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Cross-modal semantic and homograph priming in healthy young, healthy old, and in Alzheimer's disease individuals

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Abstract

Two experiments are reported that explore the influence of strength of the prime–target relationship on the observed priming effects in young, healthy old, and individuals diagnosed with dementia of the Alzheimer type (DAT). In Experiment 1, participants were auditorily presented primes (FURNITURE) and after varying delays presented visual targets that were (1) high-strength related (e.g., SOFA), (2) low-strength related (e.g., RUG), or (3) unrelated control words (e.g., COW or DEER). The results indicated that the DAT individuals produced relatively larger priming effects than both the young and the healthy old, but these data could be accommodated by increases in effect size due to general slowing of response latencies. In Experiment 2, the same cross-modal priming paradigm was used with ambiguous words presented as primes (e.g., BANK) and either high-dominant (e.g., MONEY) or low-dominant (e.g., RIVER) words as targets. The results of Experiment 2 produced a qualitatively distinct pattern of priming that indicated DAT individuals only produced priming for high-dominant targets and not for low-dominant targets, whereas, the healthy control groups produced equivalent priming for both high- and low-dominant targets. The discussion focuses on the implication that these results have for the interpretation of semantic priming effects, in general, along with implications for the apparent semantic memory loss in DAT individuals. (*JINS*, 1999, *5*, 626–640.)

Keywords: Semantic memory, Semantic priming, Homograph disambiguation, Alzheimer's disease

INTRODUCTION

Individuals with dementia of the Alzheimer type (DAT) exhibit deficits on a wide variety of cognitive tasks. Although there is considerable evidence of a breakdown in episodic memory and attention in DAT, the evidence for a deficit in semantic memory has been somewhat controversial (see Nebes, 1992, for a review). The controversy primarily involves what processes in a given task are sensitive to DAT. For example, DAT individuals perform more poorly than healthy older adults on measures of verbal fluency and object naming (Kirshner et al., 1984; Ober et al., 1986; Tröster et al., 1989). Although these findings have been interpreted as evidence for a breakdown in semantic memory in DAT, there are a number of quite distinct processing stages that could produce breakdowns in these tasks. For example, in the verbal fluency task (i.e., generating words that begin with a specific letter), the participant must keep track of previously generated items as they are searching semantic memory for new items. It is possible that the attentional and working memory demands of keeping track of previously generated items produces the breakdown in this task instead of the integrity of the semantic network itself. In this light, it is important to use a task that minimizes additional cognitive operations when investigating the integrity of the semantic network.

An alternative way to investigate semantic memory in DAT is through the use of a semantic priming paradigm wherein one measures the influence of a prime on naming or lexical decision performance (see Neely, 1991, for a review). According to spreading activation frameworks (e.g., Collins & Loftus, 1975), the prime stimulus activates its underlying representation in semantic memory, and the activation spreads along semantic links to related concepts

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thereby facilitating response latency to the target item[1]. Because, under some conditions, this spread of activation is relatively automatic, the semantic priming effect can be used to determine if the connections within the semantic network are relatively intact. Thus, if the breakdown in the verbal fluency and object naming task is due to the explicit retrieval demands imposed by these tasks, as opposed to a degradation in the semantic memory network, then one might predict relatively intact semantic priming effects in DAT. Consistent with this argument, a number of studies have reported similar or larger semantic priming effects in DAT individuals relative to age-matched controls (Balota & Duchek, 1991; Hartman, 1989; Margolin, 1987; Nebes et al., 1984, 1986, 1989; Ober et al., 1991, 1995; Shenaut & Ober, 1996). Interestingly, a recent study by Balota et al. (1999) has shown that intact spreading automatic activation processes nicely accommodate results from a study of healthy older adults and DAT individuals in a false episodic memory paradigm (Roediger & McDermott, 1995).

Of course, even the semantic priming paradigm is not totally devoid of attentional processes. Fortunately, the conditions under which semantic priming effects engage attentional processes have been well investigated (see Neely, 1991, for a review). For example, the priming effect at long prime–target stimulus onset asynchronies (SOAs) is presumably more likely to reflect attentional mechanisms (Balota, 1983; Neely, 1977). Interestingly, there appears to be a change in the nature of the priming effects at the long SOA in both healthy older adults compared to younger adults (Balota et al., 1992), and in DAT individuals compared to age-matched control individuals (e.g., Ober & Shenaut, 1995). However, in these same studies, there is little evidence of an age-related or disease related change in the priming effects at the short SOAs which presumably are more reflective of the automatic spread of activation. In fact, Ober and Shenaut (1995) have reported a meta-analysis which indicates that under conditions of automatic semantic priming there appears to be relatively little change in DAT individuals, whereas, under more attentional controlled processes, there does appear to be an increase in the magnitude of the priming effect in DAT compared to healthy age-matched control individuals.

Although there appears to be some consistency in the pattern of priming effects in DAT individuals, suggesting that semantic tasks that engage more attention-demanding processes are more likely to produce disease related changes, there is also some controversy regarding the interpretation of the semantic priming literature. For example, Chertkow et al. (1989) suggested that increases in the semantic priming effects that they have observed in DAT individuals may be due to degradation in the semantic network. However, Ober and Shenaut (1995) have interpreted the Chertkow et al. results as consistent with the notion that attentional–controlled processes were engaged in this study. In addition, one must be very cautious in interpreting larger semantic priming effects in groups that produce overall slower response latencies because of scaling problems due to general slowing of response latencies (e.g., Faust et al., 1997; Myerson et al., 1992; Ober & Shenaut, 1995; Shenaut & Ober, 1996).

The goals of the present study are threefold: First, we attempted to address the integrity of the semantic network in individuals with DAT by investigating the influence of the strength of the underlying prime-target relationship. Most semantic priming studies involve relatively high-strength prime–target pairs (see, however, Ober et al., 1991). It is possible that priming effects may change as a function of the strength of the prime–target relationship. For example, it is possible that high-strength prime–target pairs will be relatively resistant to changes in the activation patterns early on in the disease process, whereas, low-strength prime–target pairs may be more sensitive to degradation in the connections. Interestingly, there is already evidence that there is relatively little change in the pattern of priming effects as a function of strength of the prime-target relation in healthy young and older adults (Balota & Duchek, 1988). In addition, there is some controversy from sentence verification and category verification studies regarding the preservation of high- and low-strength associations in DAT individuals. For example, Smith et al. (1995) have recently provided evidence from a property verification task which suggests that there is a degradation in the representation of low-dominant properties of concepts. Likewise, Grober et al. (1985) found that DAT individuals produced a deficit in a sorting task requiring participants to sort the most significant attribute of a target object (e.g., AIRPLANE FLY *vs*. AIRPLANE RADAR). In contrast to these studies, Nebes and Brady (1990, see also Nebes & Brady, 1988) found no change in performance on a relatedness judgment task that included three levels of pair-mate strength (e.g., for *elephant* the pair-mates were *trunk*, *ivory*, and *memory*). Nebes and Halligan (1995) have recently replicated the additive effect of strength in a sentence priming relatedness decision task (see also Nebes & Halligan, 1996). It is important to note however that all of the studies in this area have required participants to explicitly retrieve the semantic information to make some decision, thereby engaging attentional and decision-making processes. Thus, the changes across these studies may be due to the differing attentional demands imposed by the tasks. It is worth noting here that Smith et al. (1995) specifically suggested that differences across the results from these studies may be due to differences in the task demands. This is precisely why we will investigate the strength of the semantic relationship in a simple word naming task, wherein attentional task demands will be minimized.

