Musical and verbal memory in Alzheimer's disease: A study of long-term and short-term memory

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ABSTRACT

Musical memory was tested in Alzheimer patients and in healthy older adults using long-term and short-term memory tasks. Long-term memory (LTM) was evaluated with a recognition procedure using unfamiliar melodies. Short-term memory (STM) was evaluated with same/different judgment tasks on short series of notes. Musical memory was compared to verbal memory using a task that used pseudowords (LTM) or syllables (STM). Results indicated impaired musical memory in AD patients relative to healthy controls. The deficit was found for both long-term and short-term memory. Furthermore, it was of the same magnitude for both musical and verbal domains whether tested with short-term or long-term memory tasks. No correlation was found between musical and verbal LTM. However, there was a significant correlation between verbal and musical STM in AD participants and healthy older adults, which suggests that the two domains may share common mechanisms.

1. Introduction

In recent years, music has been a focus of interest in cognitive neuroscience. Music is present in all cultures, increases the quality of life of individuals and contributes to social cohesion. Its role, universality, and omnipresence (Trainor, 2008) have motivated the empirical investigation of the way musical elements are processed and memorized, and have supported the development of sophisticated models of music cognition (for a review, Peretz & Zatorre, 2005). Most of these models focus on the cognitive components that are involved in the perception and production of music but some of these components have implications for musical memory. For example, Peretz and Coltheart (2003) propose the existence of a musical lexicon, a registry of familiar musical phrases that would also be involved in the formation of new musical representations. Damage to the musical lexicon would produce deficits in the retrieval of familiar melodies stored in the lexicon but could also create difficulties in forming new traces in long-term memory (LTM). Cognitive models of short-term memory (STM) have proposed the existence of a tonal loop, a dedicated short-term storage component for musical material (Benz, 1995; Marin & Perry, 1999). In addition, neurobehavioral findings support the existence of dedicated brain areas for memorizing musical material. Structures in the right temporal lobe would play an important role in musical LTM (Samson & Zatorre, 1992), particularly when memorizing less familiar melodies (Peretz & Zatorre, 2005) whereas short-term memorization of musical stimuli would engage the right auditory cortex (Zatorre, Evans, & Meyer, 1994; Zatorre & Samson, 1991) and frontal regions (Zatorre et al., 1994).

Surprisingly, little is known regarding the effect of brain-related memory disorders on musical memory (but see Samson & Peretz, 2005). The impact of Alzheimer's disease (AD), the most prevalent memory disorder, on musical memory is sparsely documented. Tasks used to assess memory in AD typically involve verbal or visuo-spatial material and only a few studies have examined musical memory. Assessment of musical memory in AD is relevant for many reasons. First, music contributes to the well-being of many older persons (Cohen, Bailey, & Nilsson, 2002). Also, music therapy is often used with AD patients and seems to bring some benefits in the management of their symptoms (Koger & Brotons, 2000). Finally, investigating the breakdown of musical memory in AD and how this compares to verbal memory disorder may contribute to our understanding of the neuroscience of musical memory.

We are aware of only three studies that speak about whether LTM for musical material is impaired in AD. Quoniam et al. (2003) tested AD patients with an incidental learning paradigm in which participants were told to listen to unfamiliar melodies that were played 1, 5 or 10 times without being instructed that they would be tested later for their memory of the melodies. When tested later with a recognition procedure, the authors found impaired memory in AD patients. Halpern and O'Connor (2000) also evaluated incidental learning of unfamiliar melodies in AD. In this study, participants were asked to rate the speed of eight unfamiliar musical excerpts and were later tested for their memory of the excerpts in a surprise recognition task. The results indicated no
significant difference between AD patients and healthy older adults in the recognition test. However, the two groups performed near chance level. This floor effect makes it difficult to interpret the absence of a group difference in the study. Finally, Bartlett, Halpenny, and Dowling (1995) compared the recognition of unfamiliar melodies in AD and in normal aging with participants receiving intentional learning instructions this time. Results indicated no difference between patients and healthy controls, but again both groups performed at a low level. Thus, only one study reported impaired musical memory in AD while the other two studies reported unimpaired performance; however, the two studies that did not find any impairment were limited by a near-floor effect which could have masked the presence of any group differences.

