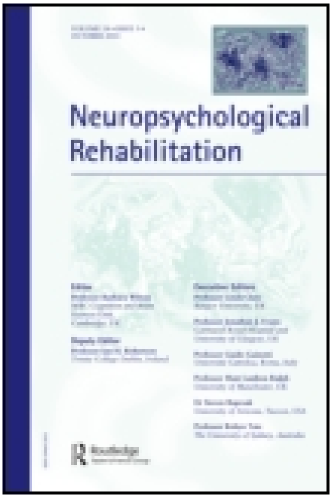

Neuropsychological Rehabilitation: An International Journal

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/pnrh20

Learning sung lyrics aids retention in normal ageing and Alzheimer's disease

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Published online: 02 Jun 2014.

To cite this article: Aline Moussard, Emmanuel Bigand, Sylvie Belleville & Isabelle Peretz (2014) Learning sung lyrics aids retention in normal ageing and Alzheimer's disease, Neuropsychological Rehabilitation: An International Journal, 24:6, 894-917, DOI: 10.1080/09602011.2014.917982

To link to this article: http://dx.doi.org/10.1080/09602011.2014.917982

Neuropsychological Rehabilitation, 2014
Vol. 24, No. 6, 894–917, http://dx.doi.org/10.1080/09602011.2014.917982

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Learning sung lyrics aids retention in normal ageing and Alzheimer's disease

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(*Received 22 October 2013; accepted 14 April 2014*)

Previous studies have suggested that presenting to-be-memorised lyrics in a singing mode, instead of a speaking mode, may facilitate learning and retention in normal adults. In this study, seven healthy older adults and eight participants with mild Alzheimer's disease (AD) learned and memorised lyrics that were either sung or spoken. We measured the percentage of words recalled from these lyrics immediately and after 10 minutes. Moreover, in AD participants, we tested the effect of successive learning episodes for one spoken and one sung excerpt, as well as long-term retention after a four week delay. Sung conditions did not influence lyrics recall in immediate recall but increased delayed

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We wish to thank Amélie Racette and Sylvie Hébert for the material. We thank Emilie Lepage (IUGM), and the Alzheimer Society of Montreal for recruitment of the Alzheimer's disease participants, and Nadia Jaffer (IUGM) for recruitment of controls; and above all, the 15 participants. We thank Patrick Bermudez for his insightful comments.

The first author holds a fellowship from the Sciences and Engineering Research Council of Canada, Collaborative Research and Training Experience Program (NSERC-CREATE) in Auditory Cognitive Neuroscience training grant, and from the French foundation Médéric-Alzheimer. Preparation of this paper was also supported by grants from Natural Sciences and Engineering Research Council of Canada (NSERC), the Canadian Institutes of Health Research (CIHR) to I. Peretz and S. Belleville, and from a Canada Research Chair to I. Peretz.

recall for both groups. In AD, learning slopes for sung and spoken lyrics did not show a significant difference across successive learning episodes. However, sung lyrics showed a slight advantage over spoken ones after a four week delay. These results suggest that singing may increase the load of initial learning but improve long-term retention of newly acquired verbal information. We further propose some recommendations on how to maximise these effects and make them relevant for therapeutic applications.

Keywords: Alzheimer's disease; Cognitive Ageing; Verbal Memory; Delayed Recall; Music.

INTRODUCTION

Music is said to improve mood and cognition in patients with Alzheimer's disease (AD) (Koger & Brotons, 2000) and is often used to stimulate their autobiographical memory (e.g., Irish et al., 2006). This study aims to investigate if singing could be used as a form of support for new acquisitions in verbal memory in both elderly individuals and patients with mild AD. It is a common belief that music can serve as a mnemonic. However, studies conducted in young adults comparing the learning of spoken versus sung lyrics reveal mixed results. Some show a beneficial effect of the sung condition (Calvert & Tart, 1993; Chazin & Neuschatz, 1990; Kilgour, Jakobson, & Cuddy, 2000; McElhinney & Annett, 1996; Rainey & Larsen, 2002; Wallace, 1994; Wolfe & Hom, 1993), while others show no effect (Gingold & Abravanel, 1987; Jellison & Miller, 1982; Kilgour et al., 2000; Rainey & Larsen, 2002; Wolfe & Hom, 1993) or even a detrimental effect of singing (Calvert & Billingsley, 1998; Jellison & Miller, 1982; Racette & Peretz, 2007).

A detrimental effect of singing information to be memorised can be explained by the fact that sung lyrics contain more material to learn (lyrics + melody) in comparison to spoken lyrics alone. Thus, learning a song may constitute a dual task and increase memory load during learning. This hypothesis is consistent with the observation that melody provides an aid when familiar, hence eliminating the cost of learning a novel tune (Korenman & Peynircioglu, 2004; Purnell-Webb & Speelman, 2008; see also Wolfe & Hom, 1993, in children). On the other hand, dual coding can be initially demanding but creates a stronger memory trace that can facilitate retrieval over time (Paivio, 1967). McElhinney and Annett (1996) provided some support for this hypothesis. In their study, sung and spoken lyrics were initially recalled equally well but repetition resulted in better retention of sung lyrics than spoken ones (see also Calvert & Tart, 1993, for similar results). Similarly, Rainey and Larsen (2002) observed no initial advantage of a sung list of words over a spoken one in the first learning session but found that participants required fewer trials to relearn the list when it was sung rather than spoken in the second learning session, one week later.

Improving memory consolidation is of great importance for a pathological population such as AD. Yet, only three studies investigated the effect of singing on new material acquisition in persons suffering from Alzheimer's disease (AD). The first study (Prickett & Moore, 1991) showed that AD patients (N = 10; with unknown severity of cognitive impairment) recalled new lyrics poorly regardless of whether they were sung or spoken. However, the study suffers from methodological problems (e.g., the stimulus complexity was not controlled across conditions). In the second study (Simmons-Stern, Budson, & Ally, 2010), mild AD participants (N = 13) were found to recognise short verbal excerpts better when they were sung rather than spoken. These findings are promising although the study used a recognition paradigm, which is not as ecologically valid as a free recall measure.

The third study (conducted in our research centres; Moussard, Bigand, Belleville, & Peretz, 2012) is a case study in a mild AD patient, JL, investigating sung versus spoken lyrics learning in a free recall task. This study also tested the familiarity of the melody and the delay of retention – two factors that have been shown to influence memory for sung lyrics in young adults. As expected, dual coding of sung lyrics led to worse performance than spoken lyrics learning in immediate recall, unless the lyrics were learned on a familiar melody. Interestingly, after repeated learning episodes, sung lyrics led to a better retention of words, measured in a delayed recall 10 minutes after each learning session, as well as after a 4 week delay (Moussard et al., 2012). These initial findings call for a replication in a group of patients, which is the goal of the present study.