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[1]There are clearly alternative theoretical models to interpret semantic priming effects. For example, Ratcliff and McKoon (1995) have developed a compound cue model and Masson (1995) has developed a parallel distributed processing model. Although we have conceptualized the present results within a spreading activation framework, we believe that the same arguments regarding the importance of strength and relatedness, and the relationship of this pattern to understanding the performance of DAT individuals in the present study can also be extended to these alternative models.

The second goal of the present experiments was to explore distinct types of prime–target relations. In Experiment 1, we used a set of category and associative items that varied in the strength of relationships (e.g., FURNITURE SOFA *vs*. FURNITURE-RUG). Although these items vary in strength of association, these items share the same set of semantic properties available within the prime item, for example, FURNITURE. The items used in Experiment 1 can be contrasted with the set of homographic items used in Experiment 2, in which we manipulate both the strength of the association and also the semantic properties of the primes. For example, the high-strength pair BANK–MONEY engages a quite distinct representation for the prime BANK, compared to the low-strength pair BANK–RIVER. As discussed later, the semantic representation for homographic items is quite different from the semantic representation for nonhomographic items. Moreover, it is noteworthy that Balota and Duchek (1991) and Faust et al. (1997) have reported breakdowns in DAT individuals in the context effects for homographs in both a semantic priming task and a relatedness judgment task, respectively. The present study will extend this work to investigate the influence of the strength of the relation for ambiguous primes.

The third goal of the present study is to explore semantic priming effects in a cross-modal priming paradigm. A number of researchers have argued that DAT is characterized by the breakdown of long pyramidal cells which connect distinct and dedicated cortical systems (Parasuraman & Haxby, 1993). It is possible that at least some component of the semantic priming effect is due to a modality specific component, which might not transfer across modalities. This might occur if the primes and targets are likely to co-occur within a given modality and co-occurrence is a mechanism that produces semantic priming effects as some researchers have recently argued (e.g., Balota & Paul, 1996; McKoon & Ratcliff, 1992; Shelton & Martin, 1992). If this is the case, one might expect decreased semantic priming effects in DAT participants when the prime and the target are presented across the auditory and visual modalities because the cortical areas that represent these modalities occur in distinct areas of the brain. Of course, it is quite likely that cross-modal semantic priming effects may be amodal in that they are produced by the activation of central conceptual representations in semantic memory. If this is the case, one might expect a pattern of priming effects in DAT individuals that is quite consistent with the extant literature that has used within-modality priming paradigm. To our knowledge, cross-modal semantic priming with single words has not been investigated in individuals with DAT (however, see Nebes & Halligan, 1995, for cross-modal sentence priming in DAT). Given the prevalence of within-modality priming studies of DAT (reviewed above), and the relatively consistent pattern of these within-modality priming studies, it is noteworthy that the present study did not attempt to directly compare within- *versus* cross-modality priming effects. Rather, we were interested in beginning to explore cross-modality priming effects in DAT individuals with single word primes. As we shall see, it appears that the cross-modal nature of the prime presentation did not strongly modulate the pattern of priming in our DAT individuals.

EXPERIMENT 1

The first experiment involved a factorial crossing of Prime–Target Strength × Prime–Target Relatedness. Single-word primes were presented auditorily, which were followed after three different delays (250 ms, 1000 ms, or 1750 ms after the detected offset of the prime) by the presentation of a stimulus word presented on a computer monitor. (The delay interval was manipulated in order to investigate the time course of the cross-modal priming effects; however, as discussed below this variable did not influence any of the observed effects.) The participant's task was to name the target word aloud as quickly and as accurately as possible. We used the naming task instead of a lexical decision task to further minimize any contribution that postaccess decision processes could make to the observed semantic priming effects (see Balota & Lorch, 1986; Neely, 1991; Seidenberg et al., 1984). Participants were not given any explicit instructions regarding how to process the prime items.

Method

Research Participants

Twenty-six healthy young adults were recruited from undergraduate courses at Washington University. Fifty-two healthy older adults and 55 DAT individuals were recruited from the Washington University Medical School Alzheimer's Disease Research Center (ADRC). The order of the experiments was counterbalanced across participants so that half of the participants received Experiment 1 first, whereas, the remaining half received Experiment 2 first. Twenty-two of the young adults, 44 of the older adults, and 41 of the DAT individuals completed both experiments. The remaining participants in each group only completed one of the two experiments. In addition, in Experiment 1, data from 1 individual with DAT was removed due to exceptionally fast response times (i.e., the participant's mean reaction time was less than 400 ms and therefore was likely due to a voice key failure). Furthermore, 1 individual with DAT and 2 healthy older adults were also removed due to experimenter error in recording the data. Therefore, Experiment 1 included a total of 24 young adults, 46 healthy older adults, and 46 DAT individuals.

All healthy older adults and DAT individuals recruited from the ADRC were seen by a physician and were screened for neurological, psychiatric, and medical disorders that could cause dementia. The inclusionary and exclusionary criteria for a diagnosis of DAT have been described in detail elsewhere (e.g., Morris et al., 1988) and conformed to those outlined in the work group of the National Institute of Neurological and Communicative Disorders and Stroke and the Alzheimer's Disease and Related Disorders Association

(McKhann et al., 1984). Diagnostic accuracy for Alzheimer's disease has been reported to be quite high for the present research team (e.g., 93%; Berg et al., 1998). Dementia severity for each individual with DAT recruited from the ADRC was staged according to the Washington University Clinical Dementia Rating (CDR) scale (Hughes et al., 1982; Morris, 1993). According to this scale, a score of zero, 0.5, 1, and 2 represent *no cognitive impairment*, *very mild dementia*, *mild dementia*, and *moderate dementia*, respectively. All healthy older adults had a CDR rating of zero, whereas the DAT group consisted of 23 individuals with very mild DAT (CDR 0.5), 22 with mild DAT (CDR 1.0), and 1 with moderate DAT (CDR 2.0).

The young adults had a mean age of 21.2 years (SD = 2.3, range = 18–27), the healthy old group had a mean age of 77.5 years (SD = 9.1, range = 53–91), and the DAT group had a mean age of 74.7 years (SD = 8.4, range = 56–90). The mean education of the healthy older adults was 15 years, and the mean education level of the DAT individuals was 13 years.

Psychometric Test Performance

Fifty healthy older adults and 49 DAT individuals recruited from the ADRC whose data met inclusionary criteria in either of our experiments also participated in a 2-hr battery of psychometric tests designed to assess psychological functions including language, memory, and intelligence. Because several individuals had completed the battery on multiple occasions, psychometric test scores were based on batteries that were administered closest to the time of participation in our experiments. Table 1 shows the results of a subset of the tasks included in this battery as a function of group (i.e., healthy old *vs*. DAT). Memory was assessed with the Wechsler Memory Scale (WMS; Wechsler & Stone, 1973) Associates Recall and Recognition subscales (paired-associates learning) and the Logical Memory subscale (surface-level story memory). Forward and backward digit span were also assessed. Participants also received the Word Fluency test, on which they were required to name as many words beginning with a specified letter (e.g., *P* or *S*) in a 60-s time period (Thurstone & Thurstone, 1949). Participants also completed the Boston Naming Test (Kaplan et al., 1983). As shown in Table 1, the DAT individuals consistently performed poorer than the healthy older adults on all tests.