The data on the STM capacities of AD persons for musical material is even scarcer than that on LTM. White and Murphy (1998) tested STM with a same/different judgment task following presentation of four and five binary-tone sequences. They found musical STM deficit in both very mild AD and mild AD. In contrast, Kurylo, Corkin, Allard, Zatorre, and Crowdon (1993) reported no deficit in AD patients in a completely different paradigm. Participants were asked to identify the tone with a pitch change in a succession of three- to five-tone melodies.

Thus, a first question this paper addresses is whether memory for musical material is impaired in AD when performance is not limited by floor effects. Our study measures both STM and LTM for musical material as most memory models identify them as independent storage systems. It is thus relevant to know whether they are both impaired in AD. Models of memory from the late sixties and early seventies (Atkinson & Shiffrin, 1968) proposed that STM and LTM have a sequential relationship, information having to transit from STM before accessing LTM. However, findings from experimental psychology and neuropsychology challenged this sequential view (for example, Basso, Spinnler, Vallar, & Zanobio, 1982; Warrington, Logue, & Pratt, 1971; Warrington & Shallice, 1982; Warrington, Logue, & Pratt, 1971; Warrington & Shallice, 1982) reported no deficit in AD patients in a completely different paradigm. Participants were asked to identify the tone with a pitch change in a succession of three- to five-tone melodies.

In summary, little is known regarding musical memory in AD. Studies on musical LTM and STM reported conflicting results. Furthermore, no study has compared verbal and musical LTM in AD. Only one study reported equivalent deficits in the STM for musical and verbal materials in AD, and this could lead to material-specific impairment. Music and language seem ideally suited to test the domain-specificity of impairment in early AD as they share a number of interesting characteristics: both can be presented auditorily, involve a temporal structure and are governed by rules. If musical and verbal memory are processed independently, patients whose degenerative process first strikes regions of the right hemisphere, which is proposed to be engaged in musical processing, should exhibit musical memory deficits, whereas those whose pathology first strikes regions of the left hemisphere, engaged in verbal processing, should exhibit verbal memory deficits. This should result in different degrees of impairment when comparing memory for musical and memory for verbal material and in a weak association between the two materials. The only study that compared memory for musical and verbal materials in AD was that of White and Murphy (1998). They compared a twotone recognition musical STM task with two verbal STM tasks: digit span forward and digit span backward. Relative to healthy older adults, very mild and mild AD showed both musical STM deficit and verbal STM deficit as measured by the digit span backward. Based on these results, the authors concluded that verbal and musical memory decline in a similar way in AD. However, the musical and verbal conditions were not ideally matched in that study. Recall was used in the verbal task whereas recognition was used in the musical task. Moreover, the digit span backward requires manipulation of information, a process that was not involved in the recognition of musical sequences. The use of digits, a material that is high in lexical and semantic content, does not compare well with the use of musical notes.

