

Facilitation of Unattended Semantic Information in Alzheimer's Disease: Evidence From a Selective Attention Task

Laura Grande
Harvard Medical School and
Veterans Affairs Medical Center,
Brockton/West Roxbury

Regina McGlinchey-Berroth
and William P. Milberg
Harvard Medical School,
Veterans Affairs Medical Center,
Brockton/West Roxbury, and Boston
University School of Medicine

Mark D'Esposito
University of Pennsylvania Medical Center

Processing of unattended semantic information was examined in 13 patients with Alzheimer's disease (AD) and 23 normal controls (NC) using a selective attention, priming task. Two vertically aligned pictures of objects served as primes, and object names were targets. Participants were instructed to attend to only 1 picture, defined by color, in the prime display. NC participants showed facilitation only for target items that were the name of the attended prime picture, but AD patients showed facilitation from the attended and unattended prime pictures. Two accounts of these data posit a deficit in the initiation of the selection component of selective attentional processing in AD. On the basis of spotlight theories, a 3rd account posits a deficit in AD patients' ability to adjust the scope of the selection "beam." Last, facilitation of attended and unattended information may be due to crosstalk between accurately selected and unselected information. Implications of the activation of irrelevant information to language function in AD are also discussed.

There is emerging consensus that the language deficits in patients with Alzheimer's disease (AD) reflect a disruption in the semantic memory system. These deficits are revealed by poor verbal fluency (e.g., Chertkow & Bub, 1990; Hodges, Salmon, & Butters, 1992; Ober, Dronkers, Koss, Delis, & Friedland, 1986; Weingartner, Kawas, Rawlings, & Shapiro, 1993), impaired naming (e.g., Hodges et al., 1992; Smith, Murdoch, & Chenery, 1989), and abnormal semantic priming effects (Albert & Milberg, 1989; Chertkow, Bub, & Seidenberg, 1989). The underlying nature of this deficit in semantic memory is currently a focus of debate. Some investigators argue that impaired performance on these tasks reflects an erosion in the database of meanings and associations that

forms the underlying basis on which language operates (i.e., semantic memory; Chertkow & Bub, 1990; Chertkow et al., 1989; Hodges et al., 1992; Martin & Fedio, 1983; Salmon, Shimamura, Butters, & Smith, 1988). Others argue that these impairments reflect a retrieval deficit (Albert & Milberg, 1989; Nebes & Brady, 1989, 1990; Ober & Shenaut, 1994). Both of these views are based on the commonly accepted assumption that difficulties in the expression of language reflect a dysfunction only in those aspects of language processing that are specific to activating and retrieving words and their meanings. While this approach is well founded in other neuropsychological populations whose deficits are characterized by acute onset (i.e., stroke patients; e.g., Milberg & Blumstein, 1981), it may not be applicable to the study of language deficits in AD. The insidious onset of AD and the multiple brain regions affected by neural pathology (i.e., association cortices) may make a focal deficit approach to understanding language deficits in AD untenable. It is possible, in fact likely, that other nonlinguistic factors contribute significantly to the language deficits observed in AD patients. One such nonlinguistic mechanism, which has been implicated in the pathology of AD in recent years, is selective attention.

Laura Grande, Department of Psychiatry, Harvard Medical School, and Geriatric Research, Education and Clinical Center, Department of Veterans Affairs Medical Center, Brockton/West Roxbury Division. Regina McGlinchey-Berroth and William P. Milberg, Department of Psychiatry, Harvard Medical School; Geriatric Research, Education and Clinical Center, Department of Veterans Affairs Medical Center, Brockton/West Roxbury Division; and Memory Disorders Research Center, Boston University School of Medicine. Mark D'Esposito, Neurology Department, University of Pennsylvania Medical Center.

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Correspondence concerning this article should be addressed to Laura Grande, who is now at the University of Florida, Department of Clinical and Health Psychology, PO Box 100165 Health Science Center, Gainesville, Florida 32610-0165.