Table 1. Scores on selected psychometric tests for healthy older adults and individuals with DAT in Experiments 1 and 2

Test measure	Group: Healthy Old (N = 50)	Group: DAT (N = 49)	F
WMS Logical Memory			
M	9.52	2.95	126.16**
SD	3.34	2.39	
Digit Forward			
M	7.02	6.29	8.57*
SD	1.1	1.38	
Digit Backward			
M	5.14	4.1	13.87**
SD	1.34	1.43	
WMS Associates Recall (Easy)			
M	16.96	13.76	42.88**
SD	1.64	3.04	
WMS Associates Recall (Hard)			
M	6.36	1.08	70.17**
SD	3.84	2.19	
WMS Associates Recognition (Easy)			
M	6	5.94	3.2
SD	0	0.24	
WMS Associates Recognition (Hard)			
M	3.94	2.57	48.44**
SD	0.24	1.37	
Boston Naming Test			
M	55.86	41.73	50.18**
SD	4.7	13.28	
Word Fluency Letter S			
M	16.8	10.45	34.70**
SD	5.16	5.56	
Word Fluency Letter P			
M	15.46	10.78	20.59**
SD	4.74	5.51	

Note. DAT = dementia of the Alzheimer type; WMS = Wechsler Memory Scale; df for each ANOVA is (1,97).
*$p < .01$.** $p < .001$.

Apparatus

Auditory stimuli were recorded by a TEAC X-2000 reel-to-reel tape recorder. The primes were presented via Panasonic loudspeakers that were driven by a Panasonic amplifier. The target stimuli were presented via an Apple IIe microcomputer which was interfaced with a Mountain Hardware Clock to obtain millisecond accuracy. A Gerbrands G1314T electronic voicekey was connected to the computer to detect the onset of the pronunciation of the target. The tape recorder was interfaced with the computer such that the detected offset of the presentation of the auditory prime triggered a signal to the computer which initiated the delay before the visual target stimulus was presented on the computer monitor.

Stimuli

A total of 144 semantically related word pairs were selected from the word list used by Lorch (1982, Experiment 3), and Balota and Duchek (1988). Half of these word pairs were category-exemplar word pairs (e.g., ANIMAL–COW, ANIMAL–CAMEL) that were selected from the Battig and Montague (1969) and Shapiro and Palermo (1970) norms. The remaining half of these word pairs were associated word pairs (e.g., JOY–HAPPY, JOY–GRIEF) selected by Lorch from the Jenkins (1970) and Keppel and Strand (1970) norms. Frequency of usage (on the basis of the Kucera and

Francis, 1967, norms), length in letters, and type of initial word phoneme were approximately equated across levels of strength (i.e., dominance or association values). In addition, unrelated prime words that matched the related primes in phoneme length and frequency were selected (e.g., INTERVAL–COW, INTERVAL–CAMEL and SOIL–HAPPY, SOIL–GRIEF) to serve as unrelated baselines. Thus, each high-strength and low-strength target word was paired with either a related prime or a matched unrelated prime, and the relatedness proportion was 50% across trials.

In addition to the critical pairs, there were a total of 32 practice trials, along with 8 buffer trials that were selected from the previously listed norms. The characteristics (i.e., the percentages of high- and low-strength associates related and unrelated pairs) of these practice–buffer pairs were consistent with the structure of the critical trials.

Each participant received three blocks of trials. First, participants received 32 practice trials which were followed by two test blocks. At the beginning of each test block, four buffer trials were presented which were followed by 72 prime–target test trials. The test trials included six prime–target pairs for each of the 12 experimental cells that were produced by factorially crossing Relatedness (2) × Strength (2) × Delay Interval (3). Each target word was rotated across participants such that it was preceded by either a related prime or an unrelated prime at each of the three delay intervals. Thus, targets were counterbalanced across prime-type and delay interval but not strength. However, it is important to note that a given target served as its own baseline for priming effects because it was preceded by both a related and unrelated prime across participants. Within each test block, items were randomly ordered anew for each participant. Finally, a given participant never saw the same word twice within the experiment.

Procedure

Participants were comfortably seated in front of the computer, approximately 60 cm from the screen. Because of differences across participants in voice volume, the gain on the voice key was individually adjusted for each participant. In addition, the volume of the presentation of the auditory primes was adjusted to a comfortable level for the participants. Participants were instructed that they would be presented with two words sequentially on each trial of the experiment. They were told to listen to the first word, but the major aspect of the task involved simply pronouncing the word on the screen as fast and as accurately as possible after that word was presented. The participants were not explicitly told about any relations between the prime and target words. They were told that their voice would trigger the computer to erase the stimuli from the screen, which was quite clear for the participants during the practice trials.

On each trial, the following sequence of events occurred: (1) a row of three asterisks separated by blank spaces was presented in the center of the screen for 250 ms; (2) the screen was blanked; (3) an auditory prime was presented; (4) immediately following the detection of the offset of the auditory prime, there was a 250-ms, 1000-ms, or 1750-ms delay; (5) the target word was presented at the same location where the asterisks had been presented until the computer detected the voice onset, at which time the target word was erased; and (6) for the older adults and the DAT individuals, the experimenter coded the accuracy of the trial by pressing a button that erased the screen and initiated a 1500 ms intertrial interval. Specifically, if a correct pronunciation did *not* trigger the voice key (e.g., on the trials in which an extraneous sound or possibly a mispronunciation triggered the voice key), the experimenter pressed the 1 button. If a correct pronunciation did trigger the voice key, the experimenter pressed the 0 button. The younger adults coded their own responses by pressing either the 1 or 0 button in the same fashion.

There were three scheduled break periods in the experiment. Participants received a short break after the practice trials, and a second break between the test blocks. In addition, participants could take additional breaks during the experiment by informing the experimenter. All of the subjects participated individually in a small isolated testing room.

Results

Response latencies exceeding 2500 ms or 2.5 standard deviations above each participant's mean and response latencies less than 150 ms or 2.5 standard deviations below each participant's mean were treated as outliers. A 3 (group) × 2 (relatedness) × 2 (strength) × 3 (delay interval) analysis of variance (ANOVA) was conducted on the participant's mean performance per condition to determine if there were any main effects or interactions. All effects referred to as statistically significant in both Experiments 1 and 2 have *p* values less than .05.

Naming latencies

Table 2 displays the mean response latencies as a function of group, prime relatedness, and strength. (We collapse here

Table 2. Mean response latencies and percentage correct from Experiment 1 as a function of group, strength, and relatedness

	High strength		Low strength	
Group	Related	Unrelated	Related	Unrelated
Young (*N* = 24)				
RTs	483	503	493	512
% Correct	97	97	97	97
Old (*N* = 46)				
RTs	637	672	656	680
% Correct	97	96	96	96
DAT (*N* = 46)				
RTs	724	796	750	799
% Correct	96	94	95	93

across delay interval, because this factor did not produce any main effects or any reliable interactions in the data.) There are four points to note about the data in Table 2. First, as expected, response latency is faster for the young adults than the older adults, which in turn was faster than the DAT individuals. Second, the difference between the unrelated and the related prime conditions was larger for high-strength than for low-strength associates. Third, the difference between unrelated and related prime conditions was larger for the DAT individuals than for the healthy older adults, which in turn was larger than the young adults. Fourth, and most importantly, the overall pattern for the healthy older adults and DAT individuals appears to be very similar.

