# Does music training facilitate the mnemonic effect of song? An exploration of musicians and non-musicians with and without Alzheimer's Dementia

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## Abstract

**Introduction:** The efficacy of using sung words as a mnemonic device for verbal memory has been documented in persons with probable Alzheimer's Dementia (AD), but it is not yet known whether this effect is related to music training. Given that music training can enhance cognitive functioning, we explored the effects of music training and modality (sung vs. spoken) on verbal memory in persons with and without AD.

**Methods:** We used a mixed factorial design to compare learning (5 trials), delayed recall (30 minute, 24 hour) and recognition of sung versus spoken information in 22 healthy elderly (15 musicians), and 11 people with AD (5 musicians).

**Results:** Musicians with AD showed better total learning (over five trials) of sung information compared with non-musicians with AD. There were no significant differences in delayed recall and recognition accuracy (of either modality) between musicians with and without AD, suggesting that music training may facilitate memory function in AD. Analysis of individual performances showed that two of the five musicians with AD were able to recall some information on delayed recall, whereas the non-musicians with AD recalled no information on delay. The only significant finding in regard to modality (sung vs. spoken) was that total learning was significantly worse for sung than spoken information for non-musicians with AD. This may be due to the need to recode information presented in song into spoken recall, which may be more cognitively demanding for this group.

**Conclusions:** This is the first study to demonstrate that music training modulates memory of sung and spoken information in AD. The mechanism underlying these results is unclear, but may be due to music training, higher cognitive abilities or both. Our findings highlight the need for further research into the potentially protective effect of music training on cognitive abilities in our ageing population.



**Key words:** Alzheimer's Dementia, Cognition, Musician, Music, Memory, Song.


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## 1. Introduction

Alzheimer's Disease is the most common cause of dementia. It is estimated that 35.6 million individuals worldwide are living with dementia, and this number will more than triple by 2050 (World Health Organization and Alzheimer's Disease International, 2012). Existing pharmacological treatments have limited efficacy, therefore identification of effective non-pharmacological treatments is required to assist persons with dementia and their carers to manage activities of daily living and maximise their quality of life.

There is accumulating evidence that music intervention is an effective non-pharmacological treatment for dementia (Baird & Samson, 2015, Cuddy, Sikka, & Vanstone, 2015; Särkämö et al., 2014; Vink, Birks, Bruinsma, & Scolten, 2011). Music in its various forms (listening, participating in musical activities, or music therapy) may have positive effects on persons with dementia. Listening to familiar music can often elicit pleasurable responses such as smiling, even in advanced stage dementia (Cohen-Mansfield et al., 2012). Participating in music therapy has been shown to reduce agitation (Vink et al., 2012), alleviate depression and anxiety symptoms (Guétin et al., 2009; Narme et al., 2014), elicit positive physiological effects, such as changes in heart rate (Raglio et al., 2010) and hormone levels (Chu et al., 2014), improve cognitive functioning, particularly language abilities (Brotons & Koger, 2000) and memory functions (Särkämö et al., 2014) in persons with dementia.

Impaired memory is the most common symptom of probable Alzheimer's Dementia (AD). The majority of research on memory functioning in AD has been conducted using verbal and visual stimuli, although some studies have specifically examined memory for music (e.g., Cuddy et al., 2012; Cuddy, Sikka, & Vanstone, 2015; Samson, Baird, Moussard, & Celement, 2012; for reviews see Baird & Samson, 2009 and 2015). There are several case studies of musicians with AD who are still able to play their musical instrument, and in some cases, learn to play new tunes (e.g., Cowles et al., 2003) suggesting preserved musical memory abilities in musicians with AD. Cuddy and colleagues have demonstrated that 'musical semantic memory' (musical knowledge such as the tune and lyrics of familiar songs) can be spared in non-musicians with mild to moderate AD and in some persons with severe AD (as in the seminal case study of EN, see Cuddy & Duffin, 2005). This can be contrasted with 'musical episodic memory', which is memory for specific music events and the context in which they were heard (e.g., recognising what was heard within an experimental session) which is typically impaired, at least in non-musicians with AD (Samson, Baird, Moussard, & Clement, 2012). Recent neuroimaging studies have provided insights into the neural correlates of preserved memory for music in AD (Sikka, Cuddy, Johnsrude, & Vanstone, 2015; Jacobsen et al., 2015). These studies have shown that brain regions that are crucial for long-term musical memories, in particular frontal brain regions (such as the caudal anterior cingulate, ventral pre-supplementary motor area and left superior frontal regions), remain relatively spared of AD pathology.

