

Investigating the Enhancing Effect of Music on Autobiographical Memory in Mild Alzheimer's Disease

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Key Words

Autobiographical memory • Alzheimer's disease • Music • Memory enhancement

Abstract

The enhancing effect of music on autobiographical memory recall in mild Alzheimer's disease individuals ($n = 10$; Mini-Mental State Examination score $>17/30$) and healthy elderly matched individuals ($n = 10$; Mini-Mental State Examination score 25–30) was investigated. Using a repeated-measures design, each participant was seen on two occasions: once in music condition (Vivaldi's 'Spring' movement from 'The Four Seasons') and once in silence condition, with order counter-balanced. Considerable improvement was found for Alzheimer individuals' recall on the Autobiographical Memory Interview in the music condition, with an interaction for condition by group ($p < 0.005$). There were no differences in terms of overall arousal using galvanic skin response recordings or attentional errors during the Sustained Attention to Response Task. A significant reduction in state anxiety was found on the State Trait Anxiety Inventory in the music condition ($p < 0.001$), suggesting anxiety reduction as a potential mechanism underlying the enhancing effect of music on autobiographical memory recall.

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Introduction

Memory impairment is one of the earliest presenting features seen in patients with Alzheimer's disease [1], with all aspects becoming progressively impaired. Remote memories of personally experienced events, unique to the individual, are often called autobiographical memories (ABMs). ABMs are viewed as temporary mental representations, constructed and maintained by a set of central processes such as the central executive of working memory [2, 3], typically impaired early in Alzheimer's disease. ABM is noted as being integral to self-concept and a cohesive identity [4]. Therefore, efforts to maintain ABM in Alzheimer's disease, largely neglected to date, warrant greater attention when considered in terms of the overall effect of memory loss on an individual's sense of self.

Increasing attention is being paid to non-pharmacologic interventions in the management of dementia [5], including a growing interest in music therapy and music stimulation. The impact of exposure to music on spatial abilities in healthy individuals, known as the 'Mozart effect' is a contentious issue that has been debated since the early 1990s. Rauscher et al. [6] reported that listening to 10 min of Mozart's sonata K.448 had a direct but transient effect on spatial abilities in comparison with relaxation

instructions or silence conditions. The 'trion model' of the cerebral cortex [7] was invoked to account for this effect, in that the neural firing patterns that occur during spatial-temporal reasoning were proposed to be similar to those that occur during music perception. Rauscher et al. [6] postulated that exposure to 'complexly structured' music might excite the cortical firing patterns used during spatial-temporal reasoning, exhibiting a priming-like effect which would improve performance.

However, whilst Rauscher et al. [6] continue to posit a direct link between music and spatial abilities, Thompson et al. [8] believe that the available evidence favours an explanation called the 'arousal-mood' hypothesis, with arousal and mood representing different but related aspects of emotional responding. There have been many failed attempts to replicate the original findings of Rauscher et al. [6], notably by Steele et al. [9] who concluded performance differences arose indirectly via mood/arousal changes as opposed to the distinct neurophysiological priming effect proposed by Rauscher et al. [6]. Chabris [10] conducted a meta-analysis of 16 studies on the effect of Mozart music on cognitive tasks and contended that any improvement in performance with music could be explained by the fact that the complex visual transformation processes involved in three-dimensional mental rotation and similar difficult spatial tasks are associated with the function of the right cerebral hemisphere [11], as is cognitive arousal, thus attributable to hemispheric lateralization of function. Chabris [10] concluded that a shared right-hemisphere locus provides a plausible explanation for an intermittent, small positive 'emotional arousal' effect of Mozart's music on difficult spatial tasks. Results of these studies have been mixed and often plagued by methodological issues such as selection of music, valence of music, tempo, duration of the effects of music, and the overreporting of results.

Within the dementia care setting, Koger and Brotons [12] attempted to conduct a meta-analysis of music therapy studies and found that no randomized controlled trials or trials with quantitative data suitable for analysis were available for inclusion in their review. They propose that music therapy, whilst not a standard treatment of dementia, does present a valid use affording a possible beneficial effect on symptoms, including social, emotional and cognitive skills, and for decreasing behavioural problems of individuals with dementias. However, research into this sphere to date has lacked methodological rigour, tending to rely on observational and anecdotal evidence, with results observed typically in behavioural domains most notably that of agitation and related behaviours. Ste-

fano et al. [13] found that listening to individualized music that is self-selected by the person induces relaxation via plasma signal molecule changes, consistent with the physiological changes associated with the reported actions of music such as lower blood pressure, providing a tenable account of why music exerts such calming effects on agitated patients.

Vink [14] reviewed studies in the area and found that mealtime agitation [15], agitation during bathing [16], and wandering behaviour [17] were all significantly reduced in Alzheimer patients when music therapy was employed within the care setting. Sung and Chang [18] reviewed studies of preferred music on agitated behaviours and found that only eight research-based articles met their inclusion criteria for the review. Relatively consistent findings from these articles indicate that the preferred music intervention demonstrated positive outcomes in reducing the occurrence of some types of agitated behaviours in older people with dementia. However, small sample sizes and variations in the application of the intervention would indicate that some caution is warranted in drawing conclusions from these studies. Vink et al. [19] attempted a similar review of music therapy interventions in dementia and found that only five randomized controlled trials could be included and that the methodological quality of the studies was generally poor and could not be validated or pooled for further analyses.

In summary, the majority of the studies investigating the effects of music therapy as a non-pharmacologic intervention in the treatment of dementia have focused primarily on the behavioural level, without recourse to investigating the potential effects of auditory stimulation on cognition. Grasel et al. [20] noted that the proof of effectiveness of such therapies is still lacking, as controlled, randomized studies have yet to be conducted.

However, some work has been attempted on the cognitive level, using the Mini-Mental State Examination (MMSE) as an index of cognitive functioning. A study conducted by Suzuki et al. [21] investigated the effectiveness of music therapy on cognitive functioning for patients with dementia and found that the total scores on the MMSE did not significantly change, but that the scores on the 'language' subscale improved significantly. This finding may be related to the idea of hemispheric lateralization, given the important advances made in understanding the similarities between the neural pathways involved in language and in music [22].