Selective attention mediates the interaction of perception and behavior by maintaining focus on salient environmental features that are consistent with an individual's current goals while ignoring or suppressing features that are inconsistent with those goals. Several models of selective attention have been proposed (Houghton & Tipper, 1994; Kahneman, 1973; Shiffrin & Schneider, 1977). Perhaps the most clearly delineated model, and the one that has been referenced to un-

derlying neuroanatomy, is that of Posner and his colleagues (Posner & Cohen, 1984; Posner, Werner-Inhoff, Friedrich, & Coshen, 1987). His model consists of three component processes: (a) disengagement of attention from the current focus, (b) moving or shifting of attention to a new focus, and (c) engagement of attention at the new focus. Experimental studies have revealed that these component processes may be mediated by different regions of the brain. For example, damage to the parietal lobe can selectively impair an individual's ability to disengage attention from a current focus (Posner et al., 1987), while midbrain lesions may impair an individual's ability to shift attention and engage it on a new stimulus (Posner, Walker, Friedrich, & Rafal, 1984).

Regardless of the particular model, most accounts of selective attention imply that a feature or item that has been "selected" by attention is perceived more effectively than is an unselected feature or item because, once selected, it undergoes additional, more elaborative processing. The selection of items in the visual array can be accomplished on the basis of their spatial location (Posner, 1980), special status as primitive features (Treisman & Gormican, 1988), task relevance (Kahneman & Treisman, 1984), or a combination of these characteristics (see Parasuraman & Haxby, 1993, for a more detailed discussion of these mechanisms in patients with AD). Items that are not selected for higher level visual processing either passively decay over time (Broadbent, 1971; Kahneman & Treisman, 1984) or are actively suppressed (Tipper, 1985; Tipper & Cranston, 1985; Tipper & Driver, 1988).

Does evidence exist suggesting a selective attentional deficit in patients with AD? Neurophysiologically, the answer is yes. The neuropathological changes that occur in the brains of AD patients—namely, neurofibrillary tangles and senile plaques—are restricted to cortical areas. In particular, these changes occur primarily in the temporoparieto-occipital junction, most notably in the temporolimbic region and the posterior cingulate gyrus (see Cummings & Benson, 1983). These areas encompass the regions that Posner has demonstrated to be critical for disengaging attention and switching to a new focus.

Neuropsychological studies also implicate a dysfunction in selective attention processes in AD patients. In particular, these studies suggest that the selection component may remain intact but that the disengaging and shifting components as well as the ability to inhibit distracting information may be impaired. For example, some studies have used variations of the Stroop (1935) task in which participants were asked first to read color names (e.g., *red* in black ink), then to name colors (e.g., *XXXX* in red ink), and lastly, to identify the color of ink in which a color name is printed (e.g., *blue* in green ink). In general, the increase in naming latency for the final incongruent condition in relation to the first two baseline conditions is thought to reflect the ability of participants to ignore or inhibit the irrelevant dimension of the stimulus (in this example, the word *blue*). A number of such studies have reported that older control participants are slowed in the incongruent condition to a greater extent than are younger participants (Cohn, Dustman, & Bradford, 1984; Comalli, Wapner, & Werner, 1962; Panek, Rush, & Slade, 1984) and that AD patients are disproportionately slowed in comparison with age-matched normal controls (NCs; Fisher, Freed, & Corkin, 1990; Koss,

Ober, Delis, & Friedland, 1984). These results suggest that the inhibitory component of selective attention may be impaired in AD patients, as revealed by an increased Stroop interference effect; AD patients simply cannot ignore the irrelevant aspect of the task. It is unclear from the Fisher et al. (1990) and Koss et al. (1984) studies, however, whether the increased Stroop effect was due to increased interference in response time or to an increased intrusion rate in the incongruous condition. Spieler, Balota, and Faust (1996) conducted an extensive examination of AD patients' performance in the Stroop task. They found that older controls showed a disproportionate interference effect in comparison with younger controls but that the AD patients' interference effects were not greater than were those of the older controls. The AD patients were, however, significantly faster in the congruent condition than were the NC participants (i.e., increased facilitation) and showed an increased intrusion rate in the incongruous condition in comparison with NC participants (they were more likely to say the printed word rather than name the color). Spieler et al. concluded that aging impairs the ability to inhibit irrelevant information and that this inability is exaggerated in AD patients.