Music in the form of song appears to be an effective verbal memory aid in persons with mild AD. Specifically, verbal information that is presented as lyrics to a song rather than as spoken words has been found to be recognized better in a forced-choice recognition paradigm (Simmons-Stern, Budson, & Ally, 2010; Simmons-Stern et al., 2012) and learnt faster and recalled better after repeated presentations (Prickett & Moore, 1991; Moussard, Bigand, Belleville, & Peretz, 2012; Moussard, Bigand, Belleville, & Peretz, 2014). A recent study has also found that the proportion of words recalled was higher when the to-be-remembered material was sung as lyrics to a familiar tune compared with text presented in a non-musical context, specifically in a silent movie (Palisson et al., 2015). In a detailed case study of a person with mild AD, Moussard et al. (2012) found that sung lyrics were learnt and recalled better than spoken lyrics after repeated learning. Initial learning (percentage of words recalled) was best in the 'low familiar' song (previously learnt unfamiliar melody). A logistic regression showed that the learning slope (across the five relearning sessions) was steeper for the sung (to an unfamiliar song) compared with spoken condition. Delayed recall (at week 1 and 2) did not differ between spoken and sung material, but at week 9 significantly more sung compared with spoken words were recalled. In a subsequent group study (Moussard et al., 2014), the authors found that song did not benefit initial learning, but it enhanced delayed recall in some AD participants. Specifically, three out of five participants with AD showed better retention of sung compared with spoken lyrics after a 10 minute and a 4 week delay (independent of melody familiarity), with no AD participant showing the opposite pattern (of better recall of spoken compared with sung lyrics).

In the two group studies conducted by Simmons-Stern and colleagues (2010, 2012) an immediate forced-choice recognition task was used. The sung version was presented with an unfamiliar song, and the lyrics were also presented visually when sung or spoken. The first study found that the AD group showed better recognition of sung lyrics, but this pattern was not evident in the healthy control group. The authors offered two explanations for this finding in AD patients: (1) that musical (compared with spoken only) stimuli are encoded more diversely and robustly in widespread neural networks; and (2) that music heightens arousal and therefore reduces the effect of attention deficits. In a follow-up study the lyrics were about activities of daily living. The results showed that 'general lyric content' (e.g., knowing that they had heard song lyrics about pills) was better recognised when sung compared with spoken. In contrast, there was no difference in recognition memory of sung or spoken 'specific lyric content' (e.g., knowing what you should do with your pills according to the song lyrics). The authors attributed this pattern of results to a dual process model of recognition memory; they proposed that music affects the process of familiarity to a greater extent than recollection (Simmons-Stern et al., 2012).

There is extensive evidence in the healthy population that music training promotes brain plasticity in the form of structural and functional brain differences (for reviews, see Herholz & Zatorre, 2012; Omigie & Samson, 2014). For example, musicians show greater volume of primary auditory cortex (Heschl's gyrus), primary and premotor regions, cerebellum and anterior corpus callosum. In regard to functional differences, compared with non-musicians, musicians are more likely to recruit both hemispheres of the brain when performing music tasks such as detection of pitch variation (Habibi, Wirantana, & Starr, 2013) or during music listening (Angulo-Perkins et al., 2014).

In the elderly population, enhanced cognitive and perceptual functions have been observed in musicians. For example, compared with non-musicians, elderly musicians show better cognitive functioning in both verbal and visual domains (Hanna-Pladdy & Gajewski, 2012; Hanna-Pladdy & MacKay, 2011) and better performance on tasks assessing auditory processing and cognitive control (Amer, Kalender, Hasher, Trehub, & Wong, 2013). Elderly individuals with self-reported high musical knowledge (associated with music training) show better scores on episodic and semantic memory tasks than those with low musical knowledge (Gooding, Abner, Jicha, Kryscio, & Schmitt, 2014). Elderly musicians also show preservation of auditory perceptual functions such as comprehension of speech in noisy environments (Zendel & Alain, 2012) and auditory brainstem timing to speech sounds (Parbery-Clark et al., 2012). Cognitive advantages have also been documented in elderly individuals with minimal early music training, or even after a short period of training in individuals with no previous music training (Bugos, Perlstein, McCrae, Brophy, & Bedenbaugh, 2007; Seinfeld, Figueroa, Ortiz-Gil, & Sanchez-Vives, 2013; White-Schwoch, Woodruff Carr, Anderson, Strait, & Kraus, 2013). These findings suggest that music training may have a protective effect in the face of age-related cognitive decline, and that cognitive enhancement can occur even after a short period of music training in the elderly brain. This raises the question of whether musical expertise gives rise to greater 'cognitive and brain reserve capacity' (Omigie & Samson, 2014). This notion has been supported by the observation that playing a musical instrument is one of several leisure activities associated with a reduced risk of dementia (Verghese et al., 2003).

Overall, these findings highlight the relevance of comparing individuals with and without musical expertise. The previous studies exploring musical mnemonics in the AD population have made no distinction between those participants with or without musical training (Simmons-Stern et al., 2010, 2012), have examined non-musicians only (Moussard et al., 2012, 2014), or have excluded those with a high level of music experience (Palisson et al., 2015). In their initial study, Simmons-Stern and colleagues described the number of participants in the healthy and AD groups with and without musical experience (one third of the AD group and one half of the healthy group had formal music training, but the number of years of training was not reported). In their follow-up study, Simmons-Stern and colleagues (2012) noted the mean years of formal and informal music training for healthy and AD groups (no significant difference between groups) but they did not distinguish participants according to musical experience in their analyses. Therefore, it is not yet known if music training modulates the efficacy of using sung words as a mnemonic device.

