_{T2} = 2.12$, $\chi^2 = 7.00$, $p = .008$, Kendall's W = .89).

To compare the familiarity ratings of songs and photos that evoked a memory, Friedman tests were calculated for each time point (T1, T2) × group (AD, Bv-FTD, Healthy Elderly) combination separately. Again, no significant differences were found in the Bv-FTD or Healthy Elderly groups, but in the AD group at T1 only, photos were rated as more familiar than songs ($M_{PEAMS} = 2.68$, $M_{MEAMS} = 2.44$, $\chi^2 = 6.00$, $p = .014$, Kendall's W = .95).

To determine any differences over time in the emotional valence ratings of the memories evoked, Friedman tests were conducted for each stimuli type (Song, Photo) × group (AD, Bv-FTD, Healthy Elderly) combination separately. No changes over time were found in the valence for any of the group × stimuli combinations, suggesting valence of memories was stable across time points.

To compare the valence of memories evoked from songs and photos, Friedman tests were calculated for each time

**Table 2.** Means (and standard deviations) of percentage of memories evoked (by songs and photos); familiarity ratings of all stimuli; familiarity ratings of stimuli evoking a memory; valence rating of memories evoked by stimuli.

| | AD ($n = 7$) | | | | Bv-FTD ($n = 6$) | | | | Healthy elderly (n=9) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 1 | | 2 | | 1 | | 2 | | 1 | | 2 | |
| Stimuli | Songs | Photos | Songs | Photos | Songs | Photos | Songs | Photos | Songs | Photos | Songs | Photos |
| % of memories evoked | 35.71 (13.36) | 28.57 (23.34) | 22.32 (13.91) | 28.57 (12.94) | 17.71 (23.19) | 28.12 (21.92) | 30.21 (26.04) | 19.79 (19.53) | 36.11 (15.87) | 57.64 (10.26) | 36.80 (13.78) | 51.39 (17.05) |
| Familiarity of all stimuli (/3) | 1.74 (0.34) | 2.09 (0.48) | 1.76 (0.42) | 1.90 (0.44) | 1.99 (0.18) | 2.38 (0.50) | 1.94 (0.44) | 2.18 (0.55) | 2.03 (0.30) | 2.67 (0.23) | 2.13 (0.26) | 2.67 (0.24) |
| Familiarity of stimuli evoking memory (/3) | 2.44 (0.32) | 2.68 (0.27) | 2.42 (0.61) | 2.12 (0.61) | 2.54 (0.46) | 2.83 (0.41) | 2.24 (0.80) | 2.63 (0.41) | 2.58 (0.20) | 2.735 (0.23) | 2.73 (0.28) | 2.82 (0.18) |
| Valence of memory (/3) | 2.96 (0.07) | 2.40 (0.35) | 2.68 (0.47) | 2.61 (0.35) | 2.73 (0.26) | 2.10 (0.55) | 2.83 (0.41) | 2.48 (0.53) | 2.78 (0.25) | 2.20 (0.16) | 2.90 (0.13) | 2.50 (0.33) |