A further study attempting to enhance cognitive function using auditory stimulation was conducted by Foster and Valentine [23] who found that background music as

compared with quiet facilitated ABM recall in a non-selected group of individuals with mild-to-moderate dementia. They conducted a further study [24] assessing recall of ABM using a substantially modified adaptation of the MMSE and found that recall was better in sound than in silence conditions. ABM recall was also better in concurrent music as compared with cafeteria noise, suggesting the importance of structured sound. There was no difference in effects of familiar and novel music, favouring an interpretation of increased arousal or reduced anxiety as opposed to associative facilitation [24], though these were not directly investigated.

Autobiographical recall was significantly related to life era, in line with previous studies demonstrating a temporal gradient for episodic autobiographical recall in dementia [25]. Accordingly, individuals with Alzheimer's disease demonstrate significantly better retrieval from the most remote past in comparison with the more recent epochs of their lives.

Whilst certain mechanisms such as increased general arousal, anxiety reduction, and attention absorption were postulated, the study performed by Foster and Valentine [24] did not investigate the mechanisms underlying the enhancing effect of music on ABM recall. Furthermore, the substantially modified adaptation of the MMSE used in the study is not a validated nor standardized measure for assessing ABMs. Many of the questions appear to assess anterograde semantic memories rather than extending back into the remote autobiographical past of the individual.

The present study seeks to redress some of the shortcomings in previous studies by partially replicating the Foster and Valentine [24] enhancement study using a standardized and validated measure of ABM assessment. The ABM Interview (AMI) [26] is a widely used and validated measure which fractionates ABMs into personal semantics (PS) and autobiographical incidences (AI). It was predicted that the presence of background music would improve autobiographical recall on both subscales in the Alzheimer patient group and induce possible amelioration of the negative temporal gradient that is customarily exhibited in this patient group [25].

The present study further sought to investigate some of the possible mechanisms underlying the enhancing effect of music on ABM, namely anxiety reduction, heightened arousal, or increased attention. The State Trait Anxiety Inventory (STAI) [27] was included to assess predisposition to anxiety and anxiety state, given that much of the reported evidence in the literature pertains to the effect of music therapy on levels of agitation and anxiety.

Arousal was measured with the Galvanic Skin Response (GSR) technique [28], using electrodermal activity which results from sympathetic stimulation of eccrine sweat glands in the skin, leading to alteration in the conductance of an applied current [29]. Sympathetic activity is linked to both emotional and cognitive states, and electrodermal activity is widely used as a sensitive index of bodily arousal related to emotion and attention [30]. The GSR [28] has been shown to be sensitive to changes in sustained attention [31], with reduced electrodermal response to errors predicting poor sustained attention performance.

Sustained attention refers to the endogenous maintenance of an alert state in the absence of exogenous input and is facilitated by a predominantly right-hemispheric neural network [32]. The Sustained Attention to Response Task (SART) [33] was included as a measure of sustained attention, as the simplicity of this task tends to encourage a routine response set, placing heavy demands on the individual's ability to endogenously maintain the overall goal of withholding to the no-go target [31]. The sensitivity of the SART for indexing self-reports of everyday attentional failures has been documented [33], as has its activation of the right-hemisphere alertness network [34]. These tests were included to investigate possible mechanisms underlying the enhancing effect of music on ABM recall. The relationship between sustained attention and arousal is at present still under investigation. It is acknowledged that whilst the constructs may exhibit some conceptual similarities, they are measured in qualitatively different ways [35]. In the present study, they were treated as separable functions, according to this conceptual dissociation made by Sarter et al. [35].

A set of specific hypotheses were proposed regarding the potential effect of music on ABM recall and the impact (if any) on the measures of arousal, sustained attention, and anxiety that were included. It was predicted that ABM recall would be enhanced in the music condition for individuals with Alzheimer's disease, with healthy individuals potentially exhibiting a ceiling effect and thus not benefiting from the intervention. If the predominant underlying mechanism related to anxiety, the state anxiety levels were expected to be reduced in the music condition, in line with previous research demonstrating the calming nature of music interventions. If arousal is the mediating factor underlying auditory enhancement of memory recall, tonic arousal levels¹ were predicted to be increased in the

¹ Tonic arousal refers to relatively slow changes of base-level arousal, whereas phasic arousal is stimulus related, focused arousal, and more short-lived.

Table 1. Demographic and clinical characteristics on screening measures of Alzheimer individuals and controls

Characteristics	Alzheimer patients	Controls
Age	76.3 ± 7.484	76.5 ± 5.191
Gender	4 f : 6 m	5 f : 5 m
Education	9.5 ± 1.509	9.6 ± 1.265
MMSE	21.6 ± 3.718	28 ± 1.944
CDT	n/a	8.8 ± 1.398
GDS	7 ± 5.142	4 ± 2.625

Screening measures used are as follows: Mini-Mental State Examination (MMSE), the Clock-Drawing Test (CDT), and the Geriatric Depression Scale (GDS). For 'age' and 'education', values denote the mean number of years.

music stimulation condition, thus facilitating performance on the SART, whereby participants would exhibit less of the customary attentional lapses commonly noted on this task. It was expected that clear differences would be observed on one or more of these subtasks in order to extrapolate regarding the mediating mechanism that underlies the enhancing effect of auditory stimulation on cognition.

Subjects and Methods

Study Participants

As this is a preliminary investigation, a convenience sample of 10 individuals with mild Alzheimer's disease (MMSE scores 17–28²) and 10 non-cognitively impaired elderly individuals (MMSE scores 25–30) were recruited (table 1). Individuals with Alzheimer's disease were recruited through Mercer's Institute for Research on Ageing in St. James's Hospital, Dublin, where they attended the memory clinic for diagnoses, clinical management, and follow-up assessments. Patients met the NINCDS-ADRDA criteria for probable Alzheimer's disease [36], and diagnosis was established on the basis of multidisciplinary consensus. Exclusion criteria for Alzheimer individuals were significant depression (>15/30 on the 30-item Geriatric Depression Scale; GDS) [37] or scoring <17/30 on the MMSE [38].