In a within subject design, we tested a group of AD patients and a group of healthy matched Controls so as to measure (1) initial learning and retention (immediate recall and 10 minute delayed recall) of sung versus spoken new lyrics, and (2) the influence of tune familiarity when sung. Then, in AD patients only, we aimed to test (3) the influence of repeated learning sessions on learning and retention of sung and spoken lyrics, and (4) learning and retention of those sung and spoken lyrics after a long delay (4 weeks).

This study was divided into two phases. The first involved mild AD participants and matched healthy older adults in a within-subject design and contrasted four conditions of new lyrics learning: lyrics recited as a poem (Spoken), sung on a non-familiar melody (SungNF), sung on an non-familiar melody that was previously learned alone before adding the lyrics (i.e., low familiarity level, SungLF), and sung on a life-long familiar melody (i.e., high familiarity level, SungHF). Because singing in unison during learning may improve performance of aphasic patients (Racette, Bard, & Peretz,

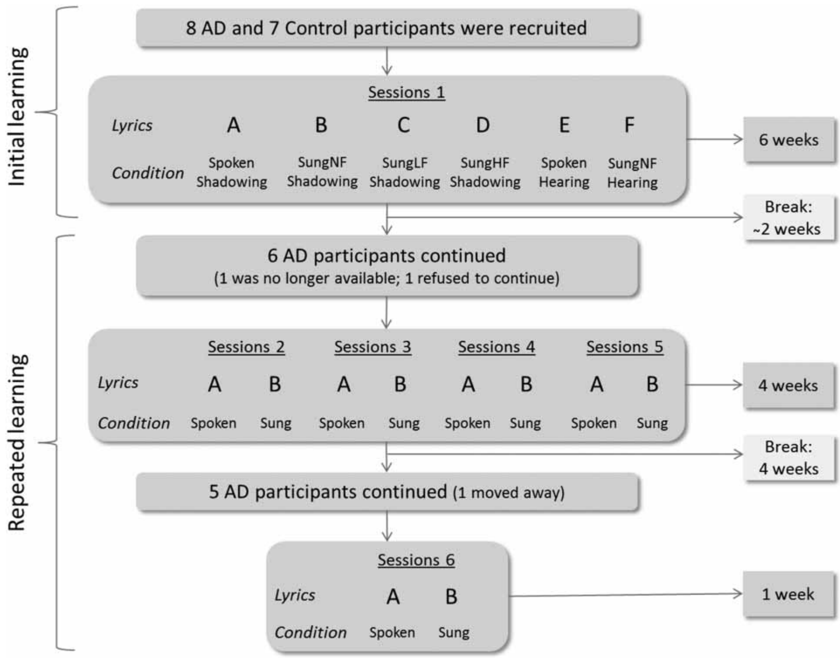

Figure 1. Illustration of the design. For initial learning, lyrics x condition matching was counterbalanced across participants (except for SungHF_Shadowing). For repeated learning, the same 2 excerpts (from initial learning: Spoken_Shadowing and SungNF_Shadowing) were learned 5 times each (4 times through 4 successive weeks and once more after a 4-week break). In the repeated learning phase, excerpts were learned over separate days (e.g., every Monday for Spoken and every Thursday for Sung).

2006), we contrasted two learning procedures for two of these presentation modes (Spoken and SungNF, with new lyrical excerpts): during the encoding of lines of lyrical excerpts, participants had to repeat the line in unison with the experimenter after a first presentation (i.e., Shadowing condition; see Figure 1) or just hear it again without singing (i.e., simple Hearing condition).

According to studies showing a possible detrimental effect of sung lyrics learning in young healthy participants (e.g., Racette & Peretz, 2007) and mild AD patients (Moussard et al., 2012), we predicted that learning both new lyrics and new melody at the same time will impair learning in immediate recall (SungNF < Spoken) in healthy elderly participants, and have a more detrimental effect in AD patients given their attentional and memory impairment. However, because familiarity of the melody should help (e.g., Korenman & Peynircioglu, 2004; Moussard et al., 2012), we predicted that performance will improve as familiarity of the melody increases (SungNF < SungLF < SungHF) for both groups. Finally, better consolidation for sung lyrics should be observed in delayed recall, with a possible interaction with melodic familiarity (Spoken $<$ SungNF $\leq$ SungLF $\leq$ SungHF).

In the second phase of the study, we investigated the rate of learning for both Spoken and SungNF excerpts through repeated learning sessions in AD participants. Given that young adults show faster learning for sung material after repeated exposures (e.g., McElhinney & Annett, 1996; Rainey & Larsen, 2002), we predicted a better progression for the Sung than for the Spoken condition across learning episodes and for this difference to be more marked after a four week delay.

METHOD

Participants

Eight AD and seven healthy matched Control participants were involved in this study. The mean age was 77.8 years ($SD = 5.2$) in the AD group and 75.7 years ($SD = 7.4$) in the Control group (Mann-Whitney U test showed no significant difference, $U = 24.5$, $p = .69$). AD participants were recruited from the Geriatric Institute of the University of Montreal (Institut Universitaire de Gériatrie de Montréal, IUGM) and the Montreal Alzheimer's Society, Quebec. They all met the NINCDS-ADRDA research criteria for probable AD (McKhann et al., 1984) and the DSM-IV clinical criteria for dementia of the Alzheimer type (APA, 1994). All were in mild stages of disease (MMSE between 23 and 27). Mixed dementias were excluded. The data of the first participant in this study (JL) have been previously reported as a case study by the same authors (Moussard et al., 2012). Control participants were older adults with no cognitive impairment matched to AD participants according to age and education level (Table 1). They were recruited from the IUGM database of elderly volunteers. For the two groups, exclusion criteria included presence or history of severe psychiatric disorders, neurological disorders, cerebrovascular diseases, alcoholism and dyslexia. For all participants, French was the native language. One Control participant (AL) was bilingual (French-English). Written informed consent was obtained from each individual and the study was authorised by the ethics committee of IUGM.