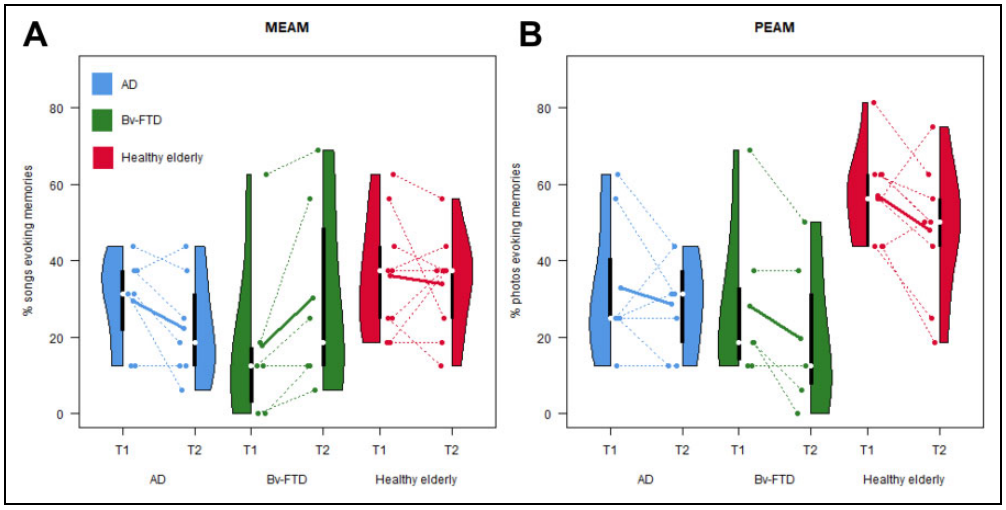


**Figure 1.** Percentage of stimuli evoking (A) Music-evoked autobiographical memories (MEAMs) and (B) Photo-evoked autobiographical memories (PEAMs) at T1 (initial visit) and T2 (6 months following the initial visit) for three participant groups. AD = Alzheimer's dementia (blue), Bv-FTD = behavioral variant frontotemporal dementia (green), Healthy Elderly (red). No significant differences were found between T1 and T2. Points and dotted lines display individual participants. Solid line shows mean change over time. Group distribution displayed as half violin plots.

point (T1, T2) × group (AD, Bv-FTD, Healthy Elderly) combination separately. At T1, all three groups showed a significant difference in the valence of memories evoked, with songs evoking more positively valanced memories than photos (AD: $M_{PEAMS} = 2.39$, $M_{MEAMS} = 2.96$, $\chi^2 = 6.00$, $p = .014$, Kendall's W = .62; Bv-FTD: $M_{PEAMS} = 2.48$, $M_{MEAMS} = 2.73$, $\chi^2 = 4.00$, $p = .046$, Kendall's W = .75; Healthy Elderly: $M_{PEAMS} = 2.20$, $M_{MEAMS} = 2.78$, $\chi^2 = 5.44$, $p = .020$, Kendall's W = .39). At T2, only the Healthy Elderly group still showed this difference ($M_{PEAMS} = 2.50$, $M_{MEAMS} = 2.90$, $\chi^2 = 4.50$, $p = .034$, Kendall's W = .43).

In addition, we examined if there was an overall relationship between percentage of memories evoked with both familiarity and valence ratings through calculating Spearman correlations for each time point separately. No significant differences were found. Figure C.3. in Appendix C shows the individual data points for Familiarity and Valence for all participants, stimulus types and time points. This figure also confirms the above finding that songs elicited more positive memories than photos, particularly at T1.

## *Stimuli Evoking Memories*

The Kruskal-Wallis tests for each of the stimuli (Photo, Song) were calculated to examine group differences (AD, Bv-FTD, Healthy Elderly) in the stability of stimuli evoking a memory as measured by the stability score (calculated as the number of songs/photos that evoked a memory at both time points, and divided by the total number of unique songs/photos that evoked a memory, as described above). The dispersion of scores were similar across the three groups. There were no significant differences in the specific music, ($H(2) = 2.23$, $p = 0.328$, $\eta^2_H = .01$), or photo stimuli, ($H(2) = 0.11$, $p = 0.949$, $\eta^2_H = .01$), that elicited memories at each time point. Participants with Bv-FTD showed the lowest stability of stimuli eliciting memories (MEAMs = 0.26, PEAMs = 0.28 compared with AD participants; MEAMs = 0.46, PEAMs = 0.46), but both groups showed similar stability across the types of stimuli. Healthy Elderly participants showed the greatest stability of stimuli, with photos having higher stability scores than songs (MEAMs = 0.51, PEAMs = 0.62). To represent this "stability of stimuli" visually, Figure 2 illustrates Venn diagrams for each participant. The blue circle shows the proportional number of songs or photos that evoked a memory at T1, with larger circles representing a larger number of stimuli. Similarly, the orange circles represent the stimuli evoking a memory at T2. The overlapping regions of each Venn diagram represent the stimuli that evoked a memory at both time points. For example, for the first AD participant's MEAMs (Figure 2, first row, first column), six memories were evoked from songs at T1 and four memories at T2, however three of these songs evoked a memory at both time points. This figure illustrates that the Healthy Elderly showed larger overlapping regions in their Venn diagrams than the AD or Bv-FTD groups, consistent with the finding that Healthy Elderly showed greater stability of stimuli that evoked memories. However, this difference was not statistically significant. Whilst this measure does not imply that the same memory is evoked necessarily, it does show when the same stimuli evoked a memory.