The convenience sample of control participants consisted of 10 healthy elderly individuals, living independently in the surrounding community, who were recruited from a cohort of willing volunteers who had either taken part in previous research in the memory clinic or were recruited from a local active retirement group. These in-

dividuals were screened prior to testing, using the MMSE (score ≥ 25) and the Clock-Drawing Test (CDT; score ≥ 8) [39] to exclude significant cognitive impairment. One control individual had some difficulties on the CDT but scored 26/30 on the MMSE and was thus included. Any individual scoring >15 on the GDS was excluded.

Materials and Methods

Screening Measures

The MMSE [38] was used as a brief screening tool to assess the overall level of cognitive functioning of patients and controls. The CDT was used as an additional screening tool for healthy elderly individuals and was scored according to the 10-point system of Manos [39]. The GDS [37] is a screening test for depression in the elderly, comprising 30 statements that probe how an individual has been feeling in the last few weeks.

Test Materials

State Trait Anxiety Inventory

This test [27] differentiates between state anxiety (A state) and trait anxiety (A trait). State anxiety can fluctuate over time and across conditions in contrast to trait anxiety which reflects relatively stable individual differences in anxiety proneness. The inventory consists of 20 statements for both schedules (state and trait) which are rated according to how frequently they are experienced.

Autobiographical Memory Interview

The AMI [26] is widely used as a validated measure of autobiographical memory in elderly populations. This consists of a semi-structured interview which probes memories over the course of three life periods: childhood, early adult life, and recent life. Questions pertaining to major life events such as educational history, employment history, wedding, birth of one's children, a recent holiday, or a recent funeral attended are asked. The present study employed modifications recommended by Greene et al. [25], whereby the 'Recent Section' of the AMI is scaled back to assess memories within the last 5 years. It is argued that this modification is more likely to assess events that occurred prior to the onset of an insidious anterograde deficit common in Alzheimer's disease [25].

Galvanic Skin Response Technique

The electrodermal activity was measured using the BIOPAC Student Lab system [28]. Skin responses were recorded from the fingertips of the index and middle fingers of the participants' non-dominant hand. Two Ag/AgCl electrodes, mounted in individual housings and shielded to avoid noise interference, were attached to the fingertips by a Velcro strap. Multipurpose gel ('Signa Gel') was used as the electrolyte. Incoming skin response signals were converted to digital signals via an MP30 data acquisition unit and were processed using BIOPAC Student Lab software on a Dell PC.

Sustained Attention to Response Task

The SART is a computerized measure of supervisory attentional control, with well-documented reliability and validity [33]. The SART consists of a 4.387-min session, during which 225 single digits from 1 to 9 are presented centrally on the computer screen. Each digit is presented 25 times and displayed on screen for 250 ms, followed by a 900-ms 'mask' consisting of a circle with a diagonal cross. On 'go trials', the participants were required to press the com-

² The overlap in MMSE scores between individuals with Alzheimer's disease and healthy elderly individuals reflects the fact that a number of Alzheimer individuals were in the very early stages of the disease.

puter mouse for all digits (1–9), with the exception of the number '3'. The no-go target (number '3') was presented a total of 25 times with a regularly paced 1,150-ms period from digit onset to the next digit onset. The Fixed-Sequence SART is considered to be a relatively pure measure of endogenous sustained attention due to its rhythmic and predictable presentation of stimuli in fixed order from 1 to 9 and was used in this study. Digits were presented in one of five randomly assigned font sizes: 48 point, 72 point, 94 point, 100 point, and 120 point. The participants used the computer mouse to respond to targets. Performance was analyzed in terms of accuracy (errors of omission – failing to make a response on a 'go trial'; errors of commission – failing to withhold a response on a 'no go trial') and reaction times.

Vivaldi's first movement 'Spring' from 'Four Seasons' was used as the background auditory stimulation in this study. This particular piece of music was chosen, because it was shown to elicit robust enhancing effects on cognition in the studies performed by Foster and Valentine [23, 24] mentioned previously. The piece was recorded by the Lucerne Festival Strings Orchestra and conducted by Rudolf Baumgartner [40]. The Spring Movement ('La Primavera'), otherwise referred to as Concerto No. 1 in E major, has a duration of 10:11 min, and is divided into three movements with a slow movement between two faster movements as follows: *allegro* (3:22) – *largo* (2:47) – *allegro* (3:55). *Allegro* is taken to mean 'moderately fast', whilst *largo* denotes that a piece is slow.

This musical piece had been rated using 5-point scales (where 1 is lowest and 5 is highest) in a previous study [24] for hedonic tone (3.3), energetic arousal (3.7), and tense arousal (3.5). The music was played ambiently during the test session on an LG CD/cassette recorder (model No. 323A), at a distance of approximately 1 m from the participants.

Cognitive Screening

The MMSE [38] was administered to assess the degree of cognitive functioning of participants, followed by the GDS [37]. In addition, the CDT was administered to healthy elderly control participants only.

Order of Testing

The order of music and silence conditions was counterbalanced in order to reduce order effects and practice effects particularly for healthy elderly control individuals. Every odd-numbered control individual (i.e., 1, 3, 5, 7, 9) was seen in the order of silence for session one and music for session two, with the order reversed for all remaining controls. This pattern was reversed for individuals with Alzheimer's disease. All participants were seen on two occasions (silence and music) at the same time of day, exactly 1 week apart.

Testing Procedures

The trait subscale of the STAI [27] was administered first, providing a measure of the individual's predisposition to anxiety. All 20 statements were read aloud to the participants who then rated the frequency of each statement with an emphasis on how they generally feel (i.e., trait, not current state).

In the music condition, the researcher began playing the 'Spring' movement from Vivaldi's 'Four Seasons' on the LG cassette recorder at a volume level of 3 out of a maximum of 20 which can be equated roughly to 40–50 db [41]. This volume level was predetermined by the experimenter as being audible yet not impeding participation in the experimental tasks nor hindering communication

between experimenter and participants, given that normal conversation is equated to 60–70 db [41]. The music was played ambiently throughout the test setting, as a background stimulus. As the musical piece lasts for approximately 10 min, it was played on a loop for the duration of the test session.

The non-dominant hand was used to measure electrodermal activity using the GSR technique. Electrodermal activity recordings took place roughly 5 min after the electrodes had been applied, to allow for hydration. Prior to each recording session, the GSR was calibrated to establish the BIOPAC hardware's internal parameters and to ensure that a change in skin response had been recorded. The silence condition proceeded as above, with the affixing of electrodes and calibration of the GSR all being completed in silence.