The current study aimed to explore whether music training modulated the learning and recall of verbal information presented in song, by comparing musicians and non-musicians within each group (AD and healthy) and across groups (musicians with and without AD, non-musicians with and without AD). We also aimed to examine the effect of modality (sung vs. spoken) on learning and recall of verbal information after 30 minute and 24 hour delays, and delayed recognition. We chose to present verbal information that is relevant to an elderly person's daily life in an attempt to make our experimental task ecologically valid. With the exception of Simmons Stern et al. (2012), previous studies of music mnemonics in AD have used song lyrics that have no relevance to the daily life of elderly people. Short (30 minute) and long (24 hour) delayed recall was also used to emulate how we typically need to retrieve information in everyday life. The repeated presentation of the to-be-remembered information (over five learning trials) also allowed us to examine learning. Previous studies on this topic have typically used unfamiliar songs, but we were interested in using a method that could be easily used in everyday life and therefore chose a song that is highly familiar to Australians (*Waltzing Matilda*). We chose to use a familiar song as several investigations in healthy and AD populations (Korenman & Peynircioglu, 2004; Moussard et al., 2014; Purnell-Webb & Speelman, 2008) have found that learning lyrics to a highly familiar melody is easier compared with an unfamiliar melody. In accordance with the previous observations (at least in non-musicians), we hypothesised that sung information would be better learnt, recalled and recognised compared with spoken information.

## 2. Methods

### 2.1 Design

This study used a mixed factorial design with group (AD vs. healthy) and music training (musician vs. non-musician) as between-subjects factors and modality (sung vs. spoken) as the within-subject factor.

### 2.2 Participants

Eleven AD patients (5 musicians) and 22 healthy controls (15 musicians) participated in the study. All patients had received a diagnosis of probable AD (and no other neurodegenerative condition) from a geriatrician or neurologist. Healthy non-musicians (no music training) were recruited through the Hunter Medical Research Institute (HMRI) volunteer register by responding to an advertisement in the HMRI newsletter. Musicians were recruited through a brief Australia wide call-out on a classical music radio station, requesting elderly musicians (at or over 65 years of age) in Brisbane, Sydney and Newcastle to make phone contact if they were interested in taking part in the research study. Potential participants were then screened by a phone interview. Exclusion criteria included current or previous neurological condition (that is comorbidity of any other neurological condition in the case of persons with dementia), severe psychiatric condition and hearing impairment. Table 1 shows the demographic details of all the groups (musicians and non-musicians with and without AD).

Table 1
*Mean (and standard deviation in parentheses) for demographic variables for musicians and non-musicians with and without Alzheimer's Dementia (AD)*

| | Musicians | | Non-musicians | |
|---|---|---|---|---|
| | AD (n=5) | Healthy (n=15) | AD (n=6) | Healthy (n=7) |
| Age (years) | 79.00 (11.05) | 74.87 (7.32) | 72.50 (7.67) | 70.00 (1.64) |
| Education (years) | 15.00 (3.47) | 15.70 (3.35) | 11.00 (3.35) | 11.57 (2.64) |
| MMSE[a] | 23.20 (4.15) | 28.53 (1.64) | 17.50 (4.28) | 28.57 (1.27) |
| WTAR[b] | 106.60 (4.56) | 112.93 (3.83) | 98.83 (9.95) | 105.00 (4.51) |
| Musical experience (yrs) | 67 (6) | 51 (22) | - | - |

[a] MMSE=Mini Mental State Examination
[b] WTAR=Wechsler Test of Adult Reading

Mean predicted premorbid IQ scores (determined by conversion of the mean WTAR raw scores) for all groups (healthy musicians and healthy non-musicians, AD musicians and AD non-musicians) were placed in the average range with the exception of healthy musicians, which was placed just within the high average range.

All musicians had 50 or more years of musical experience (formal lessons or performance) according to their own self-report, and in the case of participants with AD, verified by a family member. In the AD musician group, three participants played one or more instruments and two participants were both a vocalist and an instrumentalist. In the healthy musician group, 10 participants played one or more instruments, and five were both a vocalist and an instrumentalist. All healthy and AD musicians were still playing their instrument at least once a week, with the exception of one who was a trumpeter and ceased playing when he got false teeth a decade ago but remained highly active as a music examiner and regularly attended concerts.

**2.3 Experimental task**

The experimental task comprised two items, one referring to 'he' and the other to 'she'. Each item comprised two sentences, with each sentence containing three pieces of information: (1) day; (2) time; and (3) task; for a total of six pieces of information (maximum recall score of 6).