Neuropsychological assessment of participants is presented in Table 1. As expected, AD participants showed lower scores than Controls on the Mini Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) and verbal memory for words (Rey's 15 words; Rey, 1970) and stories (Gély-Nargeot, Cadilhac, Touchon, & Nespoulous, 1997), and slightly inferior scores for verbal comprehension (Token test; De Renzi & Vignolo, 1962). They did not show significant differences from Controls for verbal

TABLE 1
Neuropsychological assessment of AD and Control participants

	Demographic data			*General cognition*	*Memory*						*Attention*	*Executive functions*	*Language*	*Psychological state*	
					Rey's 15 words		*Story recall (number of items)*								
	Sex	*Age*	*Educ.*	*MMSE/30*	*5 free recall trials /75*	*Recognition/15*	*Immediate/46*	*10-min delayed/46*	*Short-term memory (digit span forward)*	*Working memory (digit span backward)*	*TEA (elevator task)/7*	*Verbal fluency: "Animals" | "P"; 1.5 mn (nb words)*	*Token testss/44*	*Geriatric Depression Scale (GDS) /30*	*Well-being scale /100*
AD															
HD	F	79	9	23	25	9	5	1	5	3	7	-	40	2	80
JO	M	77	17	23	12	2	1.5	0	5	3	6	5 | 4	29	0	84
JL	F	67	7	25	32	12	8	3	5	5	7	20 | 9	39	1	84
AM	F	84	12	25	22	8	3.5	0	7	4	6	24 | 20	32	7	54
JE	M	77	7	26	22	9	8	3.5	5	3	7	21 | 10	36	17	39
JR	M	79	16	26	17	7	4.5	0	6	4	7	28 | 26	42	5	69
RL	M	76	9	27	32	13	8	6	5	4	7	12 | 20	37	9	64
HU	F	83	16	27	19	4	4.5	3.5	6	5	7	13 | 20	35	6	94
Mean	4M/4F	77.8	11.6	25.3	22.65	8	5.4	2.1	5,5	3.9	6.8	17.6 | 15.6	36.3	5.9	71
SD		5.20	4.2	1.6***	7***	3.7***	2.4***	2.2***	0.8	0.8	0.5	7.9 | 7.9	4.3**	5.5	18.2
CTRL															
LL	F	82	10	28	42	15	5.5	5.5	6	4	7	10 | 9	41	6	73
RJ	F	77	15	28	63	15	23.5	19	5	4	7	28 | 17	44	1	85
RD	M	65	11	29	51	15	18.5	20	6	5	7	30 | 24	44	3	92
AL	F	70	15	29	62	15	28.5	23.5	5	4	7	27 | 12	43	1	68
LA	M	84	9	29	43	8	17.5	17.5	7	5	7	15 | 7	42	1	87
CB	F	70	8	30	45	12	21	19	5	4	7	22 | 22	36	4	79
MA	F	82	14	30	61	15	27	21	6	4	7	26 | 27	44	2	87
Mean	2M/5F	75.7	11.7	29	52.4	13.6	20.2	17.9	5.7	4.3	7	22.6 | 16.9	42	2.6	81.6
SD		7.4	2.9	0.8	9.4	2.7	7.7	5.8	0.8	0.5	0	7.4 | 7.8	2.9	1.9	8.6

short-term and working memory (forward and backward digit spans), auditory attention (Test of Everyday Attention, elevator task; Robertson, Ward, Ridgeway, & Nimmo-Smith, 1994) or verbal fluency ("animals" and the letter "P"). There were no significant differences in the questionnaires of depression (Geriatric Depression Scale; Yesavage et al., 1983) and well-being (Bravo, Gaulin, & Dubois, 1996).

Patients also completed an extensive evaluation of auditory and musical abilities (Table 2). All participants were non-musicians (questionnaire from Ehrlé, 1998). They all had normal hearing (according to a test of repetition of sentence fragments from the experimental material). Musical perception abilities were tested with adapted exercises from the child version of the Montreal Battery of Evaluation of Amusia (the MBEMA; Peretz et al., 2013): all participants showed normal ability to discriminate changes in melodies, which could either violate the key, the interval size, the contour, or the rhythm. Both groups of participants showed equivalent scores for the recognition of emotions – happiness, sadness and fear – from short instrumental excerpts (taken from Vieillard et al., 2008). They did not show any difference in short-term memory for tones (from Ménard & Belleville, 2009). Participants also showed similar recognition of familiar instrumental songs (as in Samson, Baird, Moussard, & Clément, 2012). Differences between groups were found for episodic memory of previously heard familiar and non-familiar melodies (from Samson et al., 2012), after one exposure to these songs (familiar songs: $Z = 1.94$, $p = .053$; and non-familiar songs: $Z = 2.49$, $p < .05$), as well as after three exposures to the familiar songs ($Z = 2.91$, $p < .01$).

Out of the eight AD participants involved in the initial learning phase, six participated in the repeated learning phase. Two participants stopped after the first phase; one did not wish to be re-tested (HD) and the other one was no longer available (HU). RL could not participate in the last two sessions (after the four week delay) because he had moved away (see Figure 1).

Materials and procedure

Initial learning. Materials and procedures were the same as in our previous case study (Moussard et al., 2012) and adapted from prior studies conducted by Racette and collaborators (Racette et al., 2006; Racette & Peretz, 2007). Six non-familiar songs were selected from the unknown repertoire of Claude Gauthier, a popular French-Canadian folk-singer and songwriter. These songs were deemed "good songs" in a pilot study where participants had to judge their musicality, simplicity and potential to be a hit. The six lyrics had equal linguistic familiarity, based on a French lexical database (New, Pallier, Ferrand, & Matos, 2001). Each excerpt contained eight lines, with few word or melodic line repetitions. Each line contained an average

TABLE 2
Auditory and musical assessment of AD and Control participants

	Auditory test	*Musical expertise*	*MBEA (adapted from Child version)*			*Musical short-term memory*
	Repetition of sentences /24	*Questionnaire/27*	*Scale /20*	*Intervals-Contour/20*	*Rhythm /20*	*Similarity judgement of 2 to 8 items strings of tones /28*
AD						
HD	23	4	16	15	14	–
JO	21	7	18	17	18	22
JL	23	4	18	14	16	22
AM	22	6	19	20	18	24
JE	24	3	19	19	19	21
JR	23	9	18	19	19	25
RL	23	3	17	18	17	25
HU	24	10	19	20	19	26
Mean	22.9	5.8	18	17.8	17.5	23.6
SD	1	2.7	1.1	2.3	1.8	1.9
CTRL						
LL	23	3	15	16	16	22
RJ	24	5	18	16	18	21
RD	23	4	20	20	20	26
AL	23	3	18	19	18	21
LA	22	3	18	17	18	24
CB	23	4	17	14	15	19
MA	24	7	17	14	20	22
Mean	23.1	4.1	17.6	16.6	17.9	22.1
SD	0.7	1.5	1.5	2.3	1.9	2.3

(*Continued*)