The AMI [26] was then administered, during which the tonic amplitudes of electrodermal activity for each participant were recorded. The occurrence of questions was manually logged onto the GSR wavelength as an indication of potential changes in electrodermal activity. ABM questions were called out by the researcher, and all responses were transcribed. There were no time limits imposed on participants. Verbal prompts were given by the researcher, according to standardized instructions [26].

Once the AMI had been completed, the state subcomponent of the STAI was administered to measure current level of anxiety state.

The SART [33] was then completed with participants given a description of the task and practice trial. The GSR was calibrated over a 10-second period prior to SART data collection. During the task, the occurrence of no-go targets ('3' stimulus) was manually logged by the researcher onto the GSR wavelength. The entire test session lasted for approximately 45 min.

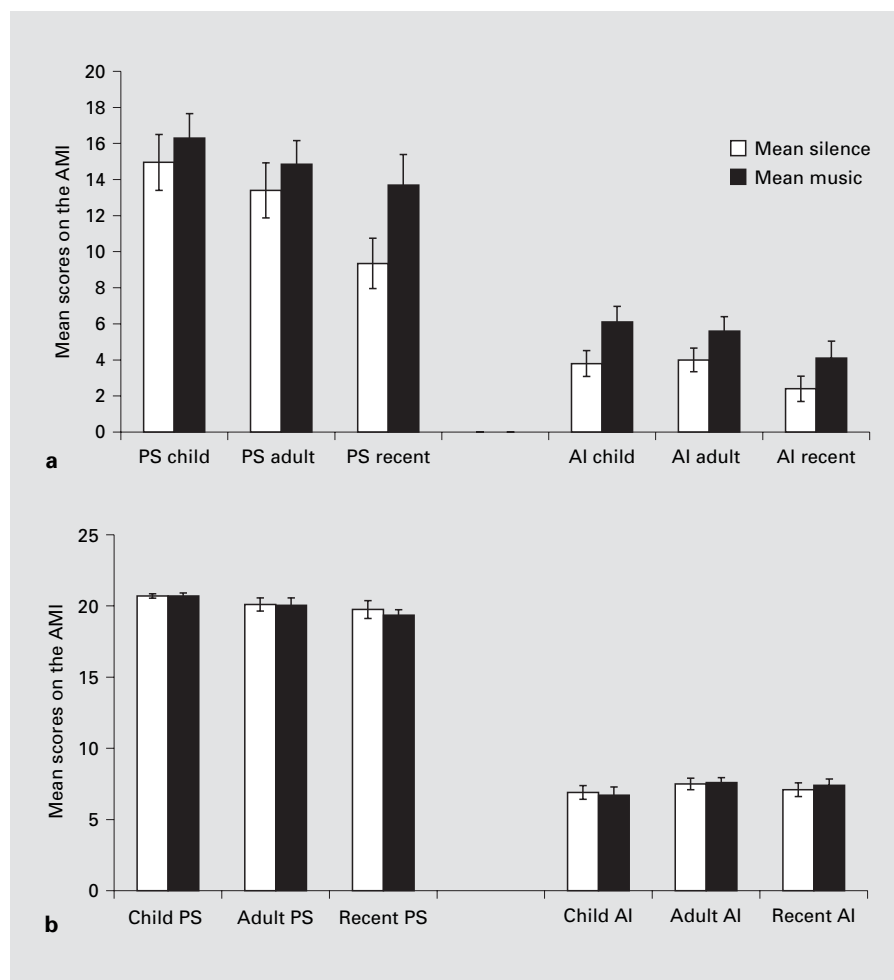
Analyses of GSR Data

GSR analyses were calculated on the basis of 9 participants' recordings in each group due to a technical failure of equipment. Electrodermal responses were analyzed as follows: For analysis of *tonic* (baseline) arousal during the AMI, an overall average of electrodermal activity was taken from the GSR wavelength. For analysis of *phasic* (response-driven) arousal changes during the SART, the rate of spontaneous, non-specific skin responses per minute of at least 0.02 m/ Ω mean amplitude was recorded, as documented in the literature [42]. For each 'no-go' target (presentation of the '3' stimulus), a latency window of 1–4 s after stimulus onset was specified. Measurement of the amplitude of skin conductance rate was taken as the conductance at the peak minus the conductance prior to the response, as defined by Stern et al. [43], referred to as the 'peak-to-peak' values (P-P). Amplitude measurements were thus recorded for skin conductance rates to correct withholds and errors of commission on the SART task.

Statistical Analyses

Data were analysed in SPSS using independent-samples *t* tests and a series of one-way and mixed-factorial analyses of variance. In cases of a lack of sphericity, Greenhouse-Geisser correction was used. The between-groups factor was group (with levels patients and controls). The within-group factors were condition (music and silence), life period (child, adult, recent), memory type (PS, AI), and anxiety (state, trait). For the SART sustained attention task, the within-groups factor was trial type ('go' trial, 'no-go' trial). An analysis of covariance was also carried out using covarying factors of 'state music' and 'state silence'.

Fig. 1. a Mean recall performance of individuals with Alzheimer's disease on the AMI in both music and silence conditions. Personal semantic recall (PS) and autobiographical Incident recall (AI) are broken down by life epochs of childhood, adulthood, and recent. **b** Mean recall performance of healthy elderly individuals on the AMI in both music and silence conditions. Personal semantic recall (PS) and autobiographical Incident recall (AI) are broken down by life epochs of childhood, adulthood, and recent. Error bars refer to the SEM.



Results

Demographics

Demographic and clinical characteristics are shown in table 1. Alzheimer individuals and healthy elderly control individuals were matched, with no significant differences in terms of age [$F(1,18) = 0.005$; $p > 0.05$], gender [$F(1,18) = 0.202$; $p > 0.5$], years in formal education [$F(1,18) = 0.026$; $p > 0.5$], and depression scores as assessed by the GDS [$F(1,18) = 2.7$; $p > 0.05$]. The Alzheimer disease group scored significantly lower than the healthy elderly group on the MMSE [$F(1,18) = 23.273$; $p < 0.001$].

