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Implicit Memory for Music in Alzheimer's Disease

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Implicit Memory for Music in Alzheimer's Disease

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Short, unfamiliar melodies were presented to young and older adults and to Alzheimer's disease (AD) patients in an implicit and an explicit memory task. The explicit task was yes–no recognition, and the implicit task was pleasantness ratings, in which memory was shown by higher ratings for old versus new melodies (the *mere exposure effect*). Young adults showed retention of the melodies in both tasks. Older adults showed little explicit memory but did show the mere exposure effect. The AD patients showed neither. The authors considered and rejected several artifactual reasons for this null effect in the context of the many studies that have shown implicit memory among AD patients. As the previous studies have almost always used the visual modality for presentation, they speculate that auditory presentation, especially of nonverbal material, may be compromised in AD because of neural degeneration in auditory areas in the temporal lobes.

Deficits in explicit memory retrieval are a signature of Alzheimer's disease (AD), but the picture is quite mixed regarding implicit memory tasks. As reviewed by Fleischman and Gabrieli (1998) and Meiran and Jelicic (1995), AD patients often but not always are successful in demonstrating memory on implicit tasks such as lexical decision, word and picture identification, and reading speed. They often but not always show deficits relative to age-matched controls on implicit memory tasks, especially when they require retrieval of conceptual information such as word-stem completion, word association, and category-exemplar generation. However, the pattern of successes and failures has been hard to categorize firmly, as distinctions such as perceptual–conceptual, production–generation, or associative–single-item seem to capture some but not all the variance in the pattern (see also Rybash, 1996). This situation is in contrast to studies with amnesic people, which have shown more consistent priming effects, both on conceptually mediated and perceptually based paradigms (Schacter, Chiu, & Ochsner, 1993).

The dissociation of implicit- and explicit-memory tasks in amnesic individuals is complemented by neuroimaging studies showing that for at least some priming tasks, the brain areas activated are different than those involved in explicit recognition of the same stimuli (Schacter, Alpert, Savage, Rauch, & Albert, 1996). Areas known to be involved in mediating explicit retrieval, such as the hippocampus and entorhinal cortex, are also areas that deteriorate early and reliably in AD (Kolb & Whishaw, 1996). Areas active in visual priming tasks in the occipital region are also areas relatively spared in AD (Esiri, Pearson, & Powell, 1986; Geula & Mesulam, 1996; Lewis, Campbell, Terry, & Morrison, 1987), making success on at least some priming tasks explicable. However, the pattern of brain damage in AD is not uniform across patients, and furthermore the brain areas responsible for each of the numerous priming tasks used in the literature are not well understood, so the lack of clarity in understanding implicit memory in AD is, again, not surprising.

Most priming studies have used verbal tasks of some kind. A few have used pictures (which are usually nameable). One example of a completely nonverbal study, by Winograd, Goldstein, Monarch, Peluso, and Goldman (1999), used unfamiliar faces as stimuli. Their choice of paradigm was also unusual in that they used a preference task. They took advantage of the *mere exposure effect*, which refers to the preference people show for previously unfamiliar stimuli that have been presented one or more times (Zajonc, 1980). The connection with implicit memory is that a preference effect implies that stimuli have been remembered, even if explicit recognition is poor. Winograd et al. exposed 19 faces three times, with a cover task of judging different features of the faces. In a two-alternative forced-choice preference task (2AFC), both AD and normal controls showed a small but significant preference for the old faces. A separate group of AD patients showed no evidence of recognition memory for the faces; the normal control participants did.

The preference paradigm has several attractions for use in studying implicit memory in impaired individuals. In addition to just generalizing from other paradigms, the response mode can be completely or nearly nonverbal, and the task is fairly pleasant for the participants, does not necessarily feel like a memory task, and is simple to explain and execute.

Several researchers have established that the mere exposure effect dissociates from explicit paradigms (Seamon et al., 1997), making "leakage" from explicit to implicit tests less likely. Furthermore, the paradigm is suitable to exploration of stimulus domains not much studied in impaired populations, such as music.