Figure 1 displays the mean semantic priming effects (i.e., the difference between the unrelated and its corresponding related prime condition) as a function of group and strength. As shown in Figure 1, the high-strength associates produced a larger semantic priming effect than the low-strength associates in both the healthy older adults and in the DAT individuals, but not in the healthy younger adults. More importantly, although the DAT individuals appear to be producing a larger overall semantic priming effect, the pattern of priming effects is very similar to the healthy older adults.

The above observations were supported by the ANOVA. This analysis yielded reliable main effects of group $[F(2,113) = 36.92$, $p < .01$, $MSE = 187, 303.72]$, strength $[F(1,113) = 29.75$, $p < .01$, $MSE = 2, 012.76]$, and prime relatedness $[F(1,113) = 87.68$, $p < .01$, $MSE = 6, 280.59]$. In addition, this analysis yielded a significant interaction between Strength × Prime Relatedness $[F(1,113) = 7.50$, $p < .01$, $MSE = 2, 215.59]$, which indicated that the semantic priming effect was larger for high-strength associates (46 ms) than for low-strength associates (32 ms). It is noteworthy that the Group × Strength × Relatedness interaction did not reach significance $[F(2,113) = 1.35$, $p = .26$, $MSE = 2, 215.59]$. The only variable that interacted significantly with group was prime relatedness $[F(2,113) = 7.88$, $p < .01$, $MSE = 6, 280.59]$, which indicated that the semantic priming effect was largest in the DAT individuals (60 ms), compared to the healthy older adults (30 ms), which in turn was larger than in the younger adults (20 ms).

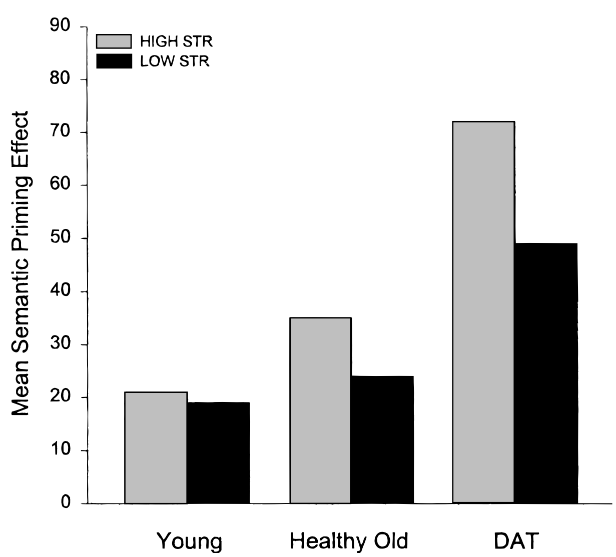

Fig. 1. The mean priming effects (unrelated minus related conditions) as a function of strength and group for Experiment 1.

In addition to the overall analyses, a second set of ANOVAs were conducted to determine if there were specific interactions that were due to age effects (young *vs*. older adults) or disease (older adults *vs*. DAT individuals) effects. In the ANOVA addressing young *versus* older adults, the same set of effects were reliable, with the exception of the Group × Relatedness interaction, which did not reach significance $[F(1,68) = 1.38$, $p = .25$, $MSE = 3, 544.20]$. No other interactions were reliable. In the ANOVA addressing the influence of disease, the Group × Relatedness interaction was significant $[F(1,90) = 8.23$, $p < .01$, $MSE = 7, 613.77]$. In fact, identical patterns of main effects and interactions occurred in both the overall analyses and in the analyses of the older adults and the DAT individuals.

Finally, although the overall Group × Relatedness × Strength interaction was not significant, separate tests were conducted on each group to determine if the critical Relatedness × Strength interaction would reach significance within each group. There was no hint of this interaction in the younger adults $[F(1,23) = .023$, $p = .82$, $MSE = 498.59]$. The Relatedness × Strength interaction also failed to reach significance in the healthy older adults $[F(1,45) = 2.04$, $p = .16$, $MSE = 2, 128.45]$. Finally, the interaction between Relatedness × Strength was significant for the DAT individuals $[F(1,45) = 5.74$, $p < .05$, $MSE = 3, 180.31]$. Thus, the present results indicated that only the DAT individuals were sensitive to the Strength × Relatedness interaction in the response latency data.

Percentage correct

In addition to the analyses on the response latencies, we also conducted ANOVAs on the number of correct responses per condition, excluding both outliers and trials in which the voice key was triggered by an incorrect or extraneous sound. The mean percentage correct as a function of group and condition are displayed in Table 2. As shown here, all groups of participants performed the speeded word naming task very accurately. The only effects to reach significance were the main effect of group $[F(2,113) = 5.97$, $p < .01$, $MSE = 1.66]$ and relatedness $[F(1,113) = 6.15$, $p < .05$, $MSE = .57]$. The Group × Relatedness interaction approached significance $[F(2,113) = 2.63$, $p = .08$, $MSE = .57]$. Separate ANOVAs on each group indicated that neither the young nor the older adults produced a significant effect of relatedness; however, the DAT individuals were more accurate on related prime trials than on unrelated prime trials $[F(1,45) = 9.86$, $p < .01$, $MSE = .64]$.

Discussion

The results of Experiment 1 yielded a number of noteworthy findings. First, it is intriguing that there was no evidence of a Strength × Relatedness interaction in the younger adults, and only a hint of such an interaction in the healthy older adults. These same stimuli have been shown to produce reliable strength by relatedness interactions in both young and healthy older adults with visual presentation of both primes and targets (see Balota & Duchek, 1988; Lorch, 1982). Thus, it is quite likely that the major difference in the results across these experiments is the cross-modal presentation of the stimuli in the present study. It is possible that the auditory presentation of the primes produced an acoustic trace for these stimuli that allowed for more integrative processing from the prime to the target and also from the target back to the prime. The Strength × Relatedness interaction is also minimized, or eliminated, in lexical decision performance conditions wherein target to prime integration processes are engaged (see Lorch et al., 1986; Neely et al., 1989). We shall further explore this possibility in the General Discussion section.

Interestingly, the DAT individuals were the only group of participants to be reliably sensitive to the Strength × Relatedness interaction. This pattern of data may suggest that there is a degradation in the semantic network in DAT individuals. Specifically, it is possible that the low-strength items produced a relatively decreased priming effect, compared to high-strength items, in the DAT individuals because these items reflect the weakest prime–target links and hence are most sensitive to degradation. However, an alternative account is that because the DAT individuals are slower overall than the healthy control individuals, the dominance effects are simply scaled up due to a general slowing phenomenon. Interestingly, if one considers the size of the priming effect for low-strength items as a function of the size of the priming effect for high-strength items, these proportions are virtually identical for the healthy older adults (24/35 = .69) and the DAT individuals (49/72 = .68). In this light, there is little evidence of a qualitatively distinct dementia-related change in priming as a function of the underlying strength of association. Finally, the relatively large semantic priming effects found in DAT individuals across auditory and visual modalities appear to suggest that the present semantic priming effects are either (1) tapping an amodal conceptual representation, or (2) the level of cortical–cortical disconnection in early DAT is not sufficient to disrupt the connections across the auditory and visual modalities that might underlie these priming effects.