## *Topic of Memories*

The Kruskal-Wallis test revealed no differences across groups for the topics of memories evoked from songs at

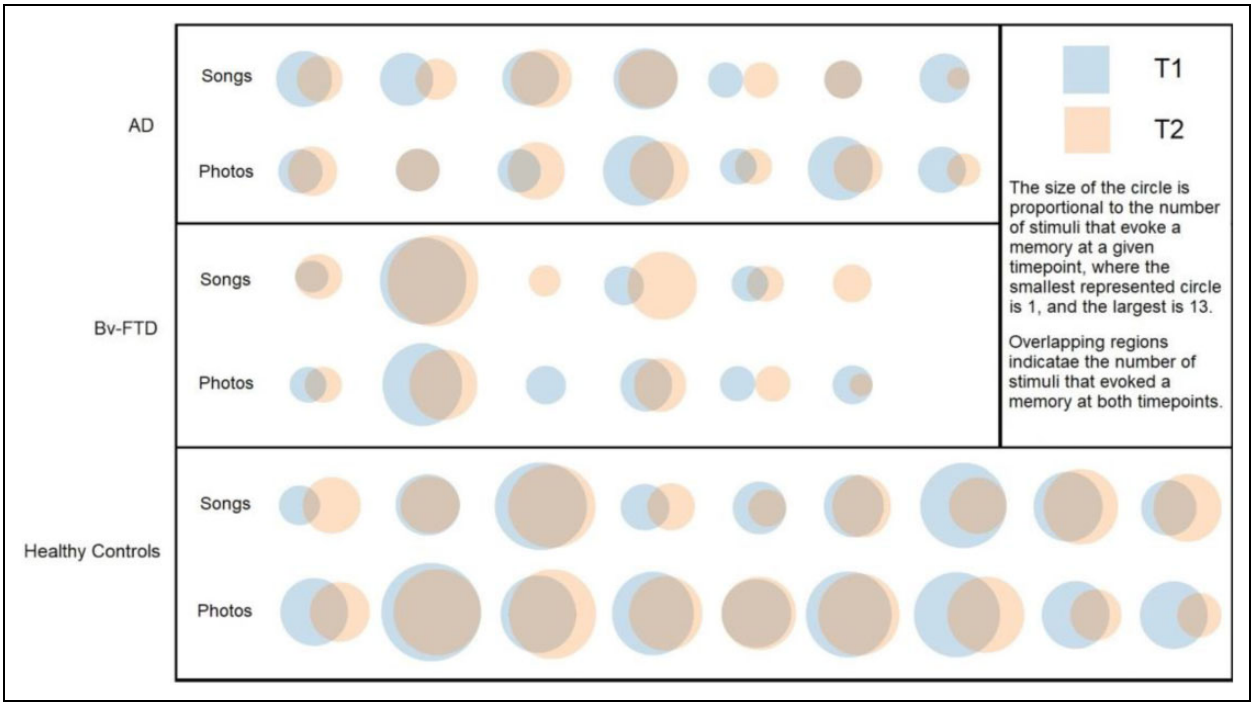


**Figure 2.** A graphical representation of the stability of stimuli in evoking a memory across all participant groups for Songs (top row) and Photos (bottom row) showing number of memories evoked at T1 (blue), at T2 (orange) and the overlap indicating when a stimuli evoked a memory at both time points. Each Venn diagram represents one participant, and their corresponding MEAM/PEAM is aligned in a column. The size of the circles is proportional to the number of stimuli that evoked memories, with the smallest circle representing 1 stimuli, up to the largest circle representing 13.