TABLE 2 Continued

	Recognition of musical emotion /% correct			*Semantic and Episodic memory for familiar and unfamiliar melodies (Hits-FA)*				
	Happiness	*Sadness*	*Fear*	*Familiarity recogn./8*	*Test 1, familiar excerpts /8*	*Test 1, unfamiliar excerpts /8*	*Test 2, familiar excerpts /8*	*Test 2, unfamiliar excerpts /8*
AD								
HD	–	–	–	7	2	1	3	0
JO	81.3	18.8	25	7	2	1	1	3
JL	81.3	62.5	56.3	8	0	3	4	2
AM	93.8	56.3	43.8	8	0	1	0	2
JE	31.3	6.3	31.3	7	2	0	2	1
JR	93.8	37.5	43.8	8	4	2	2	4
RL	93.8	43.8	25	6	0	2	5	3
HU	100	43.8	18.8	8	2	2	1	5
Mean	82.1	38.4	34.8	7.4	1.5**	1.5*	2.3***	2.5
SD	23.5	19.9	13.4	0.7	1.4	0.9	1.7	1.6
CTRL								
LL	81.3	43.8	18.8	6	4	2	7	−3
RJ	100	56.3	25	8	7	2	8	4
RD	56.3	31.3	62.5	8	3	3	8	5
AL	87.5	50	50	5	2	3	6	3
LA	93.8	43.8	68.8	6	5	1	4	5
CB	81.3	25	43.8	4	3	2	4	−1
MA	–	–	–	8	6	2	6	3
Mean	83.3	41.7	44.8	6.4	4.3	2.1	6.1	2.3
SD	15.1	11.6	19.9	1.6	1.8	0.7	1.7	3.1

of six words and eight notes, with one-to-one mapping between syllables and tones. Lines respected the grouping preference rules proposed by Lerdahl and Jackendoff (1983) and the alignment of the lyrics and of the melody rhythm conformed to the rules used for French songs (Dell, 1989). As for musical structure, the songs had a stable, standard metre, and were composed in a major mode.

Five of the six excerpts were each recorded in three modes: spoken (recited with natural intonation and speed), sung with its original (non-familiar) melody, and sung on “lala”. The “lala” version served for the prior learning of the melody in the SungLF condition. These excerpts were randomly assigned to the Spoken_Shadowing, Spoken_Hearing, SungNF_Shadowing, SungNF_Hearing, and SungLF_Shadowing conditions. Duration was on average 21 seconds for the spoken versions and 36 seconds for the sung and “lala” versions. The duration of the spoken versions was shorter than the sung ones, in line with natural speech, in order to keep stimuli as ecologically valid as possible. The sixth excerpt was sung on the familiar melody of Beethoven’s *Ode to Joy* (see Figure 2 for an example of this condition), and systematically associated to the SungHF_Shadowing condition. Its duration was 33 seconds. All the excerpts – spoken or sung – were recorded by the same female singer. The sung versions were recorded without instrumental accompaniment.

Because there is a high variability in the number of lines that a participant is able to learn, even in normal subjects (Racette & Peretz, 2007), we used an adaptive procedure (Figure 2). The participant first listened to the whole excerpt once in order to familiarise him/herself with it. Next the excerpt was learned line per line, until failure. The Shadowing procedure occurred as follows: the first line of the excerpt was presented; that same line was presented a second time and the participant had to produce it in unison with both the experimenter and the recording; then, s/he was asked to produce the line alone. Then the second line was presented according to the same procedure: listened to, repeated in unison, and repeated alone. Then the first two lines were performed together according to the same procedure, then the third line, then the first three lines together, the fourth, and so on. A new line was added if the participant recalled at least 65% of the words presented in the previous recall trial, with a minimum of four lines learned for each excerpt. Immediate recall score corresponded to the cumulative score of these recall trials. Then a delayed recall measured rate of retention 10 minutes after the end of learning, without listening to the excerpts again. The Hearing procedure was identical except that the participant did not repeat the line(s) in unison during encoding; s/he heard the line(s) twice (to have the same number of exposures) and then had to recall it.

In the LF condition, the participant was exposed to the “lala” version of the melody several times for a couple of weeks prior to the testing of lyric

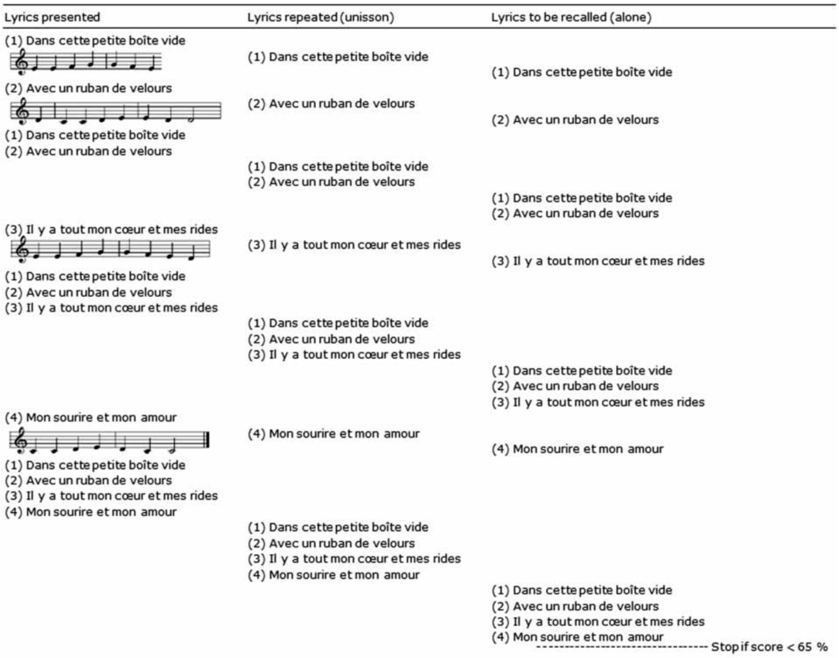

Figure 2. Illustration of the adaptive learning procedure for four lines (after listening to the entire excerpt for familiarisation). For each trial of the Shadowing condition (illustrated here), there were three steps: listening, repetition in unison with the experimenter, and repetition alone (recall). In the Hearing condition, the second step only consisted of listening to the line(s) a second time. The dotted line shows a possible stop of the task, if the participant recalled less than 65% of the words presented. This excerpt corresponds to the familiar melody condition with Beethoven's *Ode to Joy*.

learning. The number of exposures was not strictly controlled because participants had to listen to a CD recording on their own at home several times per week, with verbal and written reminders (and with spouse complicity for AD participants). The experimenter finally ensured that the participant was able to sing it on "lala" at unison with the recorder before learning the lyrics.

Participants were instructed to pay special attention to the lyrics and, if possible, to the melody for sung excerpts. Recall was measured by asking participants to reproduce orally the words of the excerpts as accurately as possible, and otherwise to report whatever came to mind. The recall trials were preferentially made in the same mode as the presentation (i.e., spoken when encoded without music or sung when encoded with music). However, if they felt more comfortable speaking than singing for sung lyrics recall, it was also accepted.