In summary, little is known regarding musical memory in AD. Studies on musical LTM and STM reported conflicting results. Furthermore, no study has compared verbal and musical LTM in AD. Only one study reported equivalent deficits in the STM for musical and verbal materials in AD. Consequently, a recognition procedure was used in all conditions, and learning occasions were equated across materials. Thus, the objectives of the present study were to evaluate the presence of musical memory deficits in AD using both LTM and STM tasks and to compare it to memory for verbal material. Our goal was to use musical and verbal memory versions that would be as comparable as possible, thus allowing optimal conditions to test the hypothesis of domain-specific impairments in AD. Consequently, a recognition procedure was used in all conditions, and learning occasions were equated across musical and verbal materials. Another aspect of the method was to match familiarity across domains by comparing LTM for pseudo-words to LTM for unfamiliar musical excerpts. Neither pseudowords nor unfamiliar melodies have representations in a verbal musical lexicon. Furthermore, pseudowords do not carry meaning,
and unfamiliar melodies are less likely to convey associated semantic content than familiar ones. This methodological control was crucial in our view because lexico-semantic characteristics of verbal material contribute to a large extent to episodic LTM. We wanted to make sure that these factors would not contribute in a disproportionate manner to the performance of AD patients in the verbal memory tasks. The pseudowords used here were constructed to obey the rules of the phonotactic and syllabic structure of the French language and the musical excerpts were constructed to obey the rules that govern the Western tonal system. Finally, we had shown in a previous study that the two tasks did actually produce a similar performance level and were thus of a comparable degree of difficulty (Mottron, Peretz, Belleville, & Rouleau, 1999). In addition, the participants’ perceptual discrimination capacities were measured for both verbal and musical materials to ensure that differences across materials did not occur as the result of an impact of perceptual difficulties on memory performance (Halpern & O’Connor, 2000). Finally, correlation analysis was used to assess material-specificity and to assess the association between STM and LTM for each domain. If the impairment is not material-specific, there should be a significant correlation between performance with the musical and verbal materials.

2. Method

2.1. Participants

Thirty-two participants were recruited for this study, 16 participants with AD and 16 older controls (AC). There were nine women and seven men in each group. The mean age was 72.3 years (SD = 8.9) in the AD group and 69.8 years (SD = 7.9) in the control group, t(30) = 82; p = .42, two-tailed. There was no difference in formal education between AD patients (M = 12.7 years, SD = 4.2) and age-matched controls (M = 12.4, SD = 3.3), t(30) = .234; p = .816, two-tailed.

AD patients were recruited from the Alzheimer and Related Disorders Clinic of the McGill Centre for Studies in Aging and from the Memory Clinic of the Jewish General Hospital in Montreal, Quebec. AD patients were diagnosed on the basis of an extensive clinical and neuropsychological assessment. They all met the NINCDS-ADRDA research criteria for probable AD (McKhann et al., 1984) and the DSM-IV criteria for dementia of the Alzheimer type (APA, 1994). Dementia severity and global functioning were assessed using the MMSE (Folstein, Folstein, & McHugh, 1975) and the Mattis dementia rating scale (MDRS; Mattis, 1976). The neuropsychological battery also included measures of memory (RL/RI 16 free and cued recall task, Van der Linden et al., 2004; text memory of the BEM-144, Signoret, 1991), executive functions (Stroop-Victoria, Regard, 1981; coding subtest of the WAIS-III, Wechsler, 1997) and constructional praxis (copy of the Rey figure, Rey, 1960). Clinical results are presented in Table 1.

Healthy older participants were recruited from a pool of volunteers living in the Montreal area. Healthy controls were matched to AD patients according to age, gender and education level. They completed the MMSE and MDRS and the neuropsychological battery.¹ None of them met criteria for dementia or mild cognitive impairment using Petersen’s criteria (Petersen, 2003).

For the two groups, exclusion criteria included presence or history of severe psychiatric disorder, neurological disorders, cerebrovascular diseases, alcoholism, dyslexia, intellectual deficiency, general anesthesia in the last six months, and medication known to affect memory. Because expertise might reduce the impact of aging on musical skills (Halpern & Bartlett, 2002), a brief questionnaire on musical training was completed by participants. Individuals who had been trained on a musical instrument for more than 10 years, those who could read and write music easily and those who had absolute pitch (the ability to name a note without a reference note) were excluded. All participants had normal or corrected vision and hearing and were native French speakers. Written informed consent was obtained from each individual. Each participant received financial compensation for their transportation expenses.

2.2. Experimental design

The clinical and experimental evaluations were conducted in two distinct sessions lasting around an hour and a half with a 10-min break. The order of presentation of experimental tasks was kept constant across participants. This methodological decision was taken to facilitate the comparison of individual patterns of performance. The order of presentation was as follows: musical LTM task, musical STM task, verbal LTM task, verbal STM task, acoustical perception task and verbal perception task.