either time point ($T1_{MEAMs}$: $H(2) = 2.35$, $p < .001$, $\eta^2_H = .01$; $T2_{MEAMs}$: $H(2) = 0.16$, $p = .924$, $\eta^2_H = .001$), suggesting a similar proportion of each topic within each group. However, there were significant differences between topics of memories ($T1_{MEAMs}$: $H(3) = 27.66$, $p < .001$, $\eta^2_H = .14$; $T2_{MEAMs}$: $H(3) = 48.02$, $p = .309$, $\eta^2_H = .26$). Each group showed similar dispersion of topics. The most common topic of memory from songs across all groups was period of life ($M_{T1} = 40.3\%$, $M_{T2} = 69.1\%$). The least common topic of memory was place ($M_{T1} = 3.2\%$, $M_{T2} = 6.0\%$). The Friedman test also showed no significant difference over time for topics of memories from songs ($\chi^2 = 0.02$, $p = .893$, Kendall's W = .69). This suggests while there were differences in the topics evoked from songs, over time the topics remained stable.

For topics of memories evoked from photos, a similar pattern of results was seen. The Kruskal-Wallis test revealed no differences across groups for the topics at either time point ($T1_{PEAMs}$: $H(2) = 0.86$, $p = .650$, $\eta^2_H = .004$; $T2_{MEAMs}$: $H(2) = 5.32$, $p = .070$, $\eta^2_H = -.02$). However, there were significant differences found between topics of memories from photos ($T1_{MEAMs}$: $H(3) = 29.97$, $p < .001$, $\eta^2_H = .16$; $T2_{MEAMs}$: $H(3) = 32.36$, $p = .309$, $\eta^2_H = .17$). For photos, the most common topic of memory evoked was an event ($M_{T1} = 49.7\%$, $M_{T2} = 44.3\%$) while the least common was also place ($M_{T1} = 5.5\%$, $M_{T2} = 2.7\%$). The Friedman test showed no significant difference over time for the topics of memories from photos ($\chi^2 = 0.02$, $p = .903$, Kendall's W = .69).

Taken together these results suggest that across conditions and over time the spread of topics was stable for both memories evoked from songs and photos. Songs most often evoked memories of a period of life. In contrast, photos most often evoked memories of events.

### *Impact of Cognitive Decline*

To determine if the greater cognitive decline (total M-ACE score) observed in the AD compared with the Bv-FTD group impacted results at all, an exploratory correlational analysis was conducted. For each group, Spearman correlations were calculated between verbal fluency (FAS) change score (T2–T1), M-ACE Change score (T2–T1) and the percentage of memories evoked from songs and photos at T2. The only significant correlation found was a negative correlation for AD group between the M-ACE Change score and percentage of memories from photos ($r = -.84$, $p = .017$). This suggests AD participants who experience greater cognitive decline in M-ACE scores over the course of the study reported fewer memories evoked from photos.

## Discussion

This study addressed a major gap in our knowledge of the integrity of MEAMs over time among people with

dementia. To date, studies of MEAMs in both healthy and clinical populations have been conducted at a single assessment, precluding any understanding of whether MEAMs remain preserved over time. We investigated this issue in people with two types of dementia, namely AD and Bv-FTD, in addition to healthy elderly people. Specifically, we explored the amount and topic of MEAMs and PEAMs on two occasions, 6 months apart, using famous songs and events from the same time periods, which enabled us to date and match the stimuli according to time.

Our prediction of no difference in the frequency of MEAMs for the AD and healthy elderly groups over time was supported. This is in keeping with findings by Cuddy et al. (2017) and Baird et al. (2018), which observed a striking preservation of MEAMs in AD. However, rather than a reduced frequency of MEAMs in Bv-FTD group, as predicted, we instead found evidence for the opposite, with an increase in MEAMs found at T2 compared to T1. We found that all participants with AD and all healthy elderly people reported memories in response to both music and photos at both time points, whereas two people with Bv-FTD reported no memories to either stimuli at one time point. In addition, our prediction that the topic and stimulus evoking the memories would remain stable was supported.

In the AD group, we predicted that PEAM frequency would decline over time given the previous finding that healthy elderly people reported significantly more PEAMs compared to the AD participants (Baird et al., 2018). While there was an overall reduction in percentage of photos evoking a memory for the AD participants, this was not significant. We found that familiarity ratings for photos that evoked memories decreased over time among the AD group, but remained stable for the Bv-FTD and healthy elderly groups.