Foldi, Jutagir, Davidoff, and Gould (1992), using a different selective attention task, provided supporting evidence. They used a cancellation task in which subjects were instructed to place a mark through all of the target symbols contained in an array of distractor symbols. These investigators found that the AD patients, like NCs, were able to accurately select the targets. However, AD patients were disproportionately impaired as the number of distractors increased, in relation to NCs. Likewise, Nebes and Brady (1989) reported that AD patients and NC participants were able to accurately select a target (by color) in an array of distractors but were unable to totally ignore irrelevant stimuli.

Further evidence indicating that the selection component of attention is intact in AD is provided by studies using visuospatial cuing paradigms. Parasuraman, Greenwood, Haxby, and Grady (1992) used a detection task in which the target was preceded by either a valid or an invalid location cue (Posner, 1980). They found that AD patients were not impaired in their ability to focus attention to a validly cued target location but were markedly impaired in their ability to shift attention from an invalidly cued location to a new location, particularly with centrally located cues (that initiate more effortful shifts) and at longer stimulus onset asynchronies (SOA).

Nebes and Brady (1989) investigated whether preserved selection would be observed if the cue was a stimulus feature other than location, specifically color. In this task, AD patients and NC participants were asked to detect a target letter in an array of distractors in both focused and divided attention tasks. In the focused attention task, the target letter was always black, but on half of the trials four of the distractors were red (reducing the relevant distractors to only two). The divided attention task also consisted of a black target letter; however, the number of distractors (all black) ranged from one to five in number. The performance of the AD patients in this experiment was similar to that of NC participants on the focused attention task, but the AD patients' performance decreased

disproportionately as the number of distractors increased on the divided attention task.

Finally, Sullivan, Faust, and Balota (1995) investigated selective attention in a group of AD patients, age-matched NCs, and young controls using a priming paradigm similar to that developed by Tipper and his colleagues (Tipper, 1985; Tipper & Cranston, 1985). Two overlapping line drawings, one red and one green, served as displays for both the priming and target stimuli. During the presentation of the prime and target displays, participants were instructed to attend to and name drawings of one color and to ignore drawings of the other color. Sullivan et al. found that AD patients could successfully discriminate a target from a distractor on the basis of color (indicating intact selection) but were disproportionately impaired in relation to the young and age-matched NCs in their ability to ignore the distracting information from the drawing in the other color.

In summary, these studies suggest that AD patients can use the advance information provided by a cue to select stimuli. However, their ability to shift the focus of attention from a cued location to an unexpected location is greatly compromised (however, see Cossa, Della Sala, & Spinnler, 1989, for conflicting findings), and they are disproportionately affected by irrelevant or distracting information in a visual array. These findings suggest that mechanisms involved in selective attention may be differentially affected by the pathology of AD. Specifically, item selection may be intact, but ignoring distracting items may be impaired to a greater extent than would be expected on the basis of aging alone. These observations raise the question: What happens to distracting information, given that AD patients do not ignore or actively suppress it? Are distractor items facilitated in a manner similar to focally selected items, or do they simply remain at a baseline level of activation? These questions have important implications for understanding the language deficits displayed by AD patients. As suggested by Posner (1980, p. 22), "it seems reasonable to suppose that orienting in semantic memory will take advantage of these same principles [component processes]" of attention. Thus, attention may not only serve to direct cognitive resources for sensory processing, it may also function to orient the activation and suppression of specific internal representations such as words, images, and memories (i.e., semantic representations; Posner et al., 1987). This speculation has recently received strong support from Dark, Vochatzer, and VanVoorhis (1996) in a selective attention priming task with normal participants. In their task, a prime word was briefly presented, followed by a pair of masked target words, one of which was sometimes related to the prime. When participants were instructed to report both of the target words, but because of the timing parameters of the experiment were able to report only one target word, they typically reported the semantically related word. Also, when one of the target words was accompanied by a precue to direct attention, relatedness and cuing had additive effects, suggesting that these two orienting mechanisms operated independently. Finally, when participants were instructed to report only one word and a peripheral precue was presented to spatially orient the participants to which target item they were to report, semantic priming for the cued and uncued item was observed. These data suggest that explicit

performance can be driven by the selective activation of specific representations in semantic memory, such that what is attended to is conceptually related to or consistent with the current state of information processing (i.e., activation) in semantic memory.