Music is widely employed in therapeutic situations with elderly patients and patients with dementia (Glassman, 1983; Prickett & Moore, 1991), and several case studies have suggested that musical skills may remain after other cognitive skills have deteriorated in AD or other dementias (Beatty et al., 1988; Crystal, Grober, & Masur, 1989). A recent meta-analysis of 21 studies (Kroger, Chapin, & Brotons, 1999) showed an overall positive result of music therapy for dementia patients. The review was unsuccessful in identifying any variables (i.e., type of task, type of music, length of treatment) that moderated the effect size, which led the authors to conclude that researchers have little understanding of the mechanisms underlying music processing in this population.

Indeed, the only experimental study that investigated music processing in a sample of AD patients looked at explicit memory for both familiar and unfamiliar tunes (Bartlett, Halpern, & Dowling, 1995, Experiment 1). In that study, patients and age-matched controls heard eight short, familiar tunes and were instructed to remember them. This was followed by a yes–no recognition test of eight old and eight new tunes. This was followed by another presentation–test sequence using eight unfamiliar but melodic tunes. For familiar tunes, the controls significantly exceeded the AD patients ($d' = 2.14$ and 0.66, respectively), largely because they and not the AD patients were able to suppress false alarms to new melodies. Both groups had poor memory for unfamiliar tunes, with the controls scoring numerically higher than the AD patients, but not significantly ($d' = 0.88$ vs. 0.41). Experiment 2 of that study used a similar paradigm with young and elderly participants and showed an age-related deficit (young adults scoring a d' of 1.23 vs. 0.73 for elderly participants).

This study of explicit memory seems to suggest that the difficulty in learning new music is largely age related, without additional loss due to AD. However, two limitations make us cautious about this finding. First, memory for the unfamiliar tunes was so poor for normal seniors that a floor effect may have obtained. Second, as the Bartlett et al. (1995) study only tested memory explicitly, we cannot conclude that either group of older participants was completely unable to form memory traces of the tunes. It is possible that encoding and storage were adequate, but conscious retrieval as required by recognition may have been impaired. An implicit-memory task for new music is necessary to distinguish these possibilities.

As alluded to previously, we chose to use a preference paradigm in our study. Similar to Winograd et al. (1999), we presented the new information, in our case unfamiliar tunes, under the guise of a cover task. The implicit-memory task was, instead of 2AFC for preference, a ratings task. Johnson, Kim, and Risse (1985) used a ratings task to test implicit memory for music among Korsakoff amnesia patients. Korsakoff patients, like the control participants, liked

the previously heard melodies more than the new melodies, and this effect increased with number of exposures in all groups. However, the patients had poor explicit memory compared with the control groups. As we noted above, this dissociation between implicit- and explicit-memory tests in amnesic patients is commonly found with many other kinds of materials, showing that music may act similarly to other materials in other neurologically impaired groups.

This study also suggests that music is subject to a mere exposure effect, which is important to establish before using it in our study. Peretz, Gaudreau, and Bonnel (1998) have confirmed the suitability of using music in such a paradigm, even when the music is culturally familiar. Several variables affected recognition success without moderating the mere exposure effect, lending weight to the idea that explicit- and implicit-memory tasks are mediated by different brain mechanisms, as has been established for verbal- and visual-stimulus domains. Gaudreau and Peretz (1999) also found that both older and younger adults showed the mere exposure effects even though the older group did not perform as well as the younger in the recognition test.

To summarize our study, we presented AD patients, age-matched controls, and young adults with the unfamiliar tunes used in the Bartlett et al. (1995) study. Each tune was heard twice in a cover task. In the test phase, old and new tunes were presented for judgment on "pleasantness," as well as for yes–no recognition. We expected young adults to show the mere exposure effect, as well as to show good explicit memory for the tunes. Given that older healthy adults often show preserved implicit memory in the face of impaired explicit memory, we expected to find that result with melodies. Because the affective ratings task is, if anything, perceptually rather than conceptually loaded—which tends to facilitate implicit memory in AD—and because of the fact that Winograd et al. (1999) found a mere exposure effect for faces, we predicted our AD participants would also show a mere exposure effect for music.