The emotional valence of the memories evoked was stable over time for all participant groups. Songs elicited more positive memories than photos across all participants, in keeping with findings from Janata and colleagues (2007), who found that emotions associated with songs that elicited autobiographical memories were more often positive than negative. This "positivity effect" in MEAMs has been explored among older adults by Cuddy et al. (2017), who found an overall positivity effect in both healthy older adults and those with AD, compared to younger adults. Likewise, our findings support the notion that MEAMs are likely a source of positive reminiscence for healthy older adults, as well as for those with AD and Bv-FTD.

We hypothesized that people with Bv-FTD would have more PEAMs than MEAMs at both time periods, given the known reliance of MEAM retrieval on medial frontal regions, and the previous finding that people with Bv-FTD reported significantly more PEAMs than MEAMs (Baird et al., 2020). This prediction, however, was not supported as Bv-FTD participants reported more MEAMs than PEAMs at the second assessment. The tendency for people with Bv-FTD to report more MEAMs at the second assessment (6 months later) is intriguing. In one willing participant with Bv-FTD, we attempted a third assessment of MEAMs at the conclusion of the second assessment session and found that his frequency increased again. While this is only a single case observation, it raises the suggestion that in people with Bv-FTD, repeated exposure to songs is required to elicit a memory. A single hearing of the song may not be sufficient to trigger an autobiographical memory in this population (see Baird et al., 2020). This is consistent with the known difficulties with autobiographical memory retrieval in people with Bv-FTD (Hornberger & Piguet, 2012) and more specifically, the integral role of the medial frontal regions in MEAMs retrieval (Belfi et al., 2018; Ford et al., 2011; Janata, 2009).

We found that across all the groups, the specific stimuli that evoked memories at T1 also did so at T2, regardless of the type of stimuli (song or photo). This suggests a stability of stimuli evoking memories over time, and is useful information for carers who may wish to use these stimuli to reminisce. We found no group differences in the topic of memories evoked by music and photo stimuli at either time point. Overall, MEAMs were typically of a "period of life" (e.g., high-school years) consistent with prior research (Baird et al., 2018, 2020; see also Janata et al., 2007). Such memories are considered to be non-specific in the sense that they represent repeated or extended events that occurred during a particular time period, rather than a specific episode. This is consistent with earlier work suggesting MEAMs are less specific than PEAMs, and more likely to comprise semantic associations, lifetime periods or repeated/extended events, while PEAMs are more likely to relate to specific events, although this could be due to the nature of the photo stimuli (Baird et al., 2018, 2020).

The limited number of participants in each group renders this investigation preliminary. The challenges of recruiting people with dementia for research are widely acknowledged (see Bardach et al., 2018). In our study sample size was also limited by death and illness in participants between T1 and T2, which is expected given the nature of this clinical population. It can also be difficult to recruit large samples of people with Bv-FTD given that it is a relatively less common form of dementia compared with AD (Warren et al., 2013). It should be noted that 6 months is a relatively short time frame for review, and progression of dementia and associated changes in MEAM/PEAM frequency may be more apparent over longer periods of time. However, previous research has documented cognitive decline in people with AD within this time frame (van Loenhoud et al., 2019) and there are inherent and substantial difficulties in retaining participants for extended time periods in this elderly and vulnerable population. Future studies on both healthy and dementia populations could examine this topic over longer time periods, possibly focusing on participants at an earlier stage of dementia.

Furthermore, although we chose "famous" song and event stimuli for the purpose of matching and dating

stimuli, this choice of stimuli may have reduced the number of memories reported in comparison with personally preferred music or photos, particularly in the dementia groups who rated the stimuli as less familiar compared with the healthy group. Previous work identified that songs from the reminiscence bump period (when people are aged 10–30 years) are most likely to elicit memories (Baird et al., 2018). Future studies could explore the phenomenon of stability of MEAMs using personally preferred or "individualized" musical stimuli (Gerdner, 2012) from the time period of the reminiscence bump to maximize the likelihood of MEAMs.