2.3. Long-term memory tasks

2.3.1. Material

Twenty-four pseudowords were constructed to be included in the verbal material (Belleville, Caza, & Peretz, 2003). All pseudowords were two-syllables long. They contained an average of 6.3 (SD = 1.0) letters and 4.9 (SD = 0.8) phonemes. Each syllable was frequent in French. Syllables were combined to produce pseudowords that complied with French phonological rules (e.g.: “transon”) and differed from real words. Verbal stimuli were recorded by a male speaker. Half of the items were used as to-be memorized targets and half were used as distractors in the recognition task. Targets and distractors were matched according to their number of letters and phonemes and to their syllable frequency. Of the 12 distractors, four shared their first syllable with one of the targets, four shared their last syllable with one of the targets, and four shared none. Twenty unfamiliar musical excerpts were used as musical material. These melodies were taken from musical stimuli provided by the Montreal Battery of Evaluation of Amusia for testing brain-damaged patients (Peretz, Chompod, & Hyde, 2003). Melodies were organized according to the Western tonal system. Their mean length was 10 s and each melody contained around 22 notes. They were generated by a Yamaha TX-812 synthesizer controlled by a microcomputer running a MIDI sequencing program using the sound of panpipes. Stimuli were edited and recorded with ProTools and transferred onto a CD. Melodies were divided into two groups: targets and distractors. Both were matched according to

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Clinical characteristics of participants (SD in parentheses).</th>
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<tbody>
<tr>
<td></td>
<td>AD</td>
</tr>
<tr>
<td>MMSE (/30)</td>
<td>24.3 (3.1)</td>
</tr>
<tr>
<td>MDRS (/144)</td>
<td>125 (11.4)</td>
</tr>
<tr>
<td>BDI/16 Delayed free recall (/16)</td>
<td>2.6 (3.5)</td>
</tr>
<tr>
<td></td>
<td>Delayed cued recall (/16)</td>
</tr>
<tr>
<td>Text memory Immediate recall (/12)</td>
<td>3.7 (2.3)</td>
</tr>
<tr>
<td></td>
<td>Delayed recall (/12)</td>
</tr>
<tr>
<td>Coding</td>
<td>7.6 (3.5)</td>
</tr>
<tr>
<td></td>
<td>Copy of the Rey figure</td>
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<tr>
<td></td>
<td>Stroop (errors on third plate)</td>
</tr>
</tbody>
</table>

* Indicates a significant difference (p < 0.05).
** Indicates a significant difference (p < 0.001).

¹ One control participant completed only the MDRS.
their length and number of notes. All items were presented through an F-355 Sony CD player.

2.3.2. Procedure

The musical and verbal conditions were tested separately. The same procedure was used with both conditions. In the learning phase, the to-be-learned items (12 pseudowords in the verbal task and 10 unfamiliar melodies in the musical task) were presented in a first study trial where participants were told to remember them for a later memory test. There were no other instructions provided at encoding. This was immediately followed by a second study trial where the same items were presented but in a different order. During that phase, each item was separated by about 4000 ms. The learning phase was followed by a 40-s period where participants were asked to count backwards. A recognition procedure was used in the test phase. Targets and distracters were presented sequentially in random order. Participants were asked to indicate if the item was part of the list they had previously learned or if it was a new one. There was no time limit, but participants typically provided their responses within three seconds.

2.4. Short-term memory tasks

2.4.1. Material

Two non-sense monosyllabic syllables (“ran-bij”) were selected to create the verbal material. The syllables were chosen so that they did not share letters and they did not form real words. Fifty-six sequences were created by combining the two items (Mottron et al., 1999). Thus, the sequences were binary, meaning that they were composed of the two items repeated in random order (e.g. ran – bij – bij – ran). A male voice was used to record the syllables which were read at a rhythm of one item per second. A recognition procedure was used in the test phase. Targets and distracters were presented sequentially in random order. Participants were asked to indicate if the item was part of the list they had previously learned or if it was a new one. There was no time limit, but participants typically provided their responses within three seconds.