Method

Participants

Controls. Young adults (YAs) were 26 college students at Bucknell University. Normal age-matched controls (NCs) were 17 senior citizens from the Boston area. They were recruited at several senior centers and one retirement community and received both the task and the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975). We used a strict inclusion criterion for our NCs. Only people scoring a 29 or 30 (out of 30) on the MMSE were included in the sample. Demographic data, including years of education, are in Table 1. Data from another sample of 18 control older adults from a retirement community in Lewisburg, Pennsylvania (NC2; demographic data incomplete) are presented briefly below as a replication sample. Older adult controls were all active and participated regularly in the numerous social, educational, and physical activities in their respective living situations.

AD patients. Fifteen patients with probable AD were referred by neurologists, psychiatrists, and neuropsychologists in the Division of Behavioral Neurology at Beth Israel Deaconess Medical Center, Harvard Medical School. Patients were diagnosed according to the criteria for probable AD developed by the National

Table 1
Demographic Characteristics of Participants

Characteristic	YA	NC	AD
Women	13	13	8
Men	13	4	7
Age (years)			
M	20.3	79.8	78.7
SD	1.0	5.2	6.2
Education (years)			
M	14.7	15.1	14.9
SD	1.2	1.7	3.7
MMSE			
M		29.5	22.5
SD		0.5	3.9

Note. Mini-Mental State Examination (MMSE) scores of 29 or 30 (out of 30) were required for the normal older controls (NCs). One Alzheimer's disease (AD) patient was missing an MMSE score and received the Dementia Rating Scale instead. Young adults (YAs) did not receive the MMSE.

Institute of Neurological and Communications Disorders and the Alzheimer's Disease and Related Disorders Association (Mc-Khann et al., 1984). All patients underwent extensive evaluation in order to exclude other causes of dementia. Patients with imaging evidence suggestive of ischemic changes were not included in the study. All of the AD patients demonstrated evidence of severe declarative-memory deficits on neuropsychological measures of list learning or paragraph recall. Variability in naming performance was noted, with 3 of the 15 patients performing in the normal range on measures of confrontation naming. The other 12 patients demonstrated moderate to severe anomic difficulties. Demographic data are presented in Table 1, which shows that the older adult groups were matched in terms of age and years of education (all groups being relatively well educated).

Another criterion for participation was an MMSE score between 15 and 25. The average MMSE score of the AD patients was 22.5 out of 30, indicating mild impairment. Because the procedure required participants to understand a rating scale, to use two different ratings scales, and to make two judgments for each tune in the test phase, successful completion of the task was also a de facto lower boundary on impairment. Three AD volunteers who had MMSE scores above 15 nevertheless could not understand the instructions or use a rating scale or otherwise seemed unable to complete the task, and they were not included in the sample. One AD participant was administered the Dementia Rating Scale (Mattis, 1976) instead of the MMSE. She scored a 128 out of 140, which indicates mild impairment on that scale.

Musical background. Most participants had some musical training in the form of a few years of instrument lessons or choral experience (4 YAs, 4 NCs, and 6 AD patients had no musical experience). One NC was a professional music teacher and performer. All participants except 1 AD patient indicated that they listened to music regularly.

Materials

The 16 unfamiliar tunes used in the Bartlett et al. (1995) study were used here. The tunes were derived by permuting the melodic and rhythmic intervals of real tunes. The resulting phrases were about 5 s long and were tuneful without sounding familiar (see the Bartlett et al. article for details of construction and an example).

Tunes were recorded with a synthesized piano timbre onto audiotape. The 16 tunes were randomly divided into two sets of 8; the old songs on Tape A served as the new songs on Tape B, and

vice versa. During presentation and test, 4 s of silence separated each tune, but in practice the experimenter often stopped the tape to give as much time as was necessary for the participant to answer.