EXPERIMENT 2

The results of Experiment 1 indicated that if primes and targets are sampled from the same semantic structure, there is little evidence of a disease-related change in the priming effects above and beyond a simple increase in the overall priming effects due to general slowing. However, as noted, both the high-strength and low-strength targets tapped into the same underlying semantic representation for the prime in Experiment 1. This is exemplified in the top panel of Figure 2, where one can see that although *SOFA* and *RUG* vary in associative strength to *FURNITURE*, there is no competition between semantic structures, that is, both associates are activated by the same interpretation of *FURNITURE*. This pattern can be contrasted with the semantic structure of ambiguous words like *BANK* which is depicted in the bottom panel of Figure 2. In this case, in addition to variability in associative strength, competition exists between alternative interpretations of the word BANK. This competition is illustrated in this figure by the presence of a segmented inhibitory connection between the two semantic nodes for BANK, each of which represent a different interpretation of BANK (i.e., MONEY *vs*. RIVER).

In Experiment 2, we explored the possibility that strength effects might change in DAT as a function of the nature of

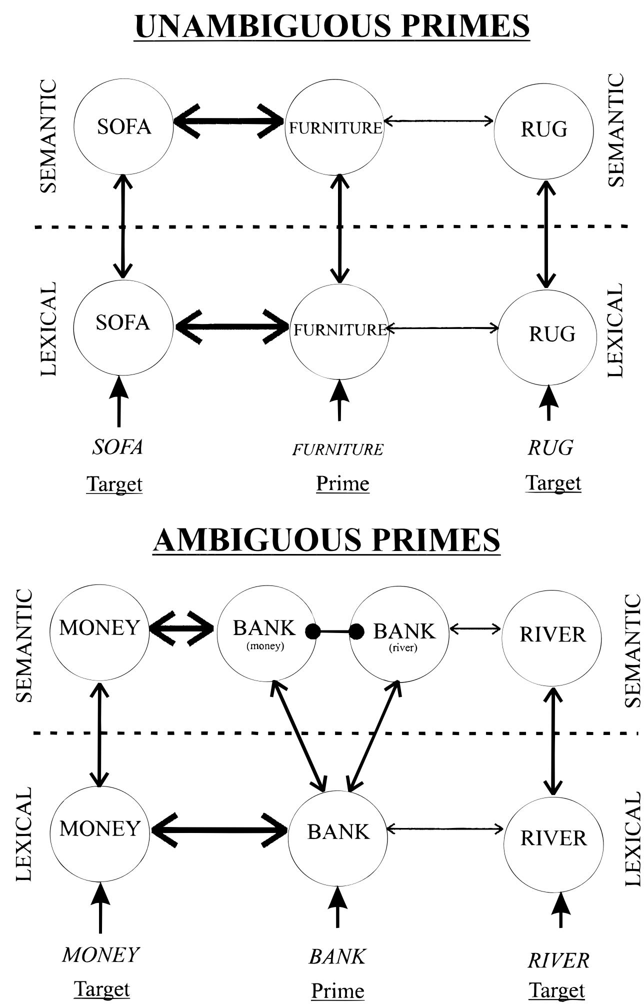

Fig. 2. Potential distinctions between the semantic structures for unambiguous targets (top panel) and ambiguous targets (bottom panel). Arrowed pathways (i.e., ↔) reflect facilitatory connections, whereas, segmented pathways (i.e., •—•) reflect inhibitory connections.

the underlying semantic representations. There are two possible ways in which this might occur. First, it may be the case that there is a breakdown in the inhibitory connections between the two interpretations of the ambiguous words. If this were the case, then one might expect relatively similar priming effects for both high- and low-strength prime target pairs in DAT individuals, but not in healthy older adults and in young adults. As noted earlier, both Balota and Duchek (1991) and Faust et al. (1997) have provided evidence that DAT individuals do show such inhibitory breakdowns with balanced homographs, and in a priming paradigm in which the context occurs before the homograph. On the other hand, one might expect to find larger dominance effects with homographs, if there is a decrease in the availability of low-strength connections. If the low-strength connections are most vulnerable to degradation, it may be the case that the connection between BANK and RIVER may be unavailable in DAT individuals.

Method

Research Participants

In Experiment 2, as was mentioned earlier, data from 1 individual with DAT was removed due to exceptionally fast response times (i.e., the participant's mean reaction time was less than 400 ms and therefore was likely due to a voice key failure). Furthermore, 1 individual with DAT and 1 healthy older adult were also removed due to experimenter error in recording the data. Therefore, the results from 24 young adults, 47 healthy older adults, and 46 individuals with DAT were retained for analysis in Experiment 2. The young group had a mean age of 20.9 years (SD = 2.2, range = 18–27), the healthy old group had a mean age of 77.3 years (SD = 9.5, range = 53–91), and the DAT group had a mean age of 74.4 years (SD = 8.3, range = 56–90). The mean education level for the older adults was 15 years, whereas, for the DAT individuals it was 13 years. (It should be noted that although the education level was higher for the healthy older adults compared to the DAT individuals, results of a median split analysis based on education indicated that this factor did not modulate the pattern of priming effects.) The DAT group consisted of 24 individuals with very mild DAT (CDR = 0.5), 20 with mild DAT (CDR = 1.0), and 2 with moderate DAT (CDR = 2.0).

Apparatus and procedure

The equipment for recording and producing the cross-modal presentation of the primes and targets was identical to that used in Experiment 1. In addition, the presentation parameters of the prime–target pairs were identical.

Stimuli

The stimulus materials were the same materials that were used by Simpson and Burgess (1985). Specifically, a total of 120 word pairs were used for the critical items in this experiment. One-half of the targets were related to the dominant interpretation of the homograph prime (e.g., BANK–MONEY), and the remaining half of the targets were related to the subordinate interpretation of the homograph prime (e.g., BANK–RIVER). The items were selected by Simpson and Burgess from the Nelson et al. (1980) norms. It is noteworthy that the high-strength and low-strength targets did not reliably differ as a function of frequency (based on Kucera & Francis, 1967) or length in letters. The unrelated primes were generated by re-pairing related prime–target pairs (e.g., the related pair BANK–MONEY was switched with the related pair TIRE–WHEEL to produce the unrelated pairs BANK–WHEEL and TIRE–MONEY). In addition to the target items, there were a set of 32 prime–target pairs constructed to serve as practice trials, and 8 buffer prime–target pairs were constructed to serve as buffer trials before each block of test trials. As in the test blocks, half of both the practice and buffer trials were semantically related and half were unrelated.

There were three blocks of trials. The first block included the 32 practice trials. Each of the two test blocks began with 4 buffer trials and was then followed by 60 test trials. Each block contained 5 prime target trials in each of the 12 cells that were produced by the factorial crossing of Relatedness (related *vs*. unrelated) × Strength (high-strength *vs*. low-strength) × Prime–Target Delay (250 ms, 1000 ms, and 1750 ms after the detected offset of the prime). Each target word was rotated across participants such that it was preceded by either a related prime or an unrelated prime at each of the three delay intervals. Thus, as in Experiment 1, targets were counterbalanced across prime type and delay interval but not strength, and the relatedness proportion was set at 50%. However, it is important to note that a given target served as its own baseline for priming effects because it was preceded by both a related and unrelated prime across participants. Within a test block, items were randomly ordered anew for each participant. A given participant never saw the same word twice within the experiment.