2.4.2. Procedure

Each material type was tested separately using a similar procedure. For each material, participants were asked to listen to and memorize a to-be-remembered sequence. After a 1-s delay, a comparison sequence was presented and participants made a same/different judgment on the comparison sequence. Half of the comparison sequences were identical to the memorized sequence. Dissimilar sequences differed by one item from the to-be-remembered sequence, with the result that one item in the sequence was replaced by the other item. There were 28 trials per material. The tasks started with trials of two-item sequences. After four trials, the length of the sequences was increased by one item until eight items were presented.

2.5. Perceptual tasks

2.5.1. Material

The perceptual tasks were same/different judgment tasks on pairs of items. Verbal perception was measured by presenting 44 pairs of syllables of which 21 were dissimilar. The syllables contained two phonemes. Dissimilar syllables differed on the basis of their first (e.g.: NA-KA) or last phoneme (e.g.: JI-JA). None of them corresponded to known words in French. Acoustical perception was measured by presenting 100 pairs of complex sounds of which 51 were dissimilar on the basis of pitch. The pitch differences range from one half-tone to twelve half-tones (one octave). The length of each complex sound was 500 ms. All items were presented through an F-355 Sony CD player.

2.5.2. Procedure

Again, the same procedure was applied to verbal and musical materials, but they were tested separately. A first item was presented to the participant and, after a 500 ms delay, the second item of the pair was presented. Participants then had to make a same/different judgment on the pair of items.

3. Results

3.1. Group analyses

In the LTM tasks, we used the proportion of hits minus false alarms (H-FA) as a first dependent variable. This dependent variable was submitted to a 2 (group: AD, aged controls) × 2 (material: musical, verbal) mixed analyses of variance (ANOVA). Fig. 1a shows the performance of AD and aged controls as a function of material type. Inspection of the data indicates that the groups are well above chance level (a H-FA score of zero) in both conditions. The analysis of the H-FA supported a main group effect, \( F(1, 30) = 7.88, p < 0.001 \), indicating that aged controls had better discrimination than AD participants. Neither the main effect of material, nor the group by material interaction reached significance, \( F < 1 \) in both cases. Separate analyses were also carried on hit and false alarm rates (Table 2). Each dependent variable was submitted to a 2 (group: AD, aged controls) × 2 (material: musical, verbal) mixed ANOVA. The ANOVA on hit rate indicated a significant group effect, \( F(1, 30) = 5.66, p < 0.05 \), participants with AD...
showing a lower hit rate than healthy controls. Neither the main material effect, $F(1, 30) = 3.15, p = 0.086$, nor the group by material interaction, $F < 1$, reached significance. The ANOVA on false alarm rate indicated a significant main group effect, AD participants producing more false alarms than healthy controls, $F(1, 30) = 4.15, p = 0.05$. Here again, neither the main effect of material, $F < 1$, nor the material by group interaction reached significance, $F < 1$ in both cases.

In the STM tasks, H-FA served as a first dependent variable. The performance of AD and aged controls is shown for each material in Fig. 1b. Again, the groups are well above chance level in both conditions. A 2 (group: AD, aged controls) x 2 (material type: musical, verbal) mixed ANOVA was conducted. Overall, AD participants performed worse than controls, as indicated by a main group effect, $F(1, 30) = 5.84, p < 0.05$. The main effect of material, $F(1, 30) = 3.34, p = 0.078$, and group by material interaction, $F(1, 30) = 1.06, p = 0.31$, failed to reach significance. Separate data for hits and false alarms are presented in Table 2. None of the main effects nor interaction reached significance when analyzing hit rates, $F < 1$ in all cases. The analysis of the false alarms supported a main group effect, $F(1, 30) = 5.19, p < 0.05$, indicating that AD participants produced more false alarms than aged controls. There was also a main effect of the material, $F(1, 30) = 8.21, p < 0.01$, musical STM being associated with a higher false alarm rate than verbal STM. The interaction was far from significance, $F < 1$.