Procedure

Because this study involved incidental memory, all participants were told that this was a study in music perception (young adults) or music appreciation (older adults). After obtaining informed consent (a family member or caretaker serving as witness for the AD patients), musical-background information was elicited. In Part 1 of the session, participants were asked to rate the speed for each of eight melodies with a 1–5 rating scale, with endpoints marked *slow* (1) and *fast* (5). The experimenter explained the use of a rating scale and what the extreme values meant. Listeners were queried as to what a rating of "3" would represent, and all were able to answer that it would be a tune of medium speed. Answers were given either by a verbal response or by pointing to the desired scale value; the rating scale was in view at all times.

Part 2 of the session was a repeat of Part 1, with the ostensible purpose of allowing the listener to change his or her opinion "now that you have heard all the tunes." The eight songs were repeated in the same order, and the experimenter dutifully recorded any speed ratings that changed.

Part 3 followed immediately and comprised the memory test. The eight old songs and eight new songs were intermixed. A pleasantness rating scale was presented, with the endpoints labeled *least pleasant* (1) and *most pleasant* (5), and again we made sure that everyone knew how to use the scale. Instructions explained that for each song, two judgments were requested. First was a pleasantness rating, followed by an old–new recognition ("say 'yes' if you remember hearing the tune on the first part of the tape"). The experimenter prompted for each judgment if necessary ("How pleasant was that?" or "Do you remember it from before?"). Approximately half of the participants received Tape A, and half Tape B. All participants were tested individually, and the session lasted between 20 and 30 min.

Results

Scoring

Because the speed judgments were a cover task, these data were not scored. However, all participants appeared to take the speed task seriously, carefully considering whether they wanted to change their ratings on the second presentation. The dependent measure for explicit memory was d', computed with the adjustment to hits and false alarms suggested by Snodgrass and Corwin (1988): adjusted score = (score + 0.5)/(n + 1). The dependent measure of implicit memory was the average rating of the old melodies minus the average rating of the new melodies. A positive value is indicative of preserved memory as indexed by the mere exposure effect.

Explicit Memory

The mean adjusted d's for the YA, NC, and AD groups are shown in Table 2, with the unadjusted hit and false alarm rates. The obvious pattern of the means was confirmed by an analysis of variance (ANOVA) showing that these three means differed, $F(2, 55) = 24.65, p < .001$; a follow-up Newman-Keuls test confirmed that the two older

Table 2
Results of Explicit (Hits, False Alarms, Adjusted d') and Implicit (Old–New) Memory Tasks

Result	YA	NC	AD	NC2
Hits				
M	0.73	0.48	0.35	0.49
SD	0.21	0.29	0.27	0.42
False alarms				
M	0.04	0.27	0.14	0.36
SD	0.09	0.19	0.19	0.41
d'				
M	2.02	0.53	0.66	0.38
SD	0.70	1.01	0.54	0.74
Old–new (O-N)				
M	0.34*	0.25*	0.03	0.41*
SD	0.45	0.43	0.77	0.53
Correlation of d' and O-N				
r	.30	.00	.20	.34
rcrit (.05)	.38	.47	.48	.51

Note. NC2 is a replication sample of 18 normal controls. YA = young adult group; NC = normal older controls; AD = Alzheimer's disease patients; rcrit = critical r.
* Significant mere exposure effect.

groups did not differ from one another (both were close to chance) and were exceeded by the YA group (who showed reasonably good memory).

Implicit Memory

Table 2 also shows the old–new implicit memory scores (O-N). The pattern of the means suggests that the YA and NC groups showed a mere exposure effect but that the AD group did not. The ANOVA using the factors of group and melody (old, new) showed a main effect of melody (3.36 old vs. 3.15 new), $F(1, 55) = 7.60$, $p < .01$, and a main effect of group just above the conventional level of significance, $F(2, 55) = 3.10$, $p = .05$. This main effect simply reflects whether one group gave overall higher or lower pleasantness ratings than another. The means for the YA, NC, and AD groups were 3.14, 3.15, and 3.47, respectively. Thus, although just shy of the conventional level of significance, the AD participants appeared to think more highly of the melodies than the other two groups.