In the current study we investigate the level of processing achieved by distracting semantic information in AD. We utilized a selective attention, semantic priming task (a modified version of Tipper & Cranston, 1985, and Tipper, 1985) in which participants were presented with dual prime picture displays and single word targets. Participants were instructed to attend to only one item in the prime display and to read the target word aloud. It was our hypothesis that NC participants would show significant facilitation (reduced response latencies) for target words following attended primes in comparison with unrelated primes and would show significantly less facilitation, if any, for targets following unattended primes in comparison with unrelated primes. AD patients were expected to show a similar pattern for targets following attended primes. However, we predicted that AD patients might also show significant facilitation for targets following unattended primes due to their inability to ignore distracting information. This latter prediction is based on previous studies, reviewed above, demonstrating disproportionate interference effects from distracting information.

Method

Participants

Thirteen patients with a diagnosis of probable AD and 23 NC individuals participated in this study (see Table 1). AD patients averaged 70 years of age (range = 53 to 80, $SD = 6$), and NC participants averaged 68 years (range = 56 to 80, $SD = 6$). Mean years of education was 14 (range = 12 to 18, $SD = 2$) for AD patients and averaged 15 (range = 12 to 19, $SD = 2$) for NC participants.

Participants completed the Folstein Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) and an abbreviated form of the Boston Naming Test (Kaplan, Goodglass, & Weintraub,

Table 1
Demographic, Mental Status, and Naming Scores for Individual AD Patients and Averages for NC Participants

Patient	Age	Education (years)	MMSE	% naming
AD1	77	16	20	100
AD2	69	18	23	90
AD3	70	12	25	96
AD4	73	12	24	93
AD5	80	NA	11	40
AD6	65	14	23	73
AD7	74	14	26	93
AD8 ^a	69	NA	12	93
AD9	69	NA	18	80
AD10 ^a	53	14	23	100
AD11	72	12	21	73
AD12	71	16	27	100
AD13	70	NA	23	73
Mean ADs	70	14	21	85
Mean NCs	68	15	29	93

Note. AD = Alzheimer's disease; NC = normal control; NA = not available; MMSE = Mini-Mental State Exam.

^aPatient was excluded from the data analysis.

1983). For the MMSE, AD patients had an average score of 21 (range = 11 to 27, $SD = 5$) and NC participants had an average score of 29 (range = 25 to 30, $SD = 2$). The mean performance of 21 for AD patients indicates that they were mildly to moderately impaired. Participants were also asked to name the 15 Boston Naming Test items included in the consortium to establish a registry of Alzheimer's disease (CERAD) battery (Morris et al., 1989). Percentage correct averaged 85% ($SD = 17$) for AD patients, ranging from 40% to 100%. Percentage correct averaged 98% ($SD = 3$) for NC participants, ranging from 93% to 100%.

Stimuli

The priming stimuli consisted of 160 pictures of concrete common objects (Snodgrass & Vanderwort, 1980). The prime display consisted of one orange picture and one blue picture, centered 1° above and below the center of the computer screen. Participants were instructed to attend to pictures of one color, either blue or orange, throughout the experiment. Target items consisted of 80 real English words, averaging six letters in length with an average frequency of 49 words per one million (Francis & Kucera, 1982). Targets were colored black and presented in point size 25 Geneva font. The targets were assigned to one of the three conditions depicted in Figure 1: In the attended repetition condition, the word target was the name of the attended picture in the prime display (20 trials); in the unattended repetition condition, the target was the name of the unattended picture in the prime display (20 trials); in the unrelated condition, the target was a word unrelated to either the attended or unattended prime picture (40 trials). The latter condition served as the baseline against which to assess the priming levels achieved by the attended and the unattended prime pictures. Targets in each of the conditions were matched in length and frequency. Attended picture location (above or below the midline of the computer monitor) was counterbalanced across trials, and picture location was counterbalanced across participants. The attended color (orange or blue) and assignment of pictures to the attended or unattended condition were also counterbalanced across







FIXATION (500 msec)	PRIME DISPLAY (200 msec)	ISI (400 msec)	TARGET (unlimited)
Attended Repetition			star
*			
Unattended Repetition			cup
*			
Unrelated (baseline)			shoe
*			

Figure 1. Sample trials for attended repetition, unattended repetition, and unrelated conditions. In these examples, the star would be presented in orange and the cup would be presented in blue. Participants would be instructed to attend to the orange picture prime. Stimuli were scaled down for this figure. ISI = interstimulus interval.

participants. This resulted in the construction of four stimulus lists, with each list serving in both the orange attended and blue attended experiment conditions. The trials within each list were randomized and presented to all participants in random order.