*On Monday at 9 o'clock he took an aspirin. On Wednesday at 6:30 he made a phone call.*
*On Friday at 5:30 she posted a letter. On Sunday at 11 o'clock she went bowling.*

The items were pre-recorded by a female voice and played to each participant through an external speaker connected to a MacBook Air computer (please refer to *Supplemental Material* for the recorded items). The sung version of each item was performed a capella (without musical accompaniment) to the first phrase of *Waltzing Matilda*, a song that is very familiar to Australians (see *Supplemental Material* for notation). The duration of the sung and spoken versions of each item was matched (15 seconds). This required slowing the presentation rate of the spoken version from normal speech rate in order to match it to the sung version. The task was performed one item and one modality at a time and the modality (sung/spoken) and item version (he/she) order was counterbalanced across participants. Each participant heard one item in one modality (sung or spoken) for a maximum of five learning trials or until recalled correctly, followed by the five learning trials of the other item (in the alternate modality to the first item).

Participants were told to try to remember the information in the sung (or spoken) item. The first presentation was a practice trial to ensure the participant understood the task and that the recording was set at the correct volume. The second time the item was played, the participant was asked to recall the information they had heard with the prompt 'what did he/she do?' Recall was in the spoken modality only. Their response was recorded as learning trial 1. If the participant could recall some but not all information on any learning trial he/she was prompted with questions about the other pieces of information they had missed, for example, '*What time (or day) did he take an aspirin*?' or '*What did he do on Monday*?' The prompting was for the purpose of maintaining rapport and highlighting what to listen for in the next learning trial. The participant was asked to repeat all the information they could recall at each learning trial, not just the information they had previously missed. All participants were assessed by the same researcher (AB) and therefore a consistent approach in administering the experimental task was employed.

The maximum recall score for each learning trial for each item was 6 (1 point for each piece of information achieved either with free or cued recall). The scoring was not dependent on presentation order. That is, a correct score was given for information given in any order. A maximum of 5 learning trials were conducted for each item, or until a score of 6/6 was achieved. If a participant obtained 6/6 on any learning trial before the fifth learning trial then they were automatically awarded 6/6 for the remaining learning trials. The maximum total learning score (across the five learning trials) for each item was 30.

The 30 minute delayed recall for each item occurred after completing 30 minutes of standard cognitive tasks (see below in Section 2.4). Participants were prompted with the statement "a little while ago you heard about what he/she did on two days of the week and it was sung/spoken to you. Can you tell me what he/she did?" If a participant was only able to recall some information, questions such as 'what day/time did he/she do this?' were provided as prompts, as had occurred during the learning trials.

The 24-hour delayed recall and recognition was conducted by phone by the same researcher who did the initial learning sessions (AB). Participants were reminded that they had taken part in a research study and completed some tasks, one of which was hearing some information about what a lady and man did (which was sung/spoken). They were asked to recall any information they could (in the same item order as it was presented initially) and were prompted with questions as described above if they could only recall some information. On completion of the recall task, a recognition task was administered. This comprised six forced-choice yes/no questions for each item (e.g., *Did he take an aspirin?*). Three of these six questions were deliberately incorrect. Recognition accuracy was determined by calculating hit rate minus false alarm rate for the 6-item recognition task.

**2.4 Procedure**

Participants were assessed individually in two sessions. During the first session they completed the experimental verbal recall task (either sung followed by spoken version or vice versa, duration approximately 5-10 minutes including task instructions), standard cognitive tasks including the Mini-Mental State Examination (MMSE, maximum score 30, with scores ranging from 25-30 considered normal) and a single word reading test of premorbid intelligence, the Wechsler Test of Adult Reading (WTAR, maximum raw score of 50 which is then converted to a standard score, average range is 90-110). A rest break occurred (if required) after the 30 minute delayed recall of the experimental task. Some additional music memory tasks were then completed, namely singing the melody of a familiar song (the first phrase of Waltzing Matilda, using 'la' rather than the lyrics) with the examiner or alone if possible, the *Famous Tunes Test*, (Hsieh, Hornberger, Piguet, & Hodges, 2011) assessing familiar melody recognition, and a music paired-associates learning task (Wilson & Saling, 2008), the results of which will be reported in a subsequent publication. During the second session (24-hours later), participants were contacted by telephone for the 24-hour delayed recall and recognition tests of the experimental task. This phone call took approximately 5 minutes. If the participant was able to recall all the information correctly the respective recognition task was not performed and they were automatically given a point for each item on the delayed recognition task. One participant with AD (a non-musician) did not complete the 24 hour recall or recognition task as he did not remember having done the task the previous day and became agitated. The phone call was therefore discontinued.

**2.5 Data analysis**

Data analysis was conducted using SPSS version 21. Due to violation of assumptions of normality and homogeneity (due to small sample sizes), we used the Mann-Whitney U test to examine between-subjects effects and the Wilcoxon signed ranks test to examine within-subjects effects. We report Z values for both tests. We also used Crawford and Garthwaite's (2007) Bayesian method to examine differences between the scores of each musician with AD and the mean of the healthy musicians. Statistical significance was evaluated against an alpha level of .05.