Results

The same screening procedure used in Experiment 1 was also used in this experiment. A 3 (group) × 2 (relatedness) × 2 (strength) × 3 (delay interval) ANOVA was conducted on the participant's mean performance per condition to determine if there were any main effects or interactions.

Naming latencies

Table 3 displays the mean response latency as a function of strength, prime relatedness, and group. (Again, as in Experiment 1, there were no reliable effects of delay interval and this factor did not interact with any of the other variables. Therefore, we collapsed across delay interval.) There are four points to note in Table 3. First, as expected, response latency was considerably slower for DAT individuals compared with the healthy older adults, which in turn was slower

Table 3. Mean response latencies and percentage correct from Experiment 2 as a function of group, dominance and relatedness

	High dominant		Low dominant	
Group	Related	Unrelated	Related	Unrelated
Young ($N = 24$)				
RTs	483	488	494	502
% Correct	98	97	95	96
Old ($N = 47$)				
RTs	637	654	662	680
% Correct	96	96	95	94
DAT ($N = 46$)				
RTs	755	793	808	811
% Correct	96	95	94	94

than in the healthy younger adults. Second, the related condition was consistently faster than the unrelated condition. Third, the priming effect overall increased across group, primarily in the high-strength condition. Fourth, only the DAT group produced a Relatedness × Strength interaction. The latter pattern of priming effects is most easily seen in Figure 3, wherein the mean priming effects as a function of group and strength are presented.

The above observations were supported by the ANOVA. This analysis yielded significant main effects of group $[F(2,114) = 38.69, p < .01, MSE = 223, 886.78]$, strength $[F(1,114) = 74.50, p < .01, MSE = 3, 317.30]$, and prime relatedness $[F(1,114) = 24.44, p < .01, MSE = 3, 829.30]$. In addition, this analysis yielded a significant interaction between Strength × Prime Relatedness $[F(1,114) = 6.03, p < .05, MSE = 2, 426.76]$, which indicated that the semantic priming effect was larger for high-strength associates (23 ms) than for low-strength associates (10 ms). However, this Strength × Relatedness interaction was qualified by a significant three-way interaction of Group × Strength × Prime Relatedness $[F(2,114) = 5.45, p < .01, MSE = 2, 426.76]$. None of the remaining main effects or interactions were significant.

In order to further investigate the three-way interaction, separate ANOVAs were conducted on each group of participants. As expected, the ANOVAs on the young adults and the healthy older adults yielded reliable effects of strength $[F(1,23) = 14.96, p < .01, MSE = 718.39; F(1,46) = 26.58, p < .01, MSE = 3, 410.95]$ and relatedness $[F(1,23) = 5.14, p < .05, MSE = 533.77; F(1,46) = 23.84$, p < .01, MSE = 1, 759.13], for the young and healthy older adults, respectively. However, neither the analysis of the young nor the healthy older adults produced a hint of a Relatedness × Strength interaction (both Fs < 1.00). This can be contrasted with the DAT individuals in which there are significant main effects of strength $[F(1,45) = 37.59, p < .01, MSE = 4, 549.90]$ and relatedness $[F(1,45) = 7.74, p < .01, MSE = 7, 629.83]$ along with a highly significant Relatedness × Strength interaction $[F(1,45) = 9.90, p < .01, MSE = 4, 141.15]$.

Percentage correct

As shown in Table 3, the mean percentage correct was again relatively high and comparable across groups and conditions. The ANOVA on the number of correct responses per condition that were included in the response latency analysis (i.e., excluding outliers and trials in which the voice key was triggered by an incorrect or extraneous response) yielded only one significant main effect. Specifically, there were slightly more responses for the high-strength targets (96%) than for the low-strength targets (94%); $[F(1,114) = 14.58, p < .01, MSE = .55]$.

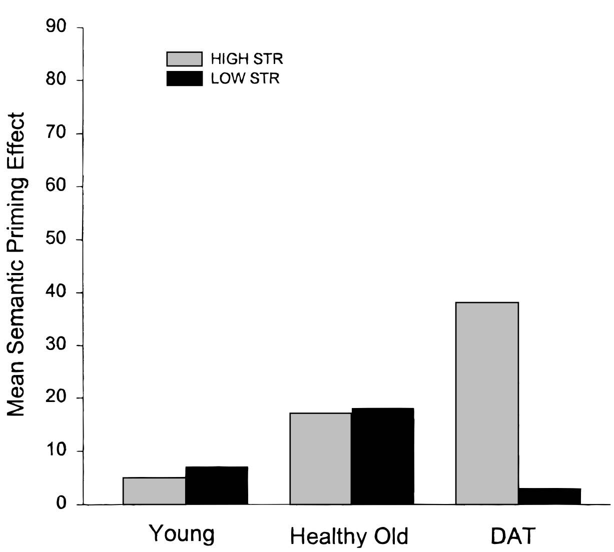

Fig. 3. The mean priming effects (unrelated minus related conditions) as a function of strength and group for Experiment 2.

Discussion

The results of Experiment 2 are quite clear and overall consistent with the pattern obtained in the first experiment. Specifically, although both the younger and healthy older adults produced reliable semantic priming effects, neither group produced the predicted Strength × Relatedness interaction. In contrast, the DAT individuals produced this interaction. However, in this case, the Relatedness × Strength interaction did not simply reflect a *relative* increase in the size of the priming effect as in Experiment 1. Specifically, the DAT individuals produced *larger* priming effects than the healthy control individuals for the high-strength items, but actually *smaller* priming effects than the healthy control individuals for the low-strength items.

As noted earlier, there have been two studies from our laboratory (Balota & Duchek, 1991; Faust et al., 1997) that have demonstrated that DAT individuals produce deficits in the processing of homographic items. In the Balota and Duchek study, there was evidence that a biasing context word (MUSIC) presented before a homographic word (e.g., ORGAN) did not control the interpretation of the homographs. Specifically, the DAT individuals produced equivalent priming for both the contextually relevant targets (e.g., PIANO) and the contextually irrelevant targets (e.g., LIVER). In contrast, the healthy older adults only produced a facilitation for the biased interpretation (e.g., PIANO). Converging evidence was recently reported by Faust et al., who utilized a target integration task with sentence contexts (i.e., participants decided whether the word ACE was related to the sentence context HE DUG THE HOLE WITH A SPADE). Thus, these studies indicate that DAT individuals produce priming for both interpretations of homographs. This would appear at first glance to be inconsistent with the present pattern in which DAT individuals only produce priming for the dominant interpretation, whereas, healthy young and older control individuals produce priming for both the dominant and the subordinate interpretations. However, there are two important differences between these studies that provide some insight to this difference. First, in the Balota and Duchek and Faust et al. studies, the homographs were relatively balanced, whereas in the present study we used biased homographs in which there was clearly a dominant and subordinate interpretation of the homographs. Second, in the present study, participants relied on preexisting differences in the strength of the interpretation of the two meanings of the homographs within the semantic network, whereas, in the previous studies, the on-line effect of contextual information on the interpretation of the homographs was measured. We believe that the DAT individuals are more likely to produce a breakdown in the integrative operations that select the appropriate meaning of the homographic items, and this produced the apparent multiple access effects that occurred in the previous studies. Although further work is needed in this area, it is quite intriguing that there are now three studies that have provided evidence of breakdowns in the processing of ambiguous words in DAT individuals. It is quite possible that ambiguous words have unique representational characteristics that demand processes that are particularly sensitive to DAT.