Persons with AD obtained scores of 93.2% ($SD = 5.5$) and 91.4%, ($SD = 8.6$) in the verbal and musical discrimination task, respectively. Aged controls obtained an average score of 95.0% ($SD = 5.14$) and 93.1% ($SD = 8.9$) in the verbal and musical discrimination task, respectively. We used a Mann-Whitney non-parametric test because the data were not normally distributed and because a small proportion of participants were at ceiling (13% and 19% for the verbal and musical task, respectively). The analyses revealed that the two groups obtained similar results in the musical ($U = 107.5, p = 0.44$) and verbal tasks ($U = 99, p = 0.27$).

### 3.2. Correlational analysis

We used Pearson correlations to assess if participants showed an association between their H-FA scores obtained with verbal and musical materials. Scatter plots are presented in Fig. 2a and b. There was a significant correlation between musical and verbal

![Fig. 2.](image-url)

Table 2

<table>
<thead>
<tr>
<th></th>
<th>AD</th>
<th>Aged controls</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Musical LTM</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hits</td>
<td>0.75 (0.05)</td>
<td>0.86 (0.04)$^*$</td>
</tr>
<tr>
<td>False alarms</td>
<td>0.31 (0.05)</td>
<td>0.2 (0.05)$^*$</td>
</tr>
<tr>
<td><strong>Verbal LTM</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hits</td>
<td>0.81 (0.03)</td>
<td>0.92 (0.02)$^*$</td>
</tr>
<tr>
<td>False alarms</td>
<td>0.27 (0.03)</td>
<td>0.19 (0.04)$^*$</td>
</tr>
<tr>
<td><strong>Musical STM</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hits</td>
<td>0.83 (0.03)</td>
<td>0.88 (0.03)</td>
</tr>
<tr>
<td>False alarms</td>
<td>0.28 (0.04)</td>
<td>0.21 (0.03)$^*$</td>
</tr>
<tr>
<td><strong>Verbal STM</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hits</td>
<td>0.81 (0.03)</td>
<td>0.88 (0.03)</td>
</tr>
<tr>
<td>False alarms</td>
<td>0.23 (0.03)</td>
<td>0.13 (0.02)$^*$</td>
</tr>
</tbody>
</table>

$^*$ Indicates a significant group difference ($p < 0.05$).
STM (AD: $r = 0.66, p < 0.01$; aged controls: $r = 0.68, p < 0.01$), but no significant correlation was obtained between musical and verbal LTM (AD: $r = 0.07$; aged controls: $r = 0.23$). When examining individual performance, it was found that across memory type (STM and LTM), 28% of the patients had impairment (defined by a performance of more than 1 SD below that of controls) in the verbal domain but not in the musical domain, 19% in the musical domain but not in the verbal domain, and 19% in both.

We also examined the association between STM and LTM for musical and verbal material. Scatter plots are presented in Fig. 2c and d. None of the correlations came out as significant in AD patients. In healthy controls, there was only a positive correlation between musical STM and LTM ($r = 0.51, p < 0.05$). When examining individual performance, it was found that across domains, 31% of the patients had a STM deficit (defined as standing more than one standard deviation below the mean of healthy controls) without LTM deficit, 16% had a LTM deficit without STM deficit and 22% had a deficit in both STM and LTM.

4. Discussion

The goal of this study was to evaluate musical short-term and long-term memory in AD. Musical memory was compared to verbal memory under testing conditions that were deemed as comparable as possible and with tasks that were matched in terms of difficulty level. Comparability in difficulty level was supported by the absence of an overall material effect. The fact that we obtained a comparable performance level, whether using musical or verbal material, indicates that one material condition was not more difficult for our participants than the other. Our group results are extremely straightforward. They indicate that musical memory – whether tested in STM or LTM- is impaired in AD patients and that the deficit is of the same magnitude as that found with verbal material. Because AD patients achieved excellent performance in the discrimination tasks, the deficits found in AD cannot be merely accounted for as difficulties in stimulus perception.