## 3. Results

### 3.1. Demographic Information

The demographic data were analysed by first comparing AD and healthy participants (collapsed across musical training). Differences within the AD group (musicians vs. non-musicians) and within the healthy group (musicians vs. non-musicians) are presented next. Finally, for completeness, differences within musicians (AD vs. healthy) and within non-musicians (AD vs. healthy) are presented.

As expected, the difference in mean MMSE scores between the healthy and AD groups (collapsed across musicians and non-musicians) was significant, $Z = 4.40$, $p < .001$, with higher scores for the healthy group ($M = 28.55$, $SD = 1.50$) than the AD group ($M = 20.09$, $SD = 4.99$). There were no significant differences between the healthy and AD groups in age (AD group $M = 75.45$, $SD = 9.47$; healthy group $M = 73.32$ years, $SD = 6.98$) or years of education (AD group $M = 12.82$, $SD = 3.84$; healthy group $M = 14.39$, $SD = 3.65$) ($p > .05$).

Comparison of musicians and non-musicians within the AD group showed no significant differences in age, MMSE score, or years of education ($p > .05$, see Table 1 for means and standard deviations). Comparison of musicians and non-musicians in the healthy group showed a significant difference in years of education, $Z = 2.52$, $p = .012$, but no differences in age or MMSE scores ($p > .05$, see Table 1 for means and standard deviations).

Finally, we compared healthy versus AD musicians as well as healthy versus AD non-musicians. Healthy musicians did not differ from AD musicians in age or years of education ($p > .05$). As expected, mean MMSE score was higher for healthy than for AD musicians, $Z = 2.87$, $p = .004$. There was no significant difference between mean years of music training between healthy and AD musicians ($p > .05$). Healthy non-musicians and AD non-musicians did not differ in age or years of education ($p > .05$), but there was a significant difference in MMSE scores, with healthy non-musicians having a higher score than AD non-musicians, $Z = 3.05$, $p = .002$ (see means and standard deviations in Table 1).

Table 2
*Mean (with standard deviation in parenthesis) for total learning, recall (at 30 minute and 24 hour delay) and recognition accuracy for the sung and spoken information in musicians and non-musicians with and without Alzheimer's Dementia (AD)*

| | | Group | | | |
|---|---|---|---|---|---|
| | | Musicians | | Non-musicians | |
| Variable | Modality | AD (n = 5) | Healthy (n = 15) | AD (n = 6) | Healthy (n = 7) |
| Total learning | Sung | 20.40 (5.81) | 28.00 (3.09) | 14.00 (6.90) | 29.14 (1.22) |
| (Max = 30) | Spoken | 17.00 (9.61) | 29.07 (1.44) | 19.67 (6.65) | 29.57 (0.79) |
| Trials to criterion | Sung | 4.60 (2.19) | 2.00 (1.20) | 5.50 (1.22) | 1.43 (0.53) |
| (Min = 1) | Spoken | 5.00 (2.24) | 1.40 (0.51) | 4.83 (2.04) | 1.29 (0.49) |
| 30 minute recall | Sung | 1.60 (2.30) | 3.33 (2.06) | 0.00 (0.00) | 3.57 (2.07) |
| (Max = 6) | Spoken | 1.20 (2.17) | 2.53 (2.20) | 0.00 (0.00) | 3.57 (1.99) |
| 24 hour recall | Sung | 1.20 (1.79) | 3.53 (2.07) | 0.00 (0.00) | 2.86 (2.34) |
| (Max = 6) | Spoken | 1.20 (2.68) | 2.87 (2.50) | 0.00 (0.00) | 3.43 (1.62) |
| Recognition accuracy[a] | Sung | 0.20 (0.77) | 0.80 (0.28) | -0.40 (0.37) | 0.66 (0.27) |
| (Max = 1) | Spoken | 0.33 (0.41) | 0.60 (0.44) | 0.33 (0.33) | 0.66 (0.27) |

[a] Accuracy = hit rate minus false alarm rate

### 3.2. Experimental Task

Means scores (and standard deviations) for total learning (Trials 1-5), trials to criterion, delayed recall (30 minute and 24 hour) and recognition accuracy for musicians and non-musicians, with and without AD, are presented in Table 2. The results of the analysis of these data are presented in three sections. First, the analysis of healthy versus AD groups collapsed across musicians and non-musicians is presented. Second, in accordance with the research aims, the effect of music training is examined by first comparing musicians versus non-musicians within the AD group and within the healthy group, and then comparing within musicians (healthy vs. AD) and non-musicians (healthy vs. AD). Third, to examine the effect of modality, we compared learning and recall of sung versus spoken information within healthy and AD musicians and non-musicians.