GENERAL DISCUSSION

There were three primary goals of the present series of experiments. The first goal was to investigate the influence of strength of association on the priming effects observed in young, healthy older adults, and in individuals diagnosed with Alzheimer's disease. In this regard, the results are relatively clear. In both experiments there was evidence of a Relatedness × Strength interaction that occurred for the DAT individuals, but not for the healthy young or older adults. The second goal was to determine if the nature of the underlying semantic representation of the primes modulated this pattern. Again, the answer is clear: In Experiment 1, with nonhomographic primes, the healthy older adults and the DAT individuals produced the same qualitative pattern of results, with the DAT individuals simply producing larger overall priming effects. On the other hand, in Experiment 2, with homographic primes, and targets with different dominance values, the effects across groups were qualitatively distinct. Specifically, there was an increase in the high-strength priming effects for the DAT individuals compared to the healthy older adults, whereas, there was a relative decrease in the low-strength priming effects for the DAT individuals compared to the healthy older adults. The third goal was to investigate whether there would be a decreased overall priming effect due to potential cortical–cortical disconnections in the DAT individuals due to the cross-modal presentation of the prime–target pairs. Consistent with other within-modality priming studies, the results indicate that the DAT group produced larger priming effects than the healthy age-matched control participants. Thus, the nature of the cross-modal presentation did not modulate the present results.

Although the surface level description of these results are quite clear, there are a number of aspects of these results that demand further analyses and discussion. We shall now turn to a more detailed analysis of these issues.

General Slowing

Overall, the present results yielded an increasing priming effect in the DAT individuals compared to the healthy older adults, which, in turn, produced a larger priming effect than the young adults. Of course, because these three groups were at different points in the response latency scale, one might expect this pattern of data (see Faust et al., 1999; Myerson et al., 1992). Thus, we conducted two sets of subsidiary analyses to determine if the pattern of data holds above and beyond what would be expected based on general slowing models (see Faust et al., 1999, for a discussion of these two approaches). The first set of analyses involved proportional scores in which each participant's mean per condition was subtracted from their overall mean and then divided by their overall mean. This analysis corrects for general slowing because it provides a *relative* measure based on the average processing speed of that individual. The second set of analyses involved transforming the data to *z* scores based on the standard deviation across the cell means within a given participant's data. This transformation also corrects for general slowing because of the linear relationship between overall response latency and standard deviations (again, see Faust et al., 1999, for a discussion of this relationship). Both of these sets of transformed data were then submitted to 3 (group) × 2 (strength) × 2 (relatedness) × 3 (delay interval) ANOVAs.

The results of these ANOVAs were remarkably similar to the original analyses. First, consider the analyses of the results from Experiment 1: The Group × Relatedness interaction was reliable in the proportional analyses [$F(2,113) = 4.97$, $p < .01$, $MSE = .009$], and marginal in the *z*-score analyses [$F(2,113) = 2.39$, $p < .10$, $MSE = 1.085$]. Thus, it does not appear that the overall increase in priming effects across these groups can be simply attributed to general slowing effects. More importantly, for Experiment 1, there was no overall Group × Strength ×

Relatedness interaction in either the proportional analyses or in the *z*-score analyses (both Fs < 1.00). Thus, there is not a hint of a Group × Strength × Relatedness interaction after one corrects for general slowing in Experiment 1.

Turning to the results from Experiment 2, it is also the case that the pattern of data withstood the test of predictions from general slowing accounts. Specifically, as in the original analyses, the Group × Relatedness interaction did not reach significance in either the *z*-score analyses or in the proportional analyses (both Fs < 1.00). More importantly, however, the critical Group × Strength × Relatedness interaction did reach significance in the proportional analyses [$F(2, 114) = 4.61$, $p = .01$, MSE = .004], and was marginally reliable in the *z*-score analyses [$F(2, 114) = 3.03$, $p = .05$, $MSE = .911$]. Thus, the critical interaction among Group × Strength × Relatedness observed in Experiment 2 clearly cannot be attributed to simple changes in priming effects due to general slowing phenomena.

Additive Effects of Relatedness and Strength in Healthy Young and Older Adults

One intriguing aspect of the present results is that both Experiments 1 and 2 did not yield significant Relatedness × Strength interactions in either the young or the older adults. This is particularly surprising given that three previous studies have found Relatedness × Strength interactions with the same set of stimuli in young adults (Balota & Duchek, 1988; Lorch, 1982; Simpson & Burgess, 1985), and in older adults with the stimuli from Experiment 1 (Balota & Duchek, 1988). Of course, one might argue that these results reflect a Type II error (i.e., a failure to detect the interactions). We do not believe that this is likely because the same pattern was replicated in both of the present experiments and there was a considerable number of observations and participants in each study. Specifically, Experiment 1 included 36 observations for each of the four cells produced by a factorial cross of Relatedness × Strength for each of 70 participants, whereas Experiment 2 included 30 observations per condition for each of 71 participants. Moreover, the priming effect sizes from Experiment 1 (20 ms and 30 ms for the young and old, respectively) were actually larger than in the Balota and Duchek (1988; 8 ms and 15 ms for the young and old, respectively) with the same set of stimuli, even though the latter study detected the reliable interaction. Thus, one cannot argue that the failure to find a Relatedness × Strength interaction in the present study can be attributed to an insensitive priming paradigm.

Because of the consistency of the results across the present two experiments, we believe that it is more likely that the mode of presentation eliminated the Relatedness × Strength interactions. To our knowledge, this is the first cross-modal presentation with single-word primes that has investigated the Relatedness × Strength interaction. We believe that it is quite possible that the auditory presentation of single-word primes may be the critical factor in the present study. Specifically, it is possible that the auditory presentation of the prime in the present experiments produced an auditory or echoic trace (see Crowder & Morton, 1969) that is extended in time and affords a type of resonating process wherein the auditory prime is combined with the visually presented target. Because this is the only auditory stimulus on a given trial (i.e., it was not "suffixed" by a subsequent speech sound; see Crowder & Morton, 1969), it is likely that this echoic type trace persists for an extended period of time (see Balota & Duchek, 1986; Crowder, 1971). The resonating process between the extended prime and target may have minimized or eliminated the Relatedness × Strength interaction. There are three pieces of evidence that are supportive of this notion. First, there is evidence that the Strength × Relatedness interaction is attenuated in the lexical decision task, wherein there is presumably a backward checking (possibly resonating) process between the target and the prime (see Lorch et al., 1986; Neely et al., 1989). Second, there is evidence from a cross-modal naming study with single-word primes by Peterson and Simpson (1989) that provides direct evidence of such backward processing from a visual target to an auditory word prime (e.g., priming from the target BELL back to the prime BOY on BOY–BELL trials). Finally, the lack of any effect of delay interval suggests that once the auditory prime was engaged, it remained available at least throughout the present delay intervals.[2] In the past visual presentation studies, the Relatedness × Strength interaction has depended upon the stimulus onset asynchrony between primes and targets that involved abrupt onsets and offsets. It is possible that the abrupt onset and offset of a visual stimulus may contribute to the time course of such Relatedness × Strength interactions that have occurred in the past priming research (e.g., Balota & Duchek, 1988; Simpson & Burgess, 1985). Of course, visually presented primes do not engage the same speech specific echoic store (see Crowder, 1971). Thus, the present results suggest that the availability of the auditory trace for the prime item throughout the delay interval may have instantiated an integration process in which the prime and target are combined, thereby eliminating the Relatedness × Strength interaction. Moreover, these results appear to suggest that there may be a speech specific code that is used for such integration processes that is quite distinct from a visual store. The integration of incoming speech with previously presented speech would make such a speech specific representation particularly advantageous in the evolution of the language processing system.