Overall Performance on the AMI

On inspection of figure 1, it is evident that there were clear differences in performance between participant groups, with healthy elderly individuals significantly outperforming Alzheimer individuals in silence and music

conditions. The mean total recall on the AMI (PS + AI scores) in the silence condition for healthy elderly individuals was 82.05 as compared with a mean total recall of 47.9 for Alzheimer individuals ($t = 5.871$; d.f. = 18; $p < 0.001$). In the music condition, healthy elderly individuals had a mean total AMI recall of 81.88 as compared with a mean total AMI recall of 60.65 for individuals with Alzheimer's disease ($t = 3.609$; d.f. = 18; $p < 0.005$). The between-group differences remained significant when total PS and total AI scores were considered separately.

There was a significant interaction for condition by group [$F(1,18) = 10.676$; $p < 0.005$], with Alzheimer disease individuals demonstrating a marked improvement in total AMI recall specifically during the music condition. There was no improvement in total AMI recall for healthy individuals in the music condition as compared with the silence condition ($t = 0.810$; d.f. = 9; $p > 0.05$).

Table 2. Mean autobiographical memory interview recall scores of participants across life epochs in music and silence conditions

	Child PS	Adult PS	Recent PS	Total mean PS	Child AI	Adult AI	Recent AI	Total mean AI
Alzheimer silence	14.95 ± 1.55	13.4 ± 1.53	9.35 ± 1.39	37.7 ± 3.99	3.8 ± 0.71	4 ± 0.65	2.4 ± 0.70	10.2 ± 1.66
Alzheimer music	16.3 ± 1.36	14.85 ± 1.31	13.7 ± 1.69	44.85 ± 4.01	6.1 ± 0.86	5.6 ± 0.79	4.1 ± 0.95	15.8 ± 2.12

Mean recall scores ($\pm$ SEM) for both Alzheimer individuals and healthy elderly individuals on personal semantic (PS) and autobiographical incidence (AI) scales of the Autobiographical Memory Interview, across the three life epochs.

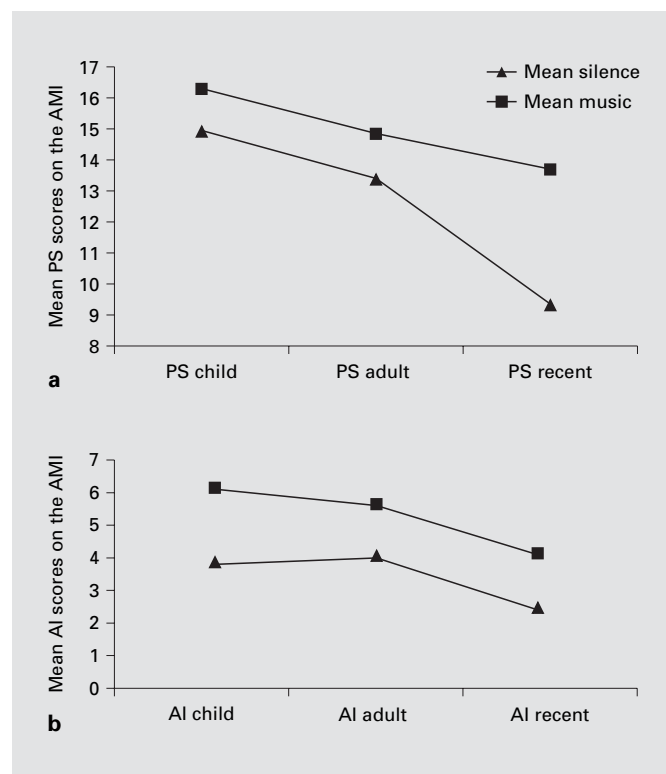


Fig. 2. a Mean personal semantic (PS) recall of individuals with Alzheimer's disease on the AMI across the life epochs of childhood, adulthood, and recent in music and silence conditions. **b** Mean autobiographical incident (AI) recall of individuals with Alzheimer's disease on the AMI across the life epochs of childhood, adulthood, and recent in music and silence conditions.

PS Recall

Temporal Gradient

Figure 2a demonstrates the negative temporal gradient exhibited by individuals with Alzheimer's disease in ABM recall in the silence condition. There was a significant difference in terms of PS recall across the three time periods [$F(1,18) = 9.018$; $p < 0.005$]. A clear reduction in

the number of PS memories recalled from childhood through adulthood to recent memories was found (see table 2). Figure 2a highlights the amelioration of the negative temporal gradient in the Alzheimer individual group during the music condition, resulting in gentle leveling off in ABM recall, particularly on the PS schedule (table 2).

Music versus Silence

For total mean recall of PS memories, there was a significant improvement in recall in the music condition [$F(1,18) = 12.537$; $p < 0.005$], with an interaction for condition by group [$F(1,18) = 16.132$; $p < 0.001$]. Only the Alzheimer individuals' scores were elevated in the music condition (table 2). Figure 2a shows the improvement in AMI scores across the three time periods for individuals with Alzheimer's disease in the music condition as compared with the silence condition ($t = -4.921$; d.f. = 9; $p < 0.001$). A significant difference for personal semantic recall in the music condition was found [$F(1,18) = 15.675$; $p < 0.005$] along with an interaction effect for time period by condition [$F(1,18) = 5.419$; $p < 0.05$], whereby the recall of 'recent' personal semantic memories was significantly enhanced in the music condition for the patients (see table 2).

AI Recall

Temporal Gradient

For AI, there was a clear difference in Alzheimer individuals' recall across the three time periods [$F(1,18) = 5.208$; $p < 0.05$], highlighting the temporally extensive nature of the recall gradient (see fig. 2b). The emergence of a 'reminiscence bump'³ in the recollections of Alzheimer individuals' AI from the early adulthood lifetime period was also noted (see table 2).

³ Reminiscence bump – preferential recall of memories from the period of 10–30 years of age [44].