#### 3.2.1 Comparison of healthy versus AD groups (collapsed across musicians and non-musicians)

As expected, healthy participants performed better than AD participants across all aspects of the experimental task (total learning sung, $Z = 3.71$, $p < .001$, total learning spoken, $Z = 3.70$, $p < .001$; trials to criterion sung, $Z = 3.96$, $p < .001$, trials to criterion spoken, $Z = 3.75$, $p < .001$; 30 minute delayed recall sung, $Z = 3.43$, $p = .001$, 30 minute delayed recall spoken, $Z = 2.87$, $p = .004$; 24 hour delayed recall sung, $Z = 3.33$, $p = .001$, 24 hour delayed recall spoken, $Z = 3.06$, $p = .002$; recognition accuracy sung, $Z = 3.16$, $p = .002$, and recognition accuracy spoken, $Z = 2.01$, $p = .044$).

Of note, for total learning of sung and spoken information, errorless performance was achieved prior to the fifth learning trial in all healthy participants (musicians and non-musicians) indicating a ceiling effect. In contrast, only two of the five musicians with AD and one of the non-musicians with AD showed errorless performance by the fifth learning trial.

#### 3.2.2 Effects of music training.

*3.2.2.1 Musicians versus non-musicians within healthy and AD groups.*

We compared musicians versus non-musicians within AD and healthy groups on each experimental task variable. Musicians with AD showed significantly better total learning of sung information, $Z = 2.02$, $p = .044$, compared with non-musicians with AD. There were no differences between musicians and non-musicians with AD for all the other experimental task variables, namely total learning of spoken information, trials to criterion, 30 minute or 24 hour delayed recall, or recognition accuracy (all $p > .05$). When musicians and non-musicians in the healthy group were compared there were no significant differences for any of the experimental task variables (all $p > .05$, see Table 2 for means and standard deviations).

*3.2.2.2 Musicians (healthy vs. AD) and non-musicians (healthy vs. AD).*

When healthy and AD musicians were compared, mean scores for healthy musicians were higher than for AD musicians in total learning of sung, $Z = 2.05$, $p = .041$, and spoken information, $Z = 2.53$, $p = .011$, trials to criterion (sung, $Z = 2.18$, $p = .030$; spoken, $Z = 2.57$, $p = .010$), and recall of sung information at 24 hour delay, $Z = 2.00$, $p = .045$. There was no significant difference between healthy musicians and AD musicians in 30 minute recall of sung or spoken information, or 24 hour recall of spoken information, or recognition accuracy performances of sung or spoken information (all $p > .05$, see Table 2 for means and standard deviations).

To explore these findings in more detail we conducted individual analyses of each of the five musicians with AD using Crawford and Garthwaite's (2007) method, which tests whether an individual score is significantly different from the mean for a control group. We found that two of the five musicians with AD were able to recall some information on delayed recall (both 30 minute and 24 hour) and their performance was in keeping with healthy musicians for both sung and spoken information ($p > .05$). Of the two musicians with AD who were able to recall information, one was both an instrumentalist (piano, organ) and singer and the other was an instrumentalist only (violin). They had 66 and 70 years of experience as musicians, respectively. Of the other three musicians with AD, two could recall no information and one could recall only one item. Their experience as musicians was 58, 70 and 73 years respectively. Thus, there does not appear to be any relationship between years of training and recall ability in the AD musicians.

In regard to recognition accuracy scores for the musicians with AD, we found that all five showed no difference compared with healthy musicians in recognition of spoken information, while two of the five showed no difference compared with healthy musicians in recognition of the sung information. These were the same two musicians with AD who were able to recall some information as described above.

Comparison of healthy and AD non-musicians revealed significantly higher scores for healthy non-musicians in total learning of sung, $Z = 2.84$, $p = .005$, and spoken information, $Z = 2.48$, $p = .013$, trials to criterion (sung, $Z = 3.15$, $p = .002$; spoken, $Z = 2.52$, $p = .012$), recall at 30 min (sung, $Z = 3.17$, $p = .002$; spoken, $Z = 3.03$, $p = .002$) and 24 hour delay (sung, $Z = 2.44$, $p = .015$; spoken, $Z = 3.18$, $p = .001$) and recognition accuracy for sung information, $Z = 2.90$, $p = .004$. There was no difference between healthy and AD non-musicians in recognition accuracy of spoken information, $p > .05$

### 3.2.3 Effect of modality (sung vs. spoken) on learning and memory

We compared learning, trials to criterion, recall (30 minute and 24 hour delays) and recognition accuracy for sung versus spoken information within each group. There were no differences in total learning between sung and spoken modalities for AD musicians ($p > .05$). In contrast, AD non-musicians showed significantly better total learning of the spoken compared with the sung information, $Z = 1.99$, $p = .046$ (see Table 2 for means and standard deviations). There was no difference in total learning between sung and spoken modalities for the healthy musicians or non-musicians, which may have been due to ceiling effects as all healthy participants achieved an errorless score prior to or on the fifth learning trial.