In conclusion, our findings demonstrate that the majority of people with AD and Bv-FTD experience memories in response to both music and photos. Our preliminary exploration of the integrity of these memories over time suggests that the same stimuli tend to trigger memories over time, and that such memories remain relatively stable in topic over a 6-month period. We also found that songs evoked more positive memories than photos across all participants groups, and that familiarity is related to frequency of memories, only at T2. Future longitudinal research using personally selected photo and music stimuli in people with different types of dementia could provide useful scientific and clinical insights into autobiographical memory function as dementia progresses.

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AB conceived and oversaw the study. AB and OB collected the data. RG analysed the data with input from AB and WFT. AB, RG, and WFT interpreted the findings and drafted the manuscript. All authors edited and approved the final version of the manuscript.

## Special Issue

Music and Autobiographical Memory

## Special Collection

Music and Autobiographical Memory

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## Appendix A. List of songs and photographs used in MEAMs/PEAMs task

### *Songs*

#### *1930s*

1. 1932—Cab Calloway & his Cotton Club Orchestra, "Minnie the moocher"
2. 1939—Judy Garland—Over the Rainbow

#### *1940s*

3. 1940—Glenn Miller & Joe Loss, "In the Mood"
4. 1947—Dinah Shore; Gene Autry, "Buttons and Bows"

#### *1950s*

5. 1951—Nat "King" Cole; Toni Arden, "Too Young"
6. 1959—Bill Haley & His Comets, "Joey's Song"

#### *1960s*

7. 1964—The Beatles, "I Feel Fine"
8. 1968—The Beatles, "Hey Jude"

#### *1970s*

9. 1971—Daddy Cool, "Eagle Rock"
10. 1976—ABBA, "Fernando"

#### *1980's*

11. 1985—USA for Africa, "We Are the World"
12. 1989—The B-52's, "Love Shack"

#### *1990s*

13. 1991—Bryan Adams, "(Everything I Do) I Do It for You"
14. 1995—Coolio featuring L.V., "Gangsta's Paradise"

#### *2000s*

15. 2002—Eminem, "Lose Yourself"
16. 2006—Sandi Thom, "I Wish I Was a Punk Rocker (With Flowers in My Hair)"

### *Photographs*

#### *1930s*

1. 1932—Sydney Harbour bridge opens
2. 1936—Edward VIII abdicates the British Throne for Mrs. Wallis Simpson

#### *1940s*

3. 1945—Victory over Japan Day
4. 1946—French engineer Louis Réard introduced the modern bikini, modeled by Micheline Bernardini

#### *1950s*

5. 1957—Jorn Utzon wins the competition for a design of Sydney Opera House.
6. 1958—"Bandstand", hosted by Brian Henderson, begins on television

#### *1960s*

7. 1963—Assassination of John F. Kennedy
8. 1969—Neil Armstrong and Buzz Aldrin take historic first steps on the Moon

#### *1970s*

9. 1972—Munich massacre
10. 1975—Australian Prime Minister Gough Whitlam is dismissed

#### *1980s*

11. 1981—Wedding of Charles, Prince of Wales, and Lady Diana
12. 1989—Fall of the Berlin Wall

#### *1990s*

13. 1990—Nelson Mandela is released from Victor Verster Prison, near Cape Town
14. 1997—Death of Diana, Princess of Wales in Paris.

#### *2000s*

15. 2001—9/11 attacks at the World Trade Center in New York.
16. 2005—Wedding of Charles, Prince of Wales, and Camilla Parker Bowles.

## Appendix B. MEAMs and PEAMs questionnaire

### *MEAMs*

- How familiar are you with this song?

1 ---------- 2 ---------- 3

Not at all I know it almost perfectly

- How much do you like the song?

1 ---------- 2 ---------- 3

Not at all One of my favorites

- Does this song bring to mind a memory? *Yes/No*
- Is this memory negative or positive?

1 ---------- 2 ---------- 3

Very negative Very positive

- What is the memory about?

Person/people; Place; Period of my life; A specific event; Other

*Please describe it briefly*_____

_____

---

- Can you place yourself back into this memory?