The six lyrical excerpts learned initially were learned over six sessions spaced one week apart and presented in a different order for each subject (within subject design). A training session using another sung excerpt was conducted with each participant prior to the experimental sessions in order to familiarise them with the task, so that the first experimental condition was not the first time participants were exposed to this task. Each session lasted for approximately 45 minutes and took place at the home of the participant, always at the same time of day. Stimuli were presented through a loudspeaker and the entire session was recorded and filmed.

Repeated learning. For each participant, we chose the excerpt that had been learned in the Spoken and SungNF Shadowing conditions at initial learning. These two excerpts were learned five more times during separate sessions (see Figure 1 for an illustration of the design). Thus, each was learned six times in total. The first session (called S1) corresponded to the initial learning (described previously). The following four sessions (S2 to S5) correspond to four successive repeated learning sessions for each excerpt. Sessions occurred twice a week (with at least one day between them) and the participant was taught alternatively either the spoken or sung lyrics (for example, the spoken excerpt was learned each Monday and the s*u*ng one each Thursday – order was counterbalanced across participants). The delay between S1 and S2 could vary from one to five weeks (two weeks on average). The last learning session (S6) occurred strictly four weeks after S5. No contact with participants occurred during this four week break. The same adaptive learning procedure was used as in the initial learning, except that the experimenter made participants learn at least the same number of lines as s/he did in the prior session for each excerpt. The shadowing procedure was used each time and the general procedure was identical to the one used in initial learning stage. Each of these repeated learning sessions also contained a delayed recall after 10 minutes.

Scoring and data analysis

Only trials where participants had more than one line to recall (i.e., lines 1 to 2, 1 to 3, and so on up to lines 1 to 8) were considered as recall trials. As participants learned at least four lines, they performed at least three recall trials in immediate recall and one in delayed recall. All the recall trials were transcribed (approximately 500 for all participants in initial learning and 300 for AD in repeated learning) from video recordings by two judges who were independent from the study. Our main measure is the words recalled. We also took advantage of having a large set of data after the relearning sessions to examine the preferred mode of recall (spoken or sung) and the type of errors[1].

[1]We also analysed the size of chunks of words recalled. There was no clear influence of conditions in initial learning. In repeated learning, AD produced larger chunks in the Sung condition compared to the Spoken one and in delayed recall only ($Z = 2.41$, $p < .05$).

A scoring distinction was made between exactly correct words and approximate words (semantically congruent words, e.g., a verb derived from a noun, or a strict synonym): 1 point was attributed for a correct word and 0.5 for an approximate one. This score was then divided by the number of expected words. This way, one score of immediate recall was obtained by accumulating the scores for all trials completed during excerpt learning (before failure). For the delayed recall score, the percentage of words recalled was computed from the number of words learned during excerpt learning.

The two subsequent measures were only applied on the first three trials (i.e., first four lines)[2]. To assess the effect of mode of recall, the ratio of words spontaneously sung to total number of correct words recalled was calculated. Errors were distinguished as (1) phonological errors (words that "sounds like" the target word, e.g., "joie" for "jouet"), (2) semantically and phonologically incongruent errors (e.g., "soldat" [*soldier*] for "frère" [*brother*]), and (3) functional word intrusion (grammatical words without semantic content, e.g., "et" [*and*], "qui" [*which*]). For each error type, we computed a ratio out of the total of words recalled (correct + errors).

Due to the small sample size, data were analysed using non-parametric tests. For initial learning, main effect of condition (Spoken_Shadowing, SungNF_Shadowing, SungLF_Shadowing, SungHF_Shadowing, Spoken_Hearing, SungNF_Hearing) was tested with a Friedman ANOVA (Friedman's χ^2) and contrasts between conditions were performed with Wilcoxon *Z*. For repeated learning, the same analyses were performed for Time (six learning sessions) and Condition (Spoken and Sung) effects. Pearson Chi-Square (Pearson's χ^2) was used for intra-individual comparisons. Spearman's correlation allowed comparison of experimental scores with neuropsychological and musical performance.

RESULTS

Initial learning

The cumulative percentage of words recalled in immediate recall for AD and Controls is presented in Figure 3 (top). With the Shadowing procedure, both

[2]Because of the adaptive procedure, the task stops or goes on depending on the number of words recalled. A problem resulting from this procedure is that the three other measures (sung words, size of chunk, and intrusion errors) depend on the number of words recalled. For example, when a participant learns more lines, the task becomes more difficult and he has more chances to make mistakes with word position; in that case, his score of intrusions will be high because overall, he recalled more words and had more lines to learn than others. To avoid this contamination of measures and control for performance level, we only adjusted performance for the first three trials (the learning of the first four lines) that were always completed by all participants.

groups showed a very similar pattern of results, with the worst performance for the SungNF condition and better performance for the familiar tune. Statistical analysis did not show any main effect of condition, but we performed Wilcoxon contrasts to test our hypothesis regarding poorer performance for Spoken versus SungNF lyrics. Contrasts did not show differences between Spoken and SungNF for either of the learning procedures. The only difference reaching significance concerned the inferiority of the SungLF_Shadowing condition to the Spoken_Shadowing one in the AD group ($Z = 2.38, p < .05$). A significant effect of the learning procedure was shown overall in favour of the Hearing procedure ($Z = 2.17$, $p < .05$). This effect was also found when comparing SungNF_Shadowing with SungNF_Hearing conditions ($Z = 2.38, p < .05$).

Percentages of words recalled in delayed recall for AD and Control groups are presented in Figure 3 (bottom). In this case, AD participants showed an effect of condition, $\chi^2(5) = 11.35$, $p < .05$. Wilcoxon comparisons showed that, independently of learning procedure, the Spoken condition was inferior to the SungNF condition ($Z = 2.43$, $p < .05$). Moreover, this effect was relatively robust across individuals, with a minority of participants recalling only a few words in the spoken conditions while a majority recalled some words in the sung condition. Controls also showed a main effect of condition in delayed recall, $\chi^2(5) = 12.21$, $p < .05$. Comparisons highlighted better performance for the SungHF_Shadowing condition (compared to Spoken_Shadowing: $Z = 2.20, p < .05$; SungNF_Shadowing: $Z = 2.37, p < .05$; and Spoken_Hearing: $Z = 2.37$, $p < .05$).

To summarise, Controls showed no effect of condition in immediate recall and the best delayed recall for lyrics sung on the highly familiar melody. AD participants showed a tendency towards better performance for spoken lyrics in immediate recall but a clear superiority for Sung conditions in delayed recall (independently of melodic familiarity).