An additional set of 32 picture primes and 16 target words was used to create 16 practice trials. Each condition was represented four times during the practice session (four attended and four matched unrelated, four unattended and four matched unrelated), and target items were matched for length and frequency. Picture location and color were counterbalanced across participants. The practice trials were intended to get the participants into the set of the task and to ascertain whether they experienced difficulty discriminating between the orange and blue picture primes. None of the participants reported difficulty with this aspect of the task.

Apparatus

Participants were tested on a Macintosh IIsi computer, adjusted so that the center of the monitor was at eye level. A microphone, interfaced with a voice-operated relay, was positioned in front of and below the participant's mouth. Psychlab (Gum, 1992) software controlled the presentation of stimuli and the timing and recording of response latencies.

Procedure

The priming task comprised 80 trials, each containing a compound priming stimulus, followed by a word target stimulus (see Figure 1). The onset of each trial was signaled by an asterisk, located at the center of the screen for 500 ms, followed immediately by the presentation of the compound prime for 200 ms. The target stimulus was presented after a 400-ms delay and remained on the screen until a response was made. This resulted in a 600-ms interstimulus interval (ISI) between onset of the prime display and onset of the target display. Participants were told that two pictures, one orange and one blue, would be presented following the asterisk, and that they would be present for only a short period of time. They were told that the two colored pictures would be replaced by a single word. The participants were instructed to attend to either the blue or the orange picture throughout the experiment and to respond by reading the target word as quickly and as accurately as possible. All participants were tested in a single session lasting no more than 40 min.

The 80 trials were divided into four blocks of 20 trials each, and participants were allowed a short rest between blocks. Before the start of the experimental trials, participants were administered the 16 practice trials.

Results

Preliminary Analyses

We first examined participant characteristics to determine whether differences existed between the two groups. AD patients and NC participants did not differ significantly with regard to age, $F(1, 30) = 0.34, p = .56$, or education, $F(1, 26) = 1.10, p = .30$. Because of possible ceiling effects in the NC participants, the existence of group differences in the neuropsychological measures was evaluated with the Mann-Whitney U statistic. The mean rank of 6 in the AD patients' MMSE was significantly different from the mean rank of 17 in the NC participants' MMSE ($U = 3.0, p < .05$). The mean rank of 8 for the AD patients' percentage of successfully named items in the CERAD battery was also significantly different from the

mean rank of 14 for the NC participants ($U = 20.0, p < .05$). These findings indicate that the AD patients were impaired, in relation to the NC participants, in overall cognitive functioning and in naming ability.

For each participant, the median response latency for correctly read targets was calculated as a function of condition. Occasionally, participants "lost set" and did not respond to the target. When this occurred, participants were encouraged to respond in order to trigger the next experimental trial, but that trial was eliminated from the data analysis. Trials of this type were defined as response times greater than two standard deviations above the median for each condition. This procedure resulted in the elimination of approximately 2 trials per participant (mean of 1.4 for NC participants and 1.6 for AD patients). Additional trials were lost because of equipment failure and were also removed from the data before analyses were performed. Equipment failure resulted in the loss of 10 trials for the AD patients and of 8 trials for NC participants.

Because the primary purpose of this study was to determine how distracting information affects semantic processing in AD, it was necessary to assure that the participants did attend to the prime display. Thus, we assumed that if participants displayed normal facilitation in the attended repetition condition in relation to the unrelated condition (baseline), they were attending to the prime display. In fact, upon examination of each participant's priming pattern, it was revealed that some participants did not show a normal facilitory pattern for attended primes in relation to the baseline. This occurred in 3 NC participants and in 2 AD patients (the AD patients are identified in Table 1 with a superscript). Their data were thus removed from all further analyses. Elimination of these 5 participants did not change the demographic and clinical makeup of the groups.