The finding of a reduced LTM for new melodies in AD is coherent with the data of Quoniam et al. (2003) indicating that AD patients are impaired in the incidental learning of unknown melodies. It is also in line with the fact that the temporal lobe, implicated in long-term musical memory (Samson & Zatorre, 1991, 1992), is affected relatively early in AD (Chetelat & Baron, 2003; Chetelat et al., 2002). However, our finding of impaired musical LTM is in contrast with Bartlett and collaborators (1995) and with Halpern and O’Connor (2000) both of whom report normal LTM for unfamiliar melodies in AD. Notably, the results obtained by those studies indicated a floor effect for the AD group and a near-floor effect for the control group that could have prevented the appearance of a difference between the two groups. Our data were not restricted by the presence of a floor effect. Because our study involved two learning trials, it might have protected participants from performing at floor. There is indeed ample empirical support indicating that an increase in learning opportunities reinforces the memory traces in healthy adults (Paolo, Troster, & Ryan, 1997) and that this is also the case in AD patients (Fox, Olin, Erblich, Ippen, & Schneider, 1998). Another potentially important difference is our use of intentional instructions, which could have promoted a more appropriate encoding in our participants. In a previous study, we compared older participants to younger ones in a similar musical memory task and found an age-related impairment when tested under an incidental condition, but no age-related impairment when tested under an intentional condition (Blanchet, Belleville, & Peretz, 2006). The advantage of intentional over incidental encoding in older participants may come from the fact that some of the incidental encoding paradigms require that participants process items on some pre-determined dimensions at encoding (for example, by asking to judge the melodies on their speed or on the meter). This implicates that they have to pay attention, at encoding, to dimensions that may not be optimal to memory to the detriment of more appropriate dimensions.

Impairment in musical STM was also found in AD. The deficit obtained in musical STM is congruent with the results of White and Murphy (1998) who also report a reduction in AD for the short-term retention of musical sequences. It has been shown that patients with AD have an impaired STM when tested with a range of verbal and visuo-spatial materials (Morris & Baddeley, 1988). Our results indicate that this STM deficit might extend to musical material. Notably, Kurylo et al. (1993) reported unimpaired musical STM in AD. However, there are important differences when comparing the paradigm used by Kurylo and collaborators (1993), the one used by White and Murphy (1998), and the one used here. One major difference is that Kurylo used melodies whereas White and Murphy (1998) and the present study relied on two-tone binary sequences, which were not constructed to obey tonal rules. It is possible that the use of melodies provided encoding cues that benefited AD patients.

Because AD is associated with a STM deficit in our study, one needs to consider whether this deficit could have prevented them from encoding properly the material presented in the LTM tasks. Correlation analyses and Fig. 2 revealed that performance of AD participants in musical STM was not associated with their performance in musical LTM and the same was true of verbal STM and LTM. Moreover, 31% of AD participants had a deficit in STM in one domain without having a deficit in LTM in the same domain. These findings indicate that a STM deficit does not necessarily result in a LTM deficit and are consistent with a non-sequential view of memory.

The second issue addressed by this study was to test the presence of material-specific impairment in AD and contribute to the debate regarding the independence between musical and verbal memory. First, we found no significant correlation between the performance of AD participants on LTM for musical and verbal materials, and a large number of patients showed dissociation at the individual level. These results are consistent with the existence of independent musical and verbal memory systems. Yet, we found that musical and verbal LTM are impaired to the same degree in AD. On logical ground, we are aware that finding a similar degree of impairment on different tasks does not mean that the two tasks rely on the same mechanisms, but this finding is certainly compatible with models that envision a link between music and language. Furthermore, lack of a correlation in AD should be interpreted with caution given our small sample size and the presence of a ceiling effect in some patients. In addition, because there is no association between verbal and musical LTM in healthy older controls as well, the data in AD cannot be interpreted as arising from differences in brain lesions. Finally, lack of an association could arise as well from an incomplete match between verbal and musical tasks. While there was an effort to equate the two tasks on a number of dimensions, the material differed on some other dimensions, including the length of the stimuli and the fact that participants were necessarily more expert in the verbal than musical domain.