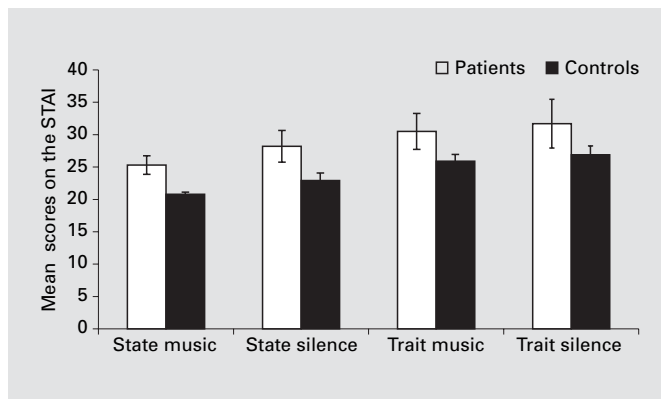


Fig. 3. Mean trait and state anxiety scores for healthy elderly and Alzheimer groups in music and silence conditions. Error bars refer to the SEM.

Music versus Silence

A significant interaction was found for AI recall by group [$F(1,18) = 5.651$; $p < 0.05$], with only the Alzheimer individuals scoring significantly higher on the AI schedule in the music condition. During the music condition, there was a significant difference in Alzheimer individuals' AI recall across the three time periods [$F(1,18) = 5.208$; $p < 0.05$] and a notable effect for condition on recall. The mean AI recall of 10.2 in the silence condition rose to 15.8 in the music condition [$F(1,18) = 19.279$; $p < 0.005$]. However, there was no significant interaction for time period $\times$ condition, indicating that music did not exert any interaction effect on AI recall specific to any one epoch [$F(1,18) = 0.239$; $p = 0.790$]. During the music condition, an attenuation of the reminiscence bump on the autobiographical incident schedule was found (see table 2).

Anxiety Reduction

Figure 3 shows state anxiety and trait anxiety scores for individuals with Alzheimer's disease and healthy elderly individuals across music and silence conditions. There was no difference in trait anxiety scores between groups [$F(1,18) = 2.179$; $p = 0.157$] or across test sessions [$F(1,18) = 0.531$; $p = 0.475$].

Scores on the state subscale of the STAI revealed reductions in the music condition as compared with the silence condition for both groups [$F(1,18) = 4.279$; $p = 0.053$]. This reduction in state anxiety was significant only for individuals with Alzheimer's disease with mean state anxiety scores of $28.2 \pm (\text{SEM}) 2.46$ (confidence interval 23.38, 33.02) in the silence condition and 25.3 ± 1.43

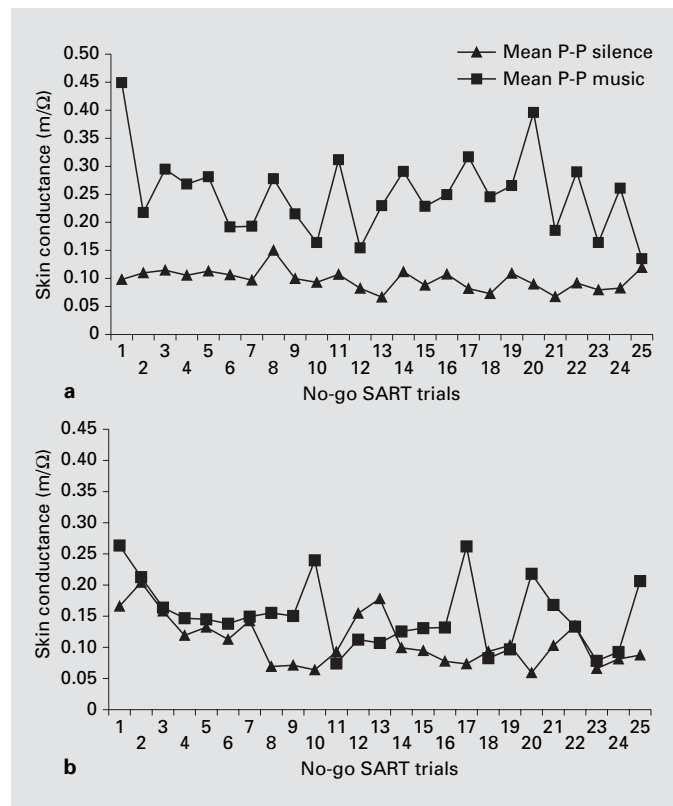


Fig. 4. a Healthy individuals' average phasic skin conductance response to no-go trials (presentation of the '3') on the SART in music and silence conditions. **b** Alzheimer individuals' average phasic skin conductance response to no-go trials (presentation of the '3') on the SART in music and silence conditions.

(confidence interval 22.50, 28.10) in the music condition [$F(1,18) = 7.187$; $p < 0.05$].

Arousal

Changes in GSR mean amplitude for patients and controls during the music and silence conditions on the AMI were not found to be significantly different [$F(1,18) = 0.953$; $p = 0.344$], nor was there any main effect for condition [$F(1,18) = 1.018$; $p = 0.328$].

Figure 4 depicts the average phasic skin conductance response of healthy elderly controls (fig. 4a) and Alzheimer individuals (fig. 4b) following presentation of the '3' stimulus (no-go trial) during the SART. The analysis of these mean amplitudes for GSR recordings during the SART for both participant groups across conditions revealed no observable differences in terms of arousal for Alzheimer individuals. There was a difference approaching significant levels between participant groups

[F(1,18) = 4.256; p = 0.056]. Healthy elderly individuals exhibited lower levels of arousal during the SART-music condition, whereas Alzheimer's individuals' arousal levels remained constant across test sessions.

Attention

Omission Errors

Analysis of the mean number of omission errors (failure to respond on a 'go trial') made on the SART revealed that individuals with Alzheimer's disease made more omission errors (36.20 ± 8.48 SEM) as compared with healthy elderly individuals (16.8 ± 5.24 SEM) in the silence condition [F(1,18) = 5.184; p < 0.05]. Between-group differences across conditions were not significant [F(1,18) = 0.143; p = 0.710].

Commission Errors

There was no difference between participant groups on errors of commission (failure to withhold response on a 'no-go trial') during SART performance [F(1,18) = 0.669; p > 0.1] (see table 3). Furthermore, there was no main effect for music on numbers of errors of commission made for both groups [F(1,18) = 0.803; p = 0.382].