There were no significant differences between recall of sung and spoken information at either time delay (30 minute or 24 hour delays) in any groups (healthy musician, healthy non-musician, AD musician or AD non-musician, all $p > 05$). Of note, non-musicians in the AD group were unable to recall *any* information of either modality on either the 30 minute or 24 hour delayed recall trials (see Table 2 for means and standard deviations).

There were no significant differences between recognition accuracy of sung or spoken information in any of the groups (healthy musician, healthy non-musician, AD musician or AD non-musician, all $p > 05$).

## 4. Discussion

To our knowledge, this is the first study to examine whether musical training modifies the previously documented facilitating effect of song on verbal memory in AD. We specifically recruited elderly musicians (all with over 50 years experience as musicians) and non-musicians (with no music training), with and without AD, to explore the effect of musical training on learning and recall of sung versus spoken information. Previous research on this topic did not distinguish between participants with or without musical training (Simmons-Stern et al., 2010, 2012; Prickett & Moore, 1991) or examined non-musicians only (Moussard et al., 2012, 2014). As expected, we found that the healthy group performed better than the AD group (collapsed across musicians and non-musicians) on all aspects of the experimental task. We will now discuss the main findings with respect to the effect of music training and modality (sung vs. spoken) at encoding, on learning and memory performance.

### 4.1 Effect of music training

We found that music training modulated the learning of sung information in the AD group only. Specifically, comparison of musicians and non-musicians with AD revealed that musicians with AD showed significantly better total learning of sung information compared with non-musicians with AD. This finding may be related to the specific effects of their music training such as facilitated processing of melodic information compared with non-musicians. In the face of AD pathology, this may be a relatively preserved cognitive skill for musicians. In contrast, the non-musicians with AD are likely to have found the learning of sung information more cognitively challenging due to the need to process melodic information, which they are not accustomed to, and to transcode this to spoken recall (see further discussion of this below). We acknowledge that although this finding reached statistical significance, it may be a weak effect size.

Importantly, musicians with AD did not differ significantly from healthy musicians in recall of both sung and spoken information at a 30 minute delay and of spoken information at a 24 hour delay. In addition, there was no difference between musicians with and without AD in recognition accuracy (for both sung and spoken information). Musicians with AD showed a memory advantage compared with non-musicians with AD, who were unable to recall any information (sung or spoken) on delayed recall. When we examined the individual performances of each musician with AD with healthy musicians, we found that the non-significant differences were primarily due to the scores of two musicians with AD. This supports previous findings of only some persons with AD demonstrating enhanced memory performance (e.g., Moussard et al., 2014). Of note there were no differences in years of music training between these two individuals and the other three musicians with AD. Our findings support the accumulating evidence of enhanced cognitive abilities in elderly musicians, and demonstrate this for the first time in persons with AD. Further research is needed to examine the mechanisms underlying the potentially protective and beneficial effect of music training on cognition in the ageing population.

We acknowledge that the small and unbalanced sample size of our subgroups may reduce the reliability and generalisabilty of the results. Nevertheless, musicians with AD are a rare group and the literature to date comprises only case studies of this population. Therefore our sample of $n$ = 5 makes an important contribution to the literature. We are also aware that the musicians (in both AD and healthy groups) had more years of education than the non-musicians (but note that this was a statistically significant difference in the healthy group only). Furthermore, in the AD group, the musicians had higher MMSE score than the non-musicians, but note that this difference did not reach statistical significance. Our finding of smaller differences in some recall and recognition performances between musicians with and without AD compared with non-musicians with and without AD may be underpinned by a combination of both their music training and higher cognitive functioning. It may be that their music training contributes to their higher MMSE score. The small number of participants in this group precludes any firm conclusions in regard to these potential relationships.

**4.2 Effect of modality**

Examining differences in modality (sung vs. spoken information), we found that total learning (across the five learning trials) was significantly worse for sung than spoken information for non-musicians with AD, but this was not the case for musicians with AD. For non-musicians with AD, the sung condition may have been distracting as it required a 'transcoding' from sung presentation to spoken recall. This additional cognitive load may have disturbed non-musicians with AD more than musicians with AD, as discussed above. In contrast, the spoken condition may have been less demanding as the encoding and recall modality was matched (i.e., both presented and recalled in spoken form).

The use of a highly familiar song that had pre-existing lyrics in our experimental task could also have been cognitively demanding due to the interference between familiar and new lyrics and the need to actively inhibit the familiar lyrics. This cognitive demand may have been greater for the non-musicians and participants with AD. This may have impacted on our results and contributed to the lack of statistical differences between sung and spoken modalities. Interestingly, while several participants commented on the familiarity of melody during the learning of the sung item, no participant made any comment about the song title or sung any of the original lyrics, suggesting that there was no explicit interference between old familiar and new experimental lyrics. All participants were able to sing the melody of the first phrase of Waltzing Matilda (without lyrics) alone or along with the examiner. We did not formally investigate their ability to produce the lyrics but note anecdotally that very few participants were able to do this spontaneously. We acknowledge that further cueing may have facilitated recall of the lyrics. As noted in the introduction, the choice of a familiar song was due to previous research in healthy and patient populations that have shown better learning of lyrics in a highly familiar melody compared with an unfamiliar melody, as well as the desire to make the task ecologically valid and easy to generalise to daily life. Future research could use a familiar melody that is easy to sing and has no associated lyrics (such as *Ode to Joy*) in order to avoid this potential confound.