Repeated learning

Words recalled. Results for the relearning phase (six AD, five AD in the very last session) are presented Figure 4[3]. Percent success in immediate recall increased across Sessions in both Spoken, $\chi^2(5) = 14.20, p < .05$, and Sung, $\chi^2(5) = 14.94, p < .05$, conditions. There was no effect of Condition. As can be seen, the Sung condition tended to be better than the Spoken one in the last session (S6), although the difference did not reach significance ($p > .1$) and no statistical difference was observed between S5 and S6 for either the Spoken or the Sung condition.

[3]Note that results of S1 (initial learning) can differ slightly from the previous results of initial learning because scores were recalculated with the 6/8 AD participants who took part in repeated learning.

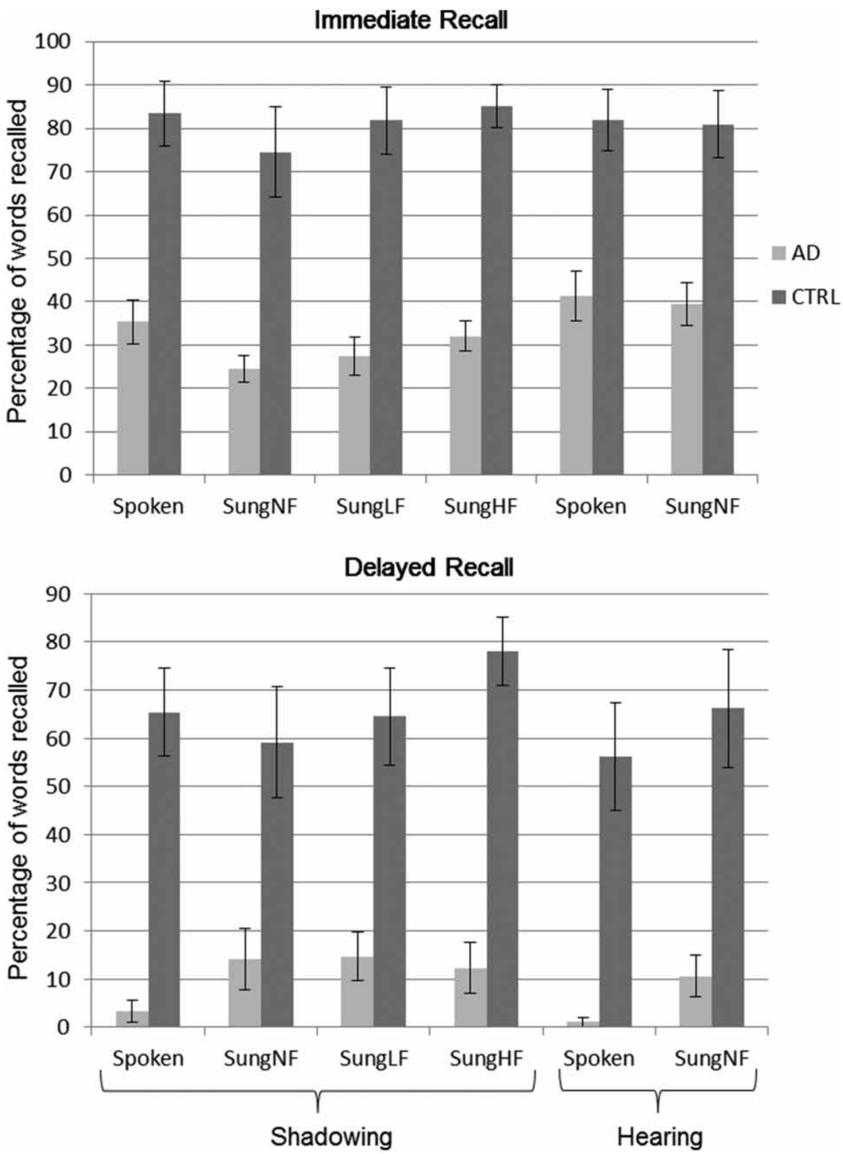

Figure 3. Percentage of words recalled depending on conditions in initial learning, for immediate (up) and delayed (down) recall, for Controls ($N = 7$) and AD ($N = 8$). Error bars represent one standard error.

The analysis of individual data revealed that two participants (JL, JO) showed a significant advantage for the Sung condition compared to the Spoken one in the very last session (S6; Pearson $\chi^2 = 12.28$, and $= 14.9$,

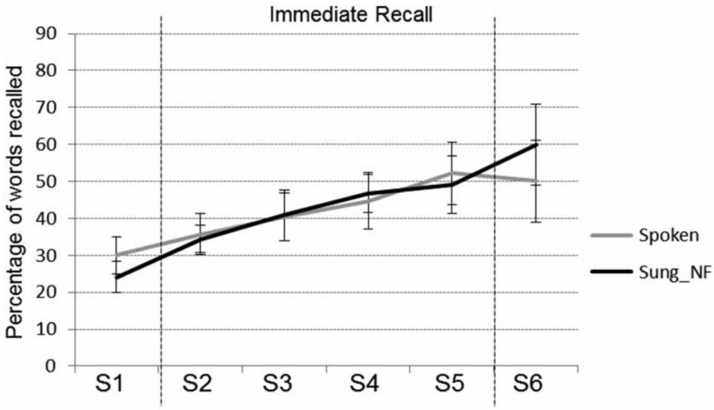

Figure 4. Percentage of words recalled though sessions depending on Sung and Spoken conditions in repeated learning for immediate recall, for 6 AD participants (5 for the last session, S6). Session 1 (S1) corresponds to initial learning, Sessions S2 to S5 correspond to the four successive relearning sessions, and the very last Session (S6) occurred 4 weeks after S5. Error bars represent one standard error. Dotted lines represent the breaks (1 to 5 weeks between S1 and S2; always four weeks between S5 and S6).

$p < .001$), while no one performed better on the Spoken lyrics than the Sung lyrics in S6. Moreover, Sung lyrics showed better progression than Spoken lyrics between S5 and S6 (i.e., over the four week break) for three out of five participants: JL, AM and JR (Pearson $\chi^2 = 18.91$, 9.36, and 4.8, $p <$ .05, respectively). Such an increase between S5 and S6 was never observed for the Spoken condition.

Delayed recall was more variable across subjects and sessions (see individual data in Figure 5). Group analysis showed an effect of Session in the Spoken condition, $\chi^2(5) = 12.81$, $p < .05$, and a trend towards significance in the Sung condition, $\chi^2(5) = 10.44$, $p = .064$, but no main effect of Condition. Based on our hypothesis of a better consolidation for Sung than Spoken lyrics after a four week delay, we contrasted Conditions for Session 6 and observed a tendency towards better performance for Sung lyrics compared to Spoken lyrics ($Z = 1.75$, $p = .079$). Individual analyses for this contrast showed that, out of the five participants who completed session S6, three performed the Sung condition better than the Spoken condition (AM, JO and JL, Fisher exact probability test, $p < .05$). The reverse pattern was not observed in any participant.