Average Reaction Times

There was no main effect of music between the two groups in terms of change in mean reaction times [F(1,18) = 2.256; p = 0.154] (see table 3). However, individuals with Alzheimer's disease exhibited a reduction in reaction times in comparison with controls, when music was present in session 1, whereas the reaction times for healthy elderly individuals were lower in the 'silence first' condition. Conversely, individuals with Alzheimer's disease tended to make slower responses (i.e., increased reaction times) in the 'silence first' condition, whereas healthy elderly individuals showed an increase in response latency in the 'music first' condition. This interaction of reaction time by condition by order of presentation was observed to be statistically significant [F(1,18) = 4.552; p < 0.05]. Although the individuals with Alzheimer's disease exhibited a quickening of response times during the music condition, this did not affect their error rates, as there was no significant difference across conditions in errors of omission and errors of commission, as previously discussed.

Analysis of Covariance

A potential mechanism to consider underlying the enhancing effect of music is that pertaining to state anxiety levels. There was a significant main effect for condition on ABM recall [F(1,18) = 24.218; p < 0.001]. An analysis of

Table 3. Breakdown of average performance of participants in terms of omission and commission errors and reaction times on the SART in music and silence conditions

	Omission errors	Commission errors	Average RT ms
Alzheimer			
Silence	36.20 ± 8.48	8.8 ± 2.24	478.16 ± 30.57
Music	37.70 ± 9.24	6.2 ± 1.84	474.72 ± 24.61
Controls			
Silence	16.8 ± 5.24	4.4 ± 2.15	418.07 ± 47.96
Music	17.70 ± 4.47	5.6 ± 1.82	488.87 ± 38.10

Mean errors of omission and commission (± SEM) for both participant groups. The average reaction times (RTs) for responses on 'go trials' are presented.

covariance revealed that this main effect for music was rendered non-significant, when the covariates of 'state music' and 'state silence' were included in the analysis [F(1,18) = 1.401; p = 0.275]. This suggests state anxiety reduction as a potential mechanism underlying the enhancing effect of music on ABM recall.

Discussion

The present study found a significant improvement in ABM recall for individuals with Alzheimer's disease during a background music condition as compared with silence, replicating the earlier findings of Foster and Valentine [24].

As predicted, healthy elderly individuals and Alzheimer individuals differed in terms of ABM recall in both music and silence conditions. Healthy elderly individuals attained near-ceiling scores on the AMI. There was little evidence of a negative temporal gradient in ABM recall for the healthy elderly group on both components (PS and AI) of the AMI, contrasting with the clear reduction of memories in the Alzheimer group, extending back from recent times through to adulthood and childhood.

The presence of background music provided amelioration to a significant degree of the negative temporal gradient on the personal semantic schedule, most notably on the 'recent events' subsection. This contrasts with the findings of Foster and Valentine [24] who did not find such enhancement for recent memories.

The emergence of a negative temporal gradient for Alzheimer individuals on one subscale of the AMI but not

the other provides robust evidence for the fractionation of ABM into PS and AI subcomponents. However, this temporally graded recall was found to occur only on the personal semantic scale of the AMI, contrasting with some previous findings [25], while consistent with others [45]. Autobiographical Incident memory has all the features of episodic memory, whereby a specific personal incident is time and context specific and has to be reconstructed [25]. Personal semantic memory is by contrast more similar to general semantic memory. Kazui et al. [45] arrived at similar conclusions, when they found that 25 individuals with Alzheimer's disease manifested a prominent temporal gradient for their recall of personal semantic memories on the Family Line Test. Greene et al. [25] used a stratified sample of minimal and mild Alzheimer participants, with MMSE scores ranging from 24–30 and 17–23, respectively. Therefore, the results of the present study may reflect a difference in dementia severity, possibly performing at an intermediate level between the minimal and mild Alzheimer groups described by Greene et al [25].

Individuals with Alzheimer's disease tended to improve by an average of 5.6 points on the autobiographical incident scale in the music condition, with an observed concomitant slight increase in the duration of the memory interview in the music condition, suggesting that these participants may have spoken for longer. A possible reason for this differential pattern of ABM enhancement may arise from the fact that autobiographical incident memories seem more amenable to probing via the use of the recommended prompts proposed by Kopelman et al. [26]. Personal semantic memories comprise a set of all-or-nothing responses, whereby patients readily offered the information, if it was easily accessible, yet did not engage in a lengthy recollection process for the desired information, if it could not readily be brought to mind. This may explain the variation in results on the two AMI subscales, whereby music may evoke a willingness to engage in a more active and thorough reminiscing endeavour for AI memories.

This study has demonstrated a significant enhancing effect for music on ABM recall. It also sought to investigate possible mechanisms by which music might evoke such improvement. A significant reduction in state anxiety levels in the music condition was found, suggestive of an anxiety reduction mechanism. When the covariates of state music and state silence were included in the statistical analysis, the enhancing effect of music dissipated, adding further weight to the hypothesis that anxiety reduction was associated with improved autobiographical recall.

The modulation of arousal was also suggested as a potential mechanism [24], yet GSR analyses did not reveal any significant effect across conditions during the AMI. Interestingly, there was a significant difference between individuals with Alzheimer's disease and healthy elderly individuals in terms of arousal during sustained attention performance. Healthy elderly individuals exhibited lower fluctuations in phasic or response-driven skin conductance levels during the SART in the music condition as opposed to Alzheimer individuals whose arousal response levels stayed relatively constant across test sessions. Khalifa et al. [46] argued that arousal changes in response to musical stimuli are more of a phasic nature, and thus continuous background noise, as presented in the current study, is unlikely to elicit significant changes in baseline (tonic) arousal levels. It could be informative to investigate the impact of brief bursts of musical stimuli on the phasic arousal levels of Alzheimer individuals and its relative impact, if any, on cognitive task performance.

Reaction times of healthy elderly individuals on the SART tended to increase in the music condition, indicating that background music may have lowered arousal below optimal levels. If a certain threshold of arousal is optimal for efficient sustained attention performance, in accordance with the Yerkes-Dodson curve [47], a distinct possibility is that such healthy elderly participants felt overly relaxed to cope efficiently with the task's parameters and thus exhibited longer response latencies and lower tonic levels of arousal. The lack of a notable effect of music on arousal would add to the validity of the anxiety mechanism postulated above. Further research should take into account the possibility of evoking an optimal level of arousal by varying background levels of music possibly via manipulations of tempo of the musical piece. Recent studies have suggested that the Mozart effect is attributable to 'enjoyment arousal' [10], in that Mozart music instantiates the optimal level of arousal necessary for enhanced performance on spatial-temporal tasks [21]. It would be interesting to replicate the present study using the widely cited Mozart sonata K.448 in an attempt to evoke this optimal level of arousal and investigate whether it has any bearing on autobiographical memory recall.