The interaction of Group × Melody was not significant, $F(2, 55) = 1.55$, $p = .22$. However, given the hypothesis and the pattern of the means, we tested the old–new difference for each of the three groups with one-tailed t tests. Old melodies were considered more pleasant than new among the YAs, $t(25) = 3.83$, $p < .001$, and NCs, $t(16) = 2.26$, $p < .05$, but not AD patients, $t(14) = .14$. The number of people showing the mere exposure effect was 21 of 26 YAs, 11 of 17 NCs, and 7 of 15 AD patients.

Prior to finalizing the procedure for the Boston older adults, a group of 18 NC older adults from Lewisburg, Pennsylvania was tested (NC2). MMSEs were not administered, and demographic data were obtained from only 10 of the 18, but for those 10, mean age was 76.5 ($SD = 3.78$) and years of education was 14.6 ($SD = 3.17$). Thus, we can offer their results at least as a replication sample. Adjusted d' for that group was .38 ($SD = .74$), and old–new differ-

ence was .41 ($SD = .53$), a significant difference; 12 of 18 people showed the mere exposure effect. These results are quite similar to those of the Boston NC sample.

Correlations

To see if performance on the implicit task was accounted for by performance on the explicit task, we correlated performance on the two tasks. As can be seen in the last row of Table 2, none of the correlations was significant. Additionally, to see whether MMSE score could account for performance on implicit or explicit memory in the AD group, we correlated MMSE with d' and O-N. The r values were −.21 for d' and −.37 for O-N, both nonsignificant by a large margin. This lack of relationship is not surprising in that the MMSE has only a few items testing explicit memory, those few items are verbal, and no items test implicit memory.

Discussion

Although this study was not primarily set up to examine age effects, it is worthwhile to comment on this, as so few studies on aging and music cognition have been published. We also would like these stimulus materials to elicit effects commonly seen in normal aging, to be more confident about effects we see in NC–AD comparisons.

As is often found with other materials (Light, 1991), the older adults were impaired compared with the younger adults in explicit memory for these songs. The difference was quite large, and indeed the older adults could not really recognize the tunes at all. This may be surprising considering that only eight tunes had to be remembered and each was presented twice. Comparing this study with performance in the previous study using these materials (Bartlett et al., 1995, Experiment 2), we note that several variables were different: In the earlier study, tunes were presented once (vs. twice here) and the instructions were intentional (vs. incidental here). Both studies showed an age effect, which was larger in the current study due to both higher performance of the younger people (particularly in suppression of false alarms) and lower performance of the older people (particularly in reduction of hits). Although this may be a random pattern due to sampling characteristics, a more intriguing possibility is that increasing number of presentations helps younger people (allowing them to suppress false alarms) more than giving intentional instructions, whereas the older people may need the intentional instructions particularly to increase their hit rate.

Despite the large age difference in explicit memory, both age groups showed evidence of implicit memory in the mere exposure effect, replicating the results of Gaudreau and Peretz (1999). If one averages the two NC groups, the magnitude of the effect is about the same in the older and younger samples. Rybash (1996) has suggested that implicit-memory tasks that do not require formation of new associations and that are perceptual in nature should be least likely to show age-related impairments. Affective judgments of tunes do not require formation of associations and also seem to fulfill criteria for being a perceptual rather than a conceptual task. Specifically, the listener does not need to

invoke any prior knowledge, and furthermore, the task is not affected by levels-of-processing encoding manipulations, as found by Peretz et al. (1998). Thus, our finding of no age-related impairment on our implicit task fits within Rybash's framework.