Accuracy

NC participants made a total of two errors (one error occurred in the attended repetition condition, and one error occurred in the unrelated condition). AD patients made a total of nine errors (four in the attended repetition condition and five in the unrelated condition). Given that the number of errors was negligible, formal statistical analyses were not performed.

Response Latency

A repeated measures analysis of variance (ANOVA) was conducted on median response latencies that included group as a between-subjects factor and prime condition as a within-subjects factor. This ANOVA revealed a main effect of group, $F(1, 29) = 18.4, p < .01$, indicating that, not surprisingly, AD patients responded significantly more slowly overall ($M = 1009$ ms, $SD = 348$) than did the NC participants ($M = 651$, $SD = 112$).

A main effect of prime condition was also revealed, $F(2, 58) = 14.3, p < .01$, indicating that response latencies to name targets were significantly affected by the pictures in the prime display. Response latencies in the attended repetition condition were the fastest ($M = 739$ ms, $SD = 256$), followed

by latencies in the unattended repetition condition ($M = 780$ ms, $SD = 256$), followed by latencies in the unrelated condition ($M = 818$ ms, $SD = 333$). Mean comparisons of this effect indicated that response latencies were significantly faster in the attended repetition condition than in the unrelated condition, $F(1, 58) = 28.4, p < .01$, suggesting that attending to the selected picture facilitated reading of the target (not surprising given that this was the inclusion criterion). A second contrast showed that response latencies were also significantly faster in the unattended repetition condition than in the unrelated condition, $F(1, 58) = 8.815, p < .01$, indicating that responses were facilitated overall even when participants were specifically instructed to ignore the prime. A third contrast indicated that response latencies were significantly faster in the attended repetition condition than in the unattended repetition condition, $F(1, 58) = 5.567, p < .05$, suggesting that naming latencies for targets that were attended in the prime display were significantly faster than for those that were unattended in the prime display.

The above pattern of results was qualified by the presence of a significant two-way interaction between group and prime type, $F(2, 58) = 3.079, p < .05$. As is indicated in Table 2, there was significant facilitation in the AD patients in both the attended repetition condition, $F(1, 58) = 20, p < .01$, and the unattended repetition condition, $F(1, 58) = 10.9, p < .01$, in comparison with the unrelated condition. The contrast between the attended repetition condition and the unattended repetition condition was not significant, $F(1, 58) = 1.4$. The NC participants showed a similar pattern of facilitation for the attended repetition condition in comparison with the unrelated condition, $F(1, 58) = 8.4, p < .01$. Unlike that with the AD patients, however, the contrast between the unattended repetition condition and the unrelated condition was not significant, $F(1, 58) = 0.28$. Also unlike that with the AD patients, the comparison between the attended repetition condition and the unattended repetition condition was significant, $F(1, 58) = 5.6, p < .05$, revealing that response latencies for targets that were attended in the prime display were faster than for targets that were ignored in the prime display.

It has frequently been noted that the magnitude of priming effects may be related to the overall speed of participants' baseline response times (RTs), the absolute magnitude of effects being larger in participants with slower RTs (see Ober & Shenaut, 1994, for a review). Therefore, these data were also subjected to an analysis of covariance to estimate the impact of cognitive slowing on the performance of patients. To estimate slowing, we used the mean of each participant's median RT across attended, unattended, and unrelated trials. The covari-

Table 2
Means and Standard Deviations of Median Response Latencies for AD Patients and NC Participants as Function of Prime Condition

Participant	Attended		Unattended		Unrelated	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
AD patients	959	311	990	303	1,078	438
NC participants	617	94	664	124	674	114

Note. AD = Alzheimer's disease; NC = normal control.

ate was significant ($p < .001$), and the main effect of group that was present in the above analysis was not significant, $F(2, 28) = 0.25$. However, the main effect of condition, $F(2, 58) = 14.26$, $p < .001$, as well as the interaction between group and condition, $F(2, 58) = 3.08$, $p = .05$, remained significant. The overall effect of slowing, then, did not influence the pattern of RT data in the critical comparison conditions.