In the healthy group (both musicians and non-musicians) there was no effect of modality on memory performance. This is likely to be due to a ceiling effect for healthy participants, as they all achieved errorless performance prior to or by the fifth learning trial, regardless of modality. This is a limitation of the current experimental task and raises the possibility that the task may measure different cognitive functions in the two groups. Nevertheless, given the present results in the AD group there is a risk of a floor effect in this group if the task was made more challenging.

There were no significant differences in recall (at either time delay) for sung versus spoken information in any of the groups. These findings are inconsistent with the results of previous studies in this population that have found enhanced recall of sung compared with spoken information (Moussard et al., 2012, 2014; Palisson et al., 2015; Prickett & Moore, 1991). This difference may be due to a number of methodological variations. In our study there was only one learning session (five trials) and recall delays of only 30 minutes and 24 hours, which contrasts with multiple learning trials (Palisson et al., 2015) or learning sessions over several days (Prickett & Moore, 1991) or weeks (Moussard et al. 2012, 2014). In addition, in these other studies (Moussard et al., 2012, 2014; Palisson et al., 2015) the authors used a natural speech rate condition (which was faster than their sung condition) rather than matching the duration of sung and spoken stimuli. The authors noted that this is consistent with natural speech and promoted ecological validity, but it is possible that the slower presentation of text in the sung version they used may have facilitated memory for sung material (compared with spoken). In contrast, in our study we slowed the rate of speech in our spoken sentences to match the duration of the sung and spoken versions. The recall scoring methods also differ between the current study and previous work. Prickett and Moore (1991) reported the percentage of words recalled, but collapsed across all there learning sessions, precluding any examination of delayed recall performance. Palisson et al. (2015) and Moussard et al. (2012, 2014) counted the proportion of words correctly recalled, whereas we tested the retention of specific information about the context of an event. The latter task is likely to be more difficult for this patient population in which pathology primarily affects temporal regions, in particular the hippocampus (Braak & Braak, 1995), which is crucial for memory binding (linking of aspects that make up an event) and recollection (Yonelinas, 2013).

In the current study, participants were prompted if they could not recall all the information in an item. When recording their responses we did not distinguish between information that was recalled freely or after prompting. This is an important distinction to explore in future studies of this topic both in regard to potential differences between healthy and AD populations and recall of information presented in sung or spoken modalities. Furthermore, it is possible that the difference in context between sessions (learning session conducted face-to-face and 24 hour delayed recall conducted by phone) and the lack of contextual/situational cues could have impacted on the results. Future studies could explore whether differences in encoding and retrieval contexts affects recall in this patient population.

There were no significant differences between recognition of spoken or sung information in any of the groups. These results are not consistent with Simmons-Stern et al. (2010, 2012). In their first study they found better recognition of sung information in their AD group, but not their healthy group. In their follow-up study, they found a memory enhancing effect for 'general lyric content' in both AD and healthy groups. The inconsistency between our findings and those of Simmons Stern et al (2010, 2012) is likely to be due to methodological differences. Simmons-Stern and colleagues used an 'old versus new' recognition task in which each item was visually presented and the participant was asked to make a judgement as to whether the lyric was old or new. In contrast, our recognition task was conducted by phone after a 24-hour delay, and comprised only six yes/no questions for each condition (sung vs. spoken) and was done by asking spoken questions, as opposed to asking each question in the same modality as the item had been presented at encoding (i.e. sung or spoken). It may be that an advantage of the sung modality may become apparent by using more items, and/or presenting the test items in the same modality as during encoding (either sung or spoken), along with visual cues. Furthermore, our recognition task required more than just a physical matching of stimuli. Rather, the participants had to comprehend the meaning of the content. Therefore, their judgements were not limited to superficial features or physical matching, but instead required deep processing of the content, which is likely to be more cognitively demanding.

An additional methodological difference between our study and those of Simmons-Stern and colleagues is the degree of cognitive impairment in our AD patients. Participants were less impaired in Simmons-Stern and colleagues studies (2010, 2012) (with mean MMSE scores of 24, compared with 17.5 in non-musicians with AD and 23.2 in musicians with AD in our sample) and therefore they may have been less affected by the cognitive demands of transcoding the sung information compared with our participants.

In conclusion, unlike previous research we did not find a mnemonic effect of song compared with spoken information in either AD or healthy groups. We did find, however, that music training modulated memory performance in the AD group. The mechanism underlying this effect of music training on memory performance in AD is unclear, but it may be due to specific effects of their music training and/or their higher cognitive functioning. These findings highlight the need to further investigate and clarify the potential modulating effect of music training on age-related and pathological cognitive decline.

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