Although an echoic–auditory trace may play a role in the present cross-modal priming results, it is still unclear why such a trace would eliminate the strength by relatedness interaction. Wouldn't the integration process be strength de-

[2] It should be noted that because the triggering of the onset of the delay presentation was dependent upon the detection of silence at the end of the offset of the auditory prime, and there are differences in sensitivity to different offsets across words, there was some variability associated with the actual delay interval across stimulus words. However, it should be noted that such variability would have been constant across the delay intervals and prime–target relations.

pendent? We believe that the failure to find Strength × Relatedness interactions in both the young and older adults provides some insight into the nature of cross-modal, single-word priming effects. These results are supportive of an all-or-none or threshold model of priming. Specifically, if the system resonates to a relationship between the prime and target, then there appears to be a constant increase in the benefit to target processing regardless of strength. As noted, this resonating process should be engaged during the 500 ms between target onset and response output (see Balota et al., 1989; Dallas & Merikle, 1976, for evidence of priming effects after target word recognition). The availability of the echoic trace during this interval serves as the stimulus for this resonating process. If this account is correct, then one might ask why past visual presentation studies produced Strength × Relatedness interactions? It is possible that with sequential presentation of primes and targets that there is a probabilistic change in the rate of finding prime–target relationships across high- and low-strength associates. Specifically, for low-strength prime-target pairs, some of these relations will not be found because of the abrupt onset and offsets of the prime-target sequence; that is, the prime is no longer available for the resonating process with visual presentation. For high-strength prime–target relationships, there would be an increased likelihood of the network settling into a relationship. Thus, when averaged across items, one finds an effect of prime–target strength, not because of increased activation, but rather because of an all-or-none priming effect that is less likely to be found for low-strength items, compared to high-strength items. Of course, this is a very different account of Relatedness × Strength interactions, wherein strength actually modulates the degree of priming (spreading activation) within a given trial. Unfortunately, the distinction between continuous and all-or-none models has historically been very difficult to make (see Crowder, 1976, for an excellent review of this issue). Although the present results are consistent with this possibility, further work is clearly needed to address this issue.

Strength × Relatedness Interactions in DAT Individuals

One of the central issues addressed in the present study is the pattern of priming effects in the DAT individuals. In contrast to the healthy young and older adults, in both experiments, these individuals produced highly reliable Strength × Relatedness interactions for the same set of stimuli. Interestingly, in Experiment 1, this interaction can be accommodated simply by a general slowing perspective, because the healthy older adults also produced some, albeit nonsignificant, evidence of this interaction. However, the results from Experiment 2 clearly did not produce a pattern that can be accommodated by general slowing. The major difference across these two experiments is the type of semantic information accessed by the primes, and the relationship between this information and the underlying strength of the association. In Experiment 1, both the high-strength (FURNITURE–SOFA) and low-strength pairs (FURNITURE–RUG) accessed the same semantic structure of the prime. In this case, there is no competition between different interpretations of the prime word (FURNITURE). On the other hand, the stimuli used in Experiment 2 included direct competition between the interpretation engaged by the high-strength (BANK–MONEY) and the low-strength pairs (BANK–RIVER). This competition may have produced difficulty in the DAT group for the low-strength pairs because DAT individuals have attentional breakdowns in which they cannot inhibit–control the high-dominant prime–target interpretation, once that interpretation has been accessed. This pattern would be consistent with the notion that DAT individuals produce breakdowns in inhibitory control systems (e.g., Balota & Duchek, 1991; Balota & Ferraro, 1993, 1996; Faust et al., 1997; Spieler et al., 1996; Sullivan et al., 1995).

Alternatively, it is possible that the representation for the low-dominant interpretation of homographs is degraded in DAT individuals. The notion here is that, although there is some exposure to the low-dominant interpretation of homographs, it is less likely than exposure to the high-dominant interpretation. Thus, it is relatively rare to be exposed to the BANK–RIVER interpretation. Therefore, low-dominant interpretations may be relatively less available and hence more sensitive to semantic degradation produced by the disease. This can be contrasted with the nonhomographic word such as FURNITURE. One might argue that every encounter of nonhomographic words consistently reinstantiates the same semantic interpretation that is related to *both* the high-dominant interpretation and the low-dominant interpretation. Thus, the continued exposure to this stimulus strengthens both connections at the same rate, and therefore, this interpretation may be less prone to the effects of degradation.

We have provided two ways to interpret the qualitatively distinct pattern of data in the DAT individuals that was observed in Experiment 2. One account appears to reflect a degradation in the semantic representation for the low dominant interpretation of ambiguous words, whereas, the second account appears to reflect more of a degradation in the control system that allows access to the subordinate interpretation. We believe that the present results cannot totally discriminate between these two alternatives, and that this distinction may be more a matter of degree rather than kind. It is likely that the present cross-modal priming paradigm, coupled with a naming task as the dependent measure, minimized the influence of attentional control processes, compared to previous priming studies. There were no direct demands to integrate the prime and the target word, and the participants were only required to name a series of visually presented words. Clearly, the demands in this task are minimal compared to the standard neuropsychological measures that have been used to measure semantic memory, such as verbal fluency and Boston Naming Test, along with the cognitive tasks that presumably tap into semantic network, such as sentence verification and category verification tasks.

Moreover, the present studies provide a dissociation between two classes of stimuli (homographs and nonhomographs) under identical presentation formats. Thus, although one may never be able to develop a fully attention-free task (per Jacoby's, 1991, process-pure measure) to tap into the integrity of semantic memory in DAT individuals, the present results provide additional evidence that ambiguous words afford a qualitatively distinct type of processing that appears to be sensitive to DAT.

Summary

The results of the present study provide two important patterns of data. Specifically, under conditions that appear to minimize attentional processing, both young and healthy older adults do not produce a prime Relatedness × Strength interaction with a set of stimuli that has been shown to produce such interactions in past within-modality studies. We believe that the present results suggest a possible all-or-none priming mechanism that may be exposed in the current single-word, cross-modal priming paradigm. The second major finding in the present results is that although DAT individuals produce relatively comparable priming effects with prime stimuli that have a single semantic representation, there appears to be a breakdown in the processing of the subordinate meaning of ambiguous words. Although these results were observed in a task that minimizes attentional controlled processes, it is likely that the pattern was produced both by a degradation in the network and the processes engaged to access that network.

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