Collapsing across all six learning sessions for the six AD patients involved in this repeated learning phase of the study increased power for the purpose of comparing spoken and sung recall. As can be seen in Figure 6, immediate recalls led globally to an equivalent number of words recalled for sung and spoken conditions, but patients showed better performance for the Sung

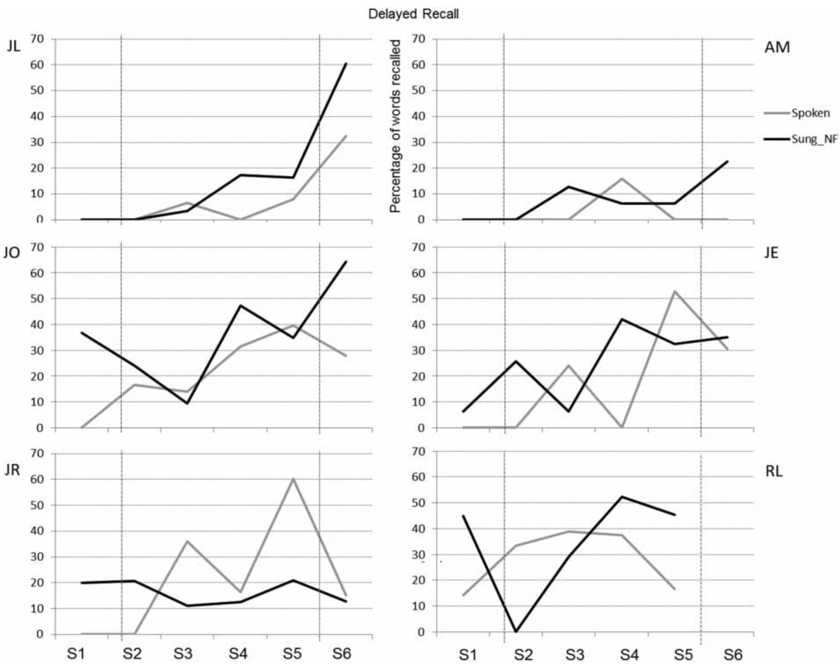

Figure 5. Individual profiles of percentage of words recalled though sessions depending on Sung and Spoken conditions in repeated learning, for delayed recall trials, for 6 AD participants. Dotted lines represent the breaks (1 to 5 weeks between S1 and S2; always four weeks between S5 and S6).

over the Spoken condition in delayed recalls. The average percentage of words recalled for the Spoken condition in delayed recall was 16.4% versus 22.8% for the Sung condition ($Z = 1.84$, $p = .065$).

Mode of recall. Comparing the results obtained from all sessions, we observed that AD participants spontaneously sang around 35% of words of sung excerpts in immediate recall and around 25% in delayed recall ($Z = 2.17$, $p < .05$). Percentage of words sung by participants in immediate recall increased across sessions, $\chi^2(5) = 13.02$, $p < .05$. Thus, the ratio of recalled words in singing increases with song familiarity.

Intrusions. We analysed intrusion errors for all six sessions in immediate and delayed recalls (Figure 7). Intrusions comprised a higher percentage of errors (out of produced words) for the Spoken than the Sung condition in delayed recall ($Z = 1.68$, $p = .093$). Interestingly, there were more phonological intrusions in the Sung condition as compared to the Spoken condition (in immediate recall, $Z = 2.55$, $p < .05$; in delayed recall, $Z = 2.02$, $p < .05$).

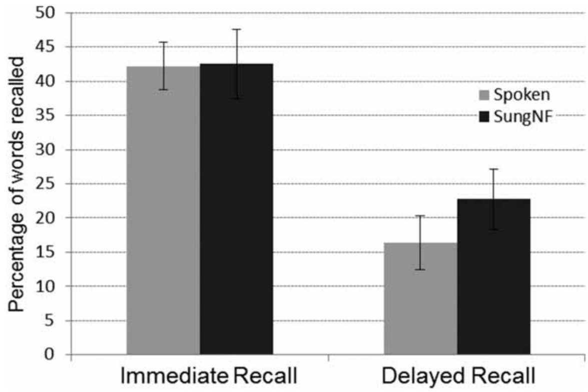

Figure 6. Percentage of words recalled, combined data of all learning sessions for Sung and Spoken conditions in immediate and delayed recall for 6 AD participants. Error bars represent one standard error.

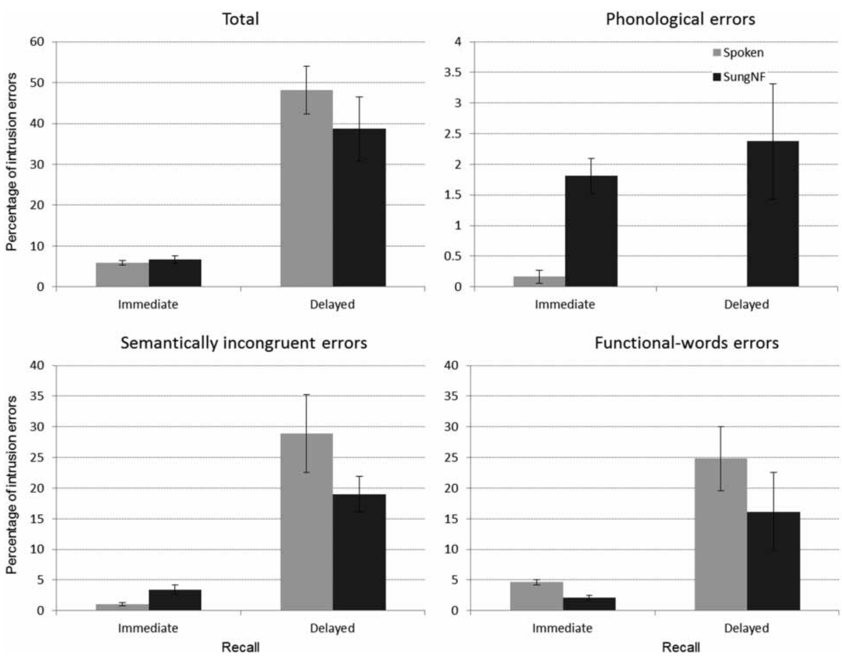

Figure 7. Percentage of intrusions depending of intrusion type (total, phonological errors, semantically incongruent errors, functional-words errors), combined data of all learning sessions for Sung and Spoken conditions in immediate and delayed recall for 6 AD participants. Error bars represent one standard error.