Effect Sizes

A series of one-sample t tests was performed on three normalized difference ratios to examine specifically whether the magnitude of the differences between attentional conditions and baseline were significantly greater than zero. In order to normalize the difference score, we formed a number of ratios by using the unrelated condition as a common denominator. Normalized scores were calculated for attended prime facilitation, unattended prime facilitation, and attention and are displayed in Figure 2 as a function of group. These scores were calculated as follows:

attended prime facilitation

$$= \frac{(\text{unrelated} - \text{attended repetition})}{\text{unrelated}}$$

unattended prime facilitation

$$= \frac{(\text{unrelated} - \text{unattended repetition})}{\text{unrelated}}$$

and

$$\text{attention} = \frac{(\text{unattended repetition} - \text{attended repetition})}{\text{unrelated}}$$

For AD participants, attended prime facilitation, $t(10) = 3.51$, $p = .01$, and unattended prime facilitation, $t(10) = 2.32$, $p < .05$, were significant, and attention, $t(10) = 2.15$, $p = .06$, was marginally significant. These results indicate that there was significant facilitation of targets from attended and unattended primes. The attention measure indicated that targets from attended primes were facilitated to a greater degree than were targets from unattended primes, albeit only marginally.

The same series of t tests was performed on the three normalized ratios for the NC participants. This revealed significant attended prime facilitation, $t(19) = 6.82$, $p < .01$, and attention, $t(19) = 3.69$, $p < .01$, but no unattended prime facilitation, $t(9) = -0.69$. These results indicate that there was significant facilitation of targets from attended primes. Pictures that were unattended in the prime display did not influence the speed of target word reading; response latencies to targets preceded by unattended primes were similar to the unrelated baseline. This explains the significant attention measure, in that targets preceded by attended primes were responded to more quickly than were targets that were preceded by unattended primes.

It has also been noted that AD patients with poor naming ability may actually show larger than normal priming effects

(Chertkow et al., 1989). In the current study AD patients did differ significantly from controls in their naming ability but did not differ in the magnitude of priming in the attended condition, though there was some evidence that they showed larger than normal priming effects in the unattended condition. However, none of these effects were significantly correlated to naming ability (attended prime facilitation with naming, $r = -.15$, $p > .60$; unattended prime facilitation with naming, $r = -.07$, $p > .80$). In addition, patients were divided into two groups depending on whether their naming was above or below the median naming ability of all patients. ANOVAs revealed no difference between good namers and poor namers for attended prime facilitation ($p > .3$) and unattended prime facilitation ($p > .9$).

Finally, 3 one-way ANOVAs were performed on each of these effects to determine whether group differences existed. The magnitude of the effects was not found to differ significantly across group ($ps > .05$). This finding is somewhat surprising given the difference in the pattern of effects reported above, where one might expect to find a significant difference in the unattended prime facilitation measure (recall that AD patients' response latencies were significantly facilitated by unattended primes, whereas NC participants were not influenced by unattended primes).

Discussion

The primary finding of this study was that unattended semantic information present in a two-stimulus prime display affected response latencies differently in AD patients and NC participants. Specifically, NC participants' response latencies to ignored pictures did not differ from their response latencies for the unrelated baseline condition. In contrast, AD patients' response latencies were facilitated by information in the prime display that they were instructed to ignore in relation to an unrelated baseline condition. Both groups demonstrated signifi-

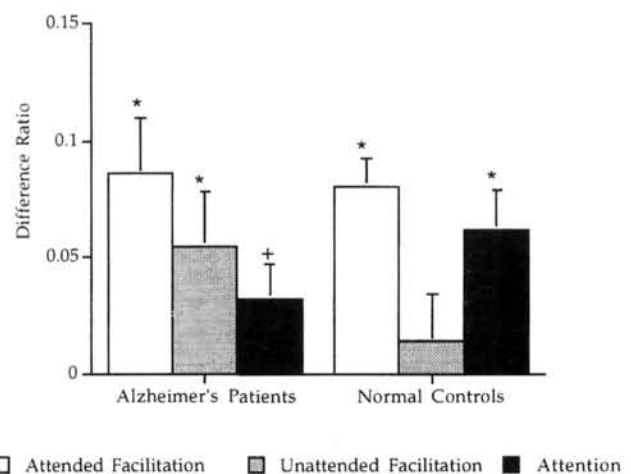


Figure 2. Difference ratios depicting the magnitude of the priming effects and standard error of Alzheimer's disease patients and normal control participants. Asterisks indicate that the difference ratio was significantly greater than zero ($p < .05$), and the cross indicates that the difference ratio was marginally greater than zero ($p = .06$).

cant facilitation from attended primes in comparison with the unrelated baseline. This pattern of data was evident in the RT measure, as well as when the data were viewed in terms of difference ratios. Although the magnitude of facilitation from the unattended prime did not differ between the AD and NC participants, an examination of Figure 2 suggests that this finding does not undermine the primary pattern of results summarized above.¹ Interestingly, as a result of this deficit, AD patients show evidence of semantic processing under circumstances in which NC participants do not.