1 ---------- 2 ---------- 3

No Yes, it feels like I'm right there

Can you name the song?

---

Can you name the singer/band?

---

Can you name the year/decade that the song came out?

---

*PEAMs*

- How familiar are you with this event?

1 ---------- 2 ---------- 3

Not at all I know it almost perfectly

- Does this event bring to mind a memory? *Yes/No*
- Is this memory negative or positive?

1 ---------- 2 ---------- 3

Very negative Very positive

- What is the memory about?

Person/people; Place; Period of my life; A specific event; Other

*Please describe it briefly*_____

_____

---

- Can you place yourself back into this memory?

1 ---------- 2 ---------- 3

No Yes, it feels like I'm right there

- Can you name the event?

---

- Can you name the person/people present in the event?

---

- Can you name the year/decade that this event occurred?

---

## Appendix C. Supplementary figures

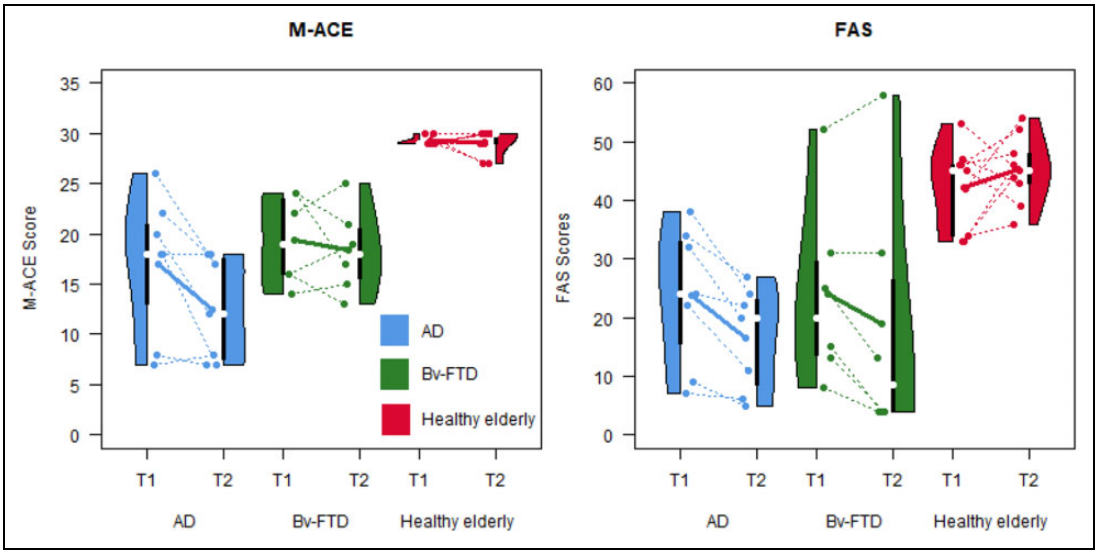


**Figure C.1.** M-ACE and FAS Scores at T1 (initial visit) and T2 (6 months following the initial visit) for three participant groups: AD = Alzheimer's dementia (blue), Bv-FTD = behavioral variant frontotemporal dementia (green), Healthy Elderly (red). No significant differences were found between T1 and T2. Points and dotted lines display individual participants. Solid line shows mean change over time. Group distribution displayed as half violin plots.