Conversely, function-word intrusions occurred more often in the Spoken as compared to the Sung condition (in immediate recall, $Z = 2.57$, $p < .05$; delayed recall, $Z = 1.96$, $p < .05$). Thus, errors in the sung conditions tend to retain the acoustic aspect of the song while errors produced in the spoken condition tend to change the structure of the excerpt (and thus its acoustic aspect).

Correlation between experimental performance and neuropsychological evaluation. Non-parametric correlations were performed between experimental results and cognitive measures at baseline in order to identify profiles of patients that might benefit most from the sung presentation of lyrics. In AD subjects, advantage for Sung lyrics (i.e., subtraction of score obtained in the spoken condition from score obtained in the sung condition) in delayed recall was negatively correlated with both their semantic and phonological fluency abilities, respectively, $r(4) = -.83$, $p < .05$; and $r(4) = -.98$, $p < .05$. This would suggest that participants with the poorer fluency abilities benefit more from the sung condition.

DISCUSSION

Studies examining music as a mnemonic device have not been conclusive as to its potential benefit. Here, we show that the singing advantage is limited to memory consolidation in both AD and healthy ageing, with better retention for sung lyrics, (1) after 10 minutes in Controls when the lyrics are sung on a familiar melody, (2) after 10 minutes in AD, independently of melodic familiarity, and (3) after four weeks in some AD participants (with none showing an advantage for spoken lyrics).

In immediate recall, music did not increase performance. In AD, sung and spoken conditions were equally poor and singing on a low-familiarity melody leads to even poorer memorisation. We also observed that participants spontaneously recalled more often sung lyrics while speaking instead of singing, suggesting that both elements might be more easily processed independently during this initial learning phase. Taken together, these results are consistent with the hypothesis of dual representations in memory for lyrics and melody (Racette & Peretz, 2007). This dual representation can slow the learning process. Indeed, binding is reduced in healthy older adults (Castel & Craik, 2003; Chalfonte & Johnson, 1996; Kessels, Hobbel, & Postma, 2007; see Deffler & Halpern, 2011, for musical field) and is impaired in AD patients (Fowler, Saling, Conway, Semple, & Louis, 2002; Lindeboom, Schmand, Tulner, Walstra, & Jonker, 2002). Weakness or impairment of the binding process can also explain why, despite being less detrimental than learning on a non-familiar melody, learning lyrics on a familiar melody does not show a significant advantage compared to spoken lyrics in immediate recall.

The learning procedure without shadowing showed an advantage in AD participants for immediate recall. This was unexpected considering that shadowing facilitates production and retention of sung lyrics in aphasic individuals (Racette et al., 2006). It is possible that the association between synchronised production and singing is less relevant for individuals without language production impairment. In AD, shadowing might have overwhelmed or distracted participants, interfering with the already weakened encoding process.

Although the sung condition was initially not helpful, it benefited the further retention of lyrics. This effect was robust across AD participants after a 10-minute delay following the first exposure to the song, independently of melodic familiarity. Moreover, despite the fact that sung lyrics were not learned faster than spoken lyrics over multiple exposures, we observed better scores for sung excerpts after a four week delay for two of five AD participants in immediate recall and for three of five in delayed recall and no participant showed the opposite pattern. This suggests that the association between melody and lyrics made the memory trace more robust. Although it will need to be confirmed with larger groups of patients, this result is consistent with our single case study (Moussard et al., 2012) and with prior findings in young adults (e.g., Rainey & Larsen, 2002). In Controls, lyrics sung on the familiar melody showed an advantage after a 10-minute delay. While we should be cautious in interpreting this result because lyrics were not counterbalanced for this condition, it may be that healthy individuals were able to use prior knowledge to make an efficient association that reinforces the mnemonic trace in long-term memory.

It should be mentioned that the benefit for the musical condition found in ADs in delayed recalls is relatively small. Considering that memory retention is particularly challenging in AD, this result is not surprising. Further studies will need to assess whether and how it might be possible to increase this effect. For example, binding between lyrics and melody could be reinforced by pairing the semantic content of the text with the acoustical characteristics of the tune (e.g., higher pitch to evoke birds). The effect might also be stronger if the lyrics would be directly relevant to the everyday needs of patients (for example, the instructions for use for the DVD player or an important telephone number).

One question raised by this study is how the effect we observed is specific to music. Further studies could investigate if similar effects would be shown if lyrics were associated with other material such as pictures or gestures. However, we think that music is an appropriate material to be matched with lyrics considering the anatomical and functional overlap observed for music and language processing (Patel, 2008), which might help memory for songs by enhancing connections between lyrics and melody. Both systems also demonstrate similar structural characteristics, such as their temporal and hierarchical structure, that make them a good match. Melody may aid the learning of lyrics by providing cues to their structure (such as the number of syllables per line) and limit the possible choices among the words that can be set to the melody (Wallace, 1994). In the present study, the advantage of the Sung condition in AD was negatively correlated with verbal fluency (both phonological and semantic). This result suggests that music may facilitate lexical search and compensate for weak retrieval strategies in AD (e.g., Souchay, Moulin, Isingrini, & Conway, 2008). Singing seems to attract attention to surface characteristics as the analysis of errors suggests. Participants produced more functional-word intrusions (which change the acoustical structure by adding a syllable, for example) in the spoken condition, while they made more phonological mistakes in the sung condition (preserving the sound of the sung excerpt).

Musical material seems generally easier to retain than verbal material for AD patients. Samson and colleagues (Samson, Dellacherie, & Platel, 2009) showed that mild to moderate AD patients better recalled new instrumental pieces than new linguistic material (poems) after a two-month delay. The authors propose that the emotional content of the musical excerpts may enhance encoding and consolidation in memory (see also Eschrich, Münte, & Altenmüller, 2008; Jäncke, 2008). Thus, if melodies are easier to learn for patients, they represent a relevant facilitator for learning more difficult material such as lyrics.

Finally, music is an enjoyable and arousing activity, which may, in turn, contribute to enhanced effects on cognition (see Latendresse, Larivée, & Miranda, 2006, for a review). Most participants enjoyed our sessions and we incurred only slight attrition due to refusal (only one participant did not wish to take part in the second phase of the study). This aspect of music is important for engagement and motivation of patients in clinical settings.

Due to the small sample size and heterogeneity of subjects in the AD group, the results of the present study must be interpreted with that important caveat in mind. Although we have many observations per participant (with resulting stability), a larger group of participants would be needed to be able to draw broader and more confident conclusions regarding the AD population. A bigger sample would also yield more robust correlational findings and thereby provide better insight into the types of patient profiles that benefit most from singing, with important consequential therapeutic implications. The study we have presented here constitutes an evidence-based step in that direction.

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