Foster and Valentine [24] proposed that music may exert its enhancing effect via an 'attention absorption' mechanism, whereby the auditory stimulus in the music condition masks potentially distracting, extraneous stimuli or absorbs surplus attention that might otherwise divert attention away from the primary task. In the present study, individuals with Alzheimer's disease were found to make significantly more errors of omission on the SART than

healthy elderly individuals and tended to exhibit long lapses or attentional drift in responding to the go targets, suggestive of a working memory deficit characteristically seen in Alzheimer's disease [2]. As a measure of sustained attention in elderly populations, the SART may not be the most reliable instrument, as the trials may be too rapid for accurate responses. A late response on a go trial may be carried forward to the presentation of the following stimulus and logged incorrectly as a swift response. A self-paced version of this test or a version with slower rates of presentation of stimuli may prove more reliable within an elderly population.

A further issue to consider regarding the SART concerns the issue of functional lateralization. As previously mentioned, SART's activation of the right-hemisphere alertness network has been well documented [34]. Peretz [48] contends that music is not a monolithic entity that can be ascribed as a whole to one particular hemisphere, but rather comprises a set of components that can be dissociated into different lateralizations and patterns. Although identification and recognition of a musical piece involve both hemispheres, the integrity of the left hemisphere is critical [49]. Platel et al. [50], using positron emission tomography, found that activations for familiarity, pitch, and rhythm were preferentially in the left hemisphere, whilst activations for timbre were found in the right hemisphere. This points towards a possible asymmetry in potential optimization of function during music stimulation studies, with a variety of factors implicated in the effects of the musical piece chosen on functions lateralized to the right or left hemisphere. There were some indications that individuals with Alzheimer's disease may have spoken for a longer duration during the music condition on the AMI, giving rise to more detailed recall of ABMs. The AMI is an exclusively verbal task, and likely relies on left-hemisphere functions, possibly proving more amenable to stimulation via the familiar music intervention than the SART. Perhaps alternative pieces of music that vary in pitch and timbre could induce predominantly right-hemispheric activation which in turn could have enhancing effects on tasks such as the SART, also contingent on right-hemisphere integrity [34]. This area of hemispheric lateralization in relation to the composition of a musical piece and accompanying neural substrates is one that requires further investigation.

A number of methodological issues in relation to the present study warrant consideration. As mentioned previously, healthy elderly individuals tended to attain near-ceiling scores on the AMI, suggesting that more open-ended tests such as Autobiographical Fluency [51] might

be better suited to investigate whether music can exert an enhancing effect to some degree on the recall of non-cognitively impaired elderly participants. As the AMI is largely interview based, there was a potential for bias effects such as participant expectations and experimenter bias. Such effects were considered to be minimal given the study sample consisted of individuals with Alzheimer's disease who, by definition, exhibit significant memory impairment. Furthermore, the tests were administered by a trained psychologist who was aware of the potential for such bias. Nevertheless, a double-blind procedure for both administration of the interview and scoring of ABMs elicited would be the preferable methodological approach. The veracity of memories elicited could be called into question due to the documented increase in false memories among the elderly [52]. However, Kopelman et al. [26] found that cross-checking memories elicited on the AMI with carers, spouses, and family members showed there to be high validity of veracity using this measure.

Given the relatively small number of participants in this pilot study, the findings reported are preliminary. Further research is needed to elucidate the precise mechanism underlying the enhancing effect of music on ABM. There are well-documented links between mood and memory [53], yet the role of mood effects were not investigated in the present study. The area of associative facilitation also requires further research, whereby the possibility of using individualized music with personal relevance and meaning to participants is used, in an attempt to evoke a facilitation related to specific eras or epochs in the participants' lives, potentially inducing optimal anxiety reduction in Alzheimer disease patients who are prone to agitation.

The choice of music used as a background stimulus raises further questions regarding the generalizability of results from the present study. Further replications of this study are warranted to determine whether the present results are specific to the Vivaldi piece used or can be extrapolated to classical music in general. It would be interesting to ascertain whether similar effects could be produced by using various selections of music that differ in terms of tempo, valence, etc. Inclusion of a measurement of emotional arousal such as the Profile of Mood States [54] in the present study could have helped to ascertain if the music intervention exerted any effects on broader aspects of participants' mood. Steele et al. [9] attempted to replicate the Mozart effect and included the Profile of Mood States to assess the effect of music on mood and arousal. Although there was no increase in spatial temporal capacities, Steele et al. [9] found an effect on mood

scores. Walter et al. [55] argued that in good moods, performance increases for assimilative memory tasks such as free recall as opposed to accommodative memory tasks such as recognition. Walter et al. [55] thus predict better recall for material encoded in a positive emotional context, in accordance with the literature on mood-congruent memory effects [53]. Walter et al. [55] further propose that memory performance will be maximal when stimuli are pleasant (content) and mood is positive (context) and the task is an active, productive one (cognitive style). When considered within the domain of auditory stimulation, selection of the musical piece becomes of paramount importance. Schmidt and Trainor [56] have shown that patterns of frontal EEG activity reflect the valence of music as well as its ability to induce arousal, with increased left-frontal EEG activity associated with pleasant music, whereas right-frontal EEG activity is associated with unpleasant music. Nantais and Schellenberg [57] refer to the Mozart effect as an 'artifact of preference', indicating the importance of the arousing and enjoyable properties of the musical piece. Whether or not these enhancing effects of music are transient, possibly resulting in habituation, also requires investigation.

The current study has found that musical stimulation and enhancement of ABM are associated with concomitant reductions in anxiety levels, an observation that warrants further validation. Future studies should take into consideration the recent conceptual developments in episodic memory research, whereby the recollective experience and the role of the frontal lobes in instantiating autonoetic consciousness during recall are emphasised [58]. Furthermore, the issue of selection of the musical piece requires further research, given that facets of the musical composition such as pitch, tempo, and emotional valence could potentially affect the cognitive performance of the participant. The present study's findings may prove applicable in dementia care, with the possibility of improving patients' moods, relaxation, and ABM recall by introducing calming background music.

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