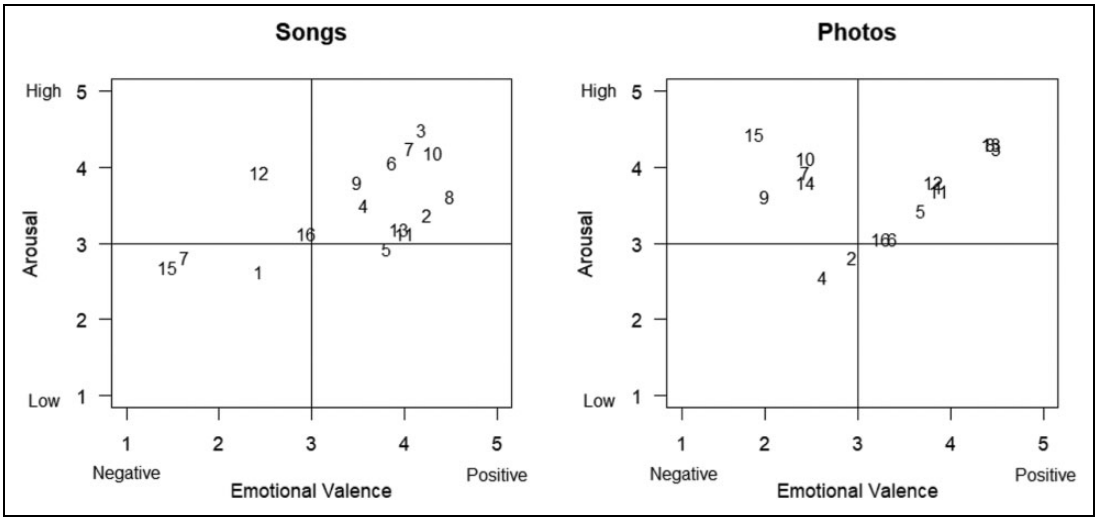


**Figure C.2.** Mean Emotional Valence and Arousal rated by independently by 16 healthy elderly adults for each of the songs and photos. The number indicates the stimulus number consistent with Appendix A. Higher valence indicates positive emotional valence whilst lower valence indicates negative emotional valence.

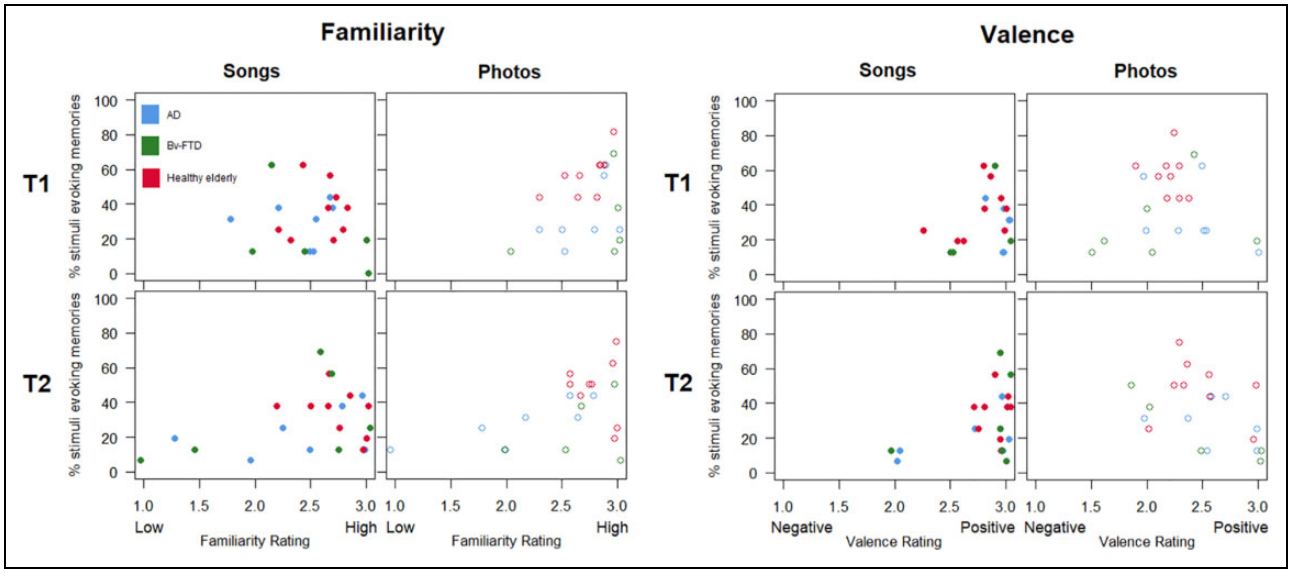


**Figure C.3.** Familiarity (Left) and Valence (Right) Ratings for individuals compared with their % of stimuli evoking memories scores at T1 and T2 from songs (solid circles) and photos (open circles). AD = Alzheimer's dementia (blue), Bv-FTD = behavioral variant frontotemporal dementia (green), Healthy Elderly (red).