Contrary to what was found in LTM, verbal and musical STM were associated at the group and individual levels. Both domains were impaired to the same extent in AD and there was a strong and significant correlation in STM between verbal and musical materials in both groups of participants. This finding might arise from the fact that the cognitive and brain mechanisms underlying verbal and musical STM are partly or fully overlapping as was suggested to be the case for syntax processing (Patel, 2003). The process that allows the tagging of item order could be one of these shared mechanisms as both tasks required that participants retain an ordered representation of the sequence. This process may be a
central component that is shared by the musical and verbal systems involved in STM. The association between musical and verbal STM in AD could also be explained by the fact that the STM reduction in AD is related to impairment of a central executive component involved in attentional control (Baddeley, 1986; Baddeley & Hitch, 1974). Many authors have suggested that the deficit in deploying attentional resources in AD has repercussions on their capacity to complete simple STM tasks irrespective of material type (Belleville, Peretz, & Malenfant, 1996; Collette, Van der Linden, Bech, & Salmon, 1999; Peters et al., 2007). If the STM decline of AD patients arises from the deficit of an attentional controller that is shared by domain-specific storage components, this should indeed result in an association between STM performances across various material types including verbal and musical materials. Note, however, that our finding of a strong correlation between verbal and musical STM in healthy controls as well as in AD patients suggests that this association is not due simply to the fact that attentional resources are depleted in AD. Finally, rather than implying common mechanisms between musical and verbal STM, our strong correlation could reflect the particular nature of our STM tasks as tasks relying, to a great extent, on the memorization of sequential order.

Our results of impaired memory in AD may seem at odds with the reports that AD persons benefit from music therapy. First, although musical memory in AD was not as good as in healthy older adults, participants were not at floor and they exhibited sizeable retention reports that AD persons benefit from music therapy. First, although our strong correlation could reflect the particular nature of our STM tasks as tasks relying, to a great extent, on the memorization of sequential order.

The emotion of music plays a role in modulating pain reduction (Roy, Peretz, & Rainville, 2008). The positive emotions conveyed by melodies used in music therapy are often taken from a repertoire of songs that accompanied the patients throughout their lives. Because older memories are generally better preserved than more recent ones (Dorrego et al., 1999), they could contribute to the efficacy of music therapy. Case reports of preserved musical memory for familiar melodies have been reported (for example, Cuddy & Duffin, 2005) and Bartlett and collaborators (1995) reported only marginal deficits in AD for the recognition of traditional melodies. Thus, the familiarity of the melodies that are used in music therapy could have a significant impact on its efficacy. Finally, the contribution of emotions in music therapy should be addressed. On the one hand, there are data suggesting dissociation between musical processing and the emotions conveyed by melodies (Peretz & Gagnon, 1999). On the other hand, there are promising findings indicating that the emotional valence of music can play a role in modulating pain reduction (Roy, Peretz, & Rainville, 2008). The positive emotions conveyed by familiar melodies may thus have an impact on AD by reducing feelings of distress and insecurity.

In summary, this study shows that musical memory is impaired in AD, whether tested with LTM or STM paradigms. Group comparisons of persons with AD and healthy controls indicate that musical memory is as vulnerable as verbal memory in AD pathology. Measurement of performance on perceptual tasks and examination of patterns of association indicate that the memory deficit is not merely due to perceptual deficits and that the LTM deficit is not caused by a limitation at encoding related to STM deficits. Musical and verbal memory is impaired to the same degree in AD patients, which lends support to the combined view. The fact that STM in verbal material is correlated also suggests that the two domains may share common structures or mechanisms. However, the lack of an association between musical and verbal LTM is not entirely supportive of a combined view. Future studies will be necessary to clarify further the nature and extent of the relationship between musical and verbal memory. It seems obvious that the study of persons with AD may be particularly informative in this endeavor.

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