Turning now to the main result, we found that the AD patients had the same low level of recognition ability as age- and education-matched controls, but unlike the NCs, they also failed to show a mere exposure effect. This provides an interesting contrast to the only other published study using the mere exposure paradigm with AD patients; Winograd et al. (1999) did find such an effect with faces. However, besides the obvious difference of using faces versus melodies, their study used more stimuli (19 vs. 8), exposed the faces three times instead of two, used a different cover task for each exposure (although all referred to facial features), used a forced-choice preference instead of rating scale, and did not use the same participants for the explicit and implicit task. The pattern of success and failure of AD patients on implicit tasks is hard to characterize; both Meiran and Jelicic (1995) and Fleischman and Gabrieli (1998) concluded that no one theory or taxonomy can account for the pattern. Thus, it is difficult to speculate about which variable or variables may be the crucial ones accounting for the difference between our study and Winograd et al.'s study.

However, we can consider and, we hope, reject some relatively uninteresting reasons for our finding. First, we ask whether our paradigm had insufficient power to find an effect. The effect in Winograd et al.'s (1999) study was numerically small (preference among AD patients for old faces = .56, chance = .50), and so it may be difficult to capture. However, our patient sample was the same size as the patient sample in their study. Also, our two samples of normal elderly individuals were also about the same size, and we showed the mere exposure effect in that group. Finally, we observed that the proportion of people showing the mere exposure effect ranged from .64 to .80 in the neurologically normal groups but was under .50 for the AD group. Therefore, we do not think that our failure to find the mere exposure effect in the AD group was due to insensitivity of our paradigm or our sample size.

When dealing with a cognitively impaired group, we should also consider whether a null effect is due to failure to understand instructions. The minimum MMSE score for inclusion into the study was 15; the range was in fact 16 to 28, with only three scores below 20. This typically meant that the memory items on the MMSE were failed but that respondents could answer questions about their surroundings, name objects, and follow commands. Compliance with instructions and general comprehension was also monitored during the testing. The individuals excluded from the final sample showed their inability to understand the task by either using all the same rating scale value on the speed or pleasantness phases, not changing set from the speed to the pleasantness rating task, or showing general confusion. As noted above, all participants, including the AD group, took both the cover task and pleasantness ratings seriously, often making comments about the tempo or how much they liked a melody. Finally, we had an informal test of the ability to use a scale consistently in that we elicited two judgments of

speed for each tune. The AD participants were as consistent as the other people in assigning tempo ratings to the tunes, rarely changing their rating by more than one scale value on the second listening.

A third possibility for our null finding was that the implicit effect was largely dependent on having explicit memory for the tunes. Under this scenario, if the explicit memory is impaired (or nonexistent in the AD case), the implicit effect will disappear. Indeed, the young people showed both memory effects and a positive (although nonsignificant) relationship between the two tasks. However, we noted above previous work supporting the independence of mere exposure effects from explicit memory (Peretz et al., 1998; Seamon et al., 1997). We also noted that in the Johnson et al. (1985) study, the amnesic patients showed preference effects in the absence of explicit memory, as did the two groups of normal older controls in the current study.

A further point to consider is whether our AD participants failed to show the mere exposure effect not because of a memory failure per se but because of some difficulty in dealing with affective judgments. It is possible that the illness impairs the appreciation of artistic objects or perhaps impairs the ability to order such objects into some kind of aesthetic framework. We have been unable to locate studies expressly studying such questions, although a few studies have looked at the related issue of processing of emotion in AD. When measures of cognitive dysfunction are statistically controlled, impairment in tasks such as identifying the emotion of faces or recorded sentences is small or nonexistent in AD patients (Cadiuex & Greve, 1997; Koff, Zaitchik, Montepare, & Albert, 1999). These authors have concluded that emotion-detection problems are secondary to general problems in visuospatial or abstraction ability. We also excluded any potential AD participants suffering from depression or other affective disorders. Thus, we think it unlikely that we can attribute our results to any primarily emotional disorder.

Nevertheless, it would be interesting to investigate the more purely aesthetic appreciation skills of AD patients. It would be useful to confirm that AD patients are fully capable of processing the "affect" in affective judgment tasks. Also, care providers would be interested in knowing to what extent AD patients can process and appreciate aesthetic experiences such as exposure to art, music, and literature. In this vein, we note that our AD group rated the melodies as more pleasant, overall, than did the other groups. Many participants seemed to enjoy the task, trying to hum along with tunes, commenting on parts that seemed familiar, and so on. This suggests that although not remembered, the experience of listening and judging the music not only made sense to them but was also pleasurable.

We conclude by speculating on what may be a more interesting explanation for the absence of implicit-memory effects here and their presence in many other tasks. We consulted three major review articles on implicit memory and AD (Meiran & Jelicic, 1995; Rybash, 1996; Fleischman & Gabrieli, 1998) plus additional articles to survey the range of implicit-memory techniques that have been used with AD patients. We were particularly interested in repetition priming tasks, in which the same information is pre-

sented at study and test. Word-stem completion is perhaps the most popular task, and many other tasks are verbal in nature, including word identification, naming, and lexical decision. Among the small number of nonverbal tasks, we find object decision, picture naming, and pattern learning. What all these have in common is that the information is invariably presented in the visual modality, with the exception of homophone spelling tasks. This involves auditory presentation of the verbal material and does show intact priming in AD patients, at least over short intervals (Fennema-Notestine, Butters, Heindel, & Salmon, 1994). We have not been able to locate any studies with AD patients other than ours that presented auditory, nonverbal information in a repetition priming paradigm.

This leads us to consider whether modality of presentation may be an important variable, with some advantage of visual over auditory presentation in eliciting priming effects. Autopsy studies have shown that the pattern of neural degeneration in AD is less apparent in the primary visual cortex even at the end stage of the disease, whereas the auditory cortex and visual-association cortex are more affected (Esiri et al., 1986; Geula & Mesulam, 1996; Lewis et al., 1987). It is harder to pinpoint the pattern of neural progression in vivo in more mildly affected patients because we must rely on brain imaging rather than neuropathological techniques.

A recent positron emission tomography study (Stein, Buchsbaum, Hof, Siegel, & Shihabuddin, 1998) compared glucose metabolism in AD (mean MMSE = 19) and in control participants in each cytoarchitechtonic (Brodmann) area during performance of a running verbal-memory task. Considered on an absolute basis, metabolic rates were lower in the patients in all brain areas. An analysis of regional activity relative to total brain activity revealed no group difference in the primary visual cortex and actually higher relative metabolism in patients versus controls in the primary auditory cortex and secondary visual cortex. However, the right secondary auditory cortex (Brodmann Area 22) showed decreased relative metabolism in patients versus controls. Melodic information processing is important in the secondary auditory cortex in the right temporal lobe, as shown by difficulties experienced by right compared with left anterior temporal lobectomy patients in discrimination tasks for tones and melodies (Zatorre, 1985; Zatorre & Samson, 1991), as well as for comparing pitches within well-known tunes either heard or imagined (Zatorre & Halpern, 1993). Impairment in explicit memory for tunes without words is sometimes found after either right or left lobectomy but always after right lobectomy (Samson & Zatorre, 1991, 1992; Zatorre, 1985). It may be the case that the secondary auditory cortex, particularly on the right, is also important in mediating implicit learning of melodies.

Putting this information together, we offer the possibility that in addition to other factors that may influence whether implicit memory is or is not shown in AD, modality of presentation may be important. Auditory information in general may be more compromised than visual, or nonverbal auditory information may be particularly resistant to memory formation in AD. Few implicit memory studies have been carried out in the auditory domain, relative to the

visual domain, and even fewer, if any, with Alzheimer's patients. Thus, a way to explore this possibility is to carry out verbal and nonverbal auditory memory studies with auditory presentation, using a variety of response measures. Particularly informative in this regard would be studies that can be carried out in parallel forms in visual and auditory modalities.

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