We propose four accounts of the data; two suggest that initiation of selection processes did not occur for the AD patients, while the remaining two postulate that AD patients were accurate in their initial selection of the prime and that deficits occurred following selection. One possibility is that NC participants were able to use the advanced cue information (i.e., color) to effectively engage in selective attentional processing, which led to selection of task-relevant information in the prime display. This effectively limited the level of processing achieved by unattended information. In contrast, it is possible that the color cue was ineffective in the AD patients in evoking selective attention mechanisms. Consequently, they selected both pictures in the prime display, which subsequently facilitated processing of the target items for both the attended repetition and the unattended repetition conditions. This possibility is not supported by the Sullivan et al. (1995) study, however, as they found that AD patients could select on the basis of color.

A second possibility is that AD patients are slower to evoke or initiate selective attention mechanisms, and as a result AD patients were disadvantaged by the severe time constraints of our study. Recall that the prime displays were present for only 200 ms, followed by a 400-ms ISI. The total 600-ms SOA is considerably less than that in any previous study investigating the mechanism of selection in AD. For example, Nebes and Brady (1989) allowed their participants 5 s to select a target from among a display of distracting letters. Similarly, Foldi et al. (1992) allowed their participants unlimited time to locate targets in a cancellation task. In the Sullivan et al. (1995) study, the prime was presented for 250 ms, but then participants were allowed unlimited time to name the attended picture in the prime display prior to target onset. Using their baseline condition to estimate the amount of time the AD participants needed to name a picture, Sullivan et al. added an average of 780 ms to the 250-ms ISI. Thus it is clear that the timing parameters of the present study were more demanding than were those of previous investigations. It is possible that given sufficient time, AD patients will evoke the mechanism of selection on the basis of a precue, but the fast-paced conditions of the present study may have precluded AD patients' ability to allocate resources for selective mechanisms to operate. Please note that this account differs from one of general cognitive slowing (which we addressed in the Results section) in that we are proposing that the strict time demands of the current study did not even permit the initiation of selective attentional mechanisms.

Spotlight theories of selection offer a third possibility that can account for facilitation of both attended and unattended primes in our AD patients. This class of theories suggests that

attention is not distributed uniformly across the visual fields but is highly focused on a relatively small, restricted part of the visual array (e.g., Treisman & Gelade, 1980). In this way, spatial attention is thought of as a beam or spotlight that is independent of eye fixations and, importantly for the current discussion, can vary in size and shape (Eriksen, 1990; Eriksen & Murphy, 1987; Eriksen & St. James, 1986; Shulman, Sheehy, & Wilson, 1986; Shulman & Wilson, 1987). One important determinant for the size of the spotlight is the amount of time participants have to focus or constrain the beam. Consequently, given the limited amount of time that participants were allowed to view the prime display, AD patients may not have had sufficient time to "zoom" their covert attentional spotlight on the precued picture; in this way, both prime pictures fell within the AD patients' spotlight. For NC participants, however, the time constraints were not sufficient to impair their ability to narrow their scope of attention.

A final explanation may be derived by considering the semantic processing that normally occurs for unattended visually presented information. It is now well established that semantic information is activated even when participants are presented with words or pictures that they have not attended to and cannot report (e.g., Marcel, 1983; McGlinchey-Berroth, Milberg, Verfaellie, Alexander, & Kilduff, 1993; Merikle & Reingold, 1990; Tipper & Cranston, 1985; Tipper & Driver, 1988). In our task it appears that with selective attention instructions, NC participants were able to minimize the potential interfering effect of this automatically activated information. This may have been achieved either through increasing the processing resources allocated to the selected item or through partial inhibition of the unselected item (Houghton & Tipper, 1994). In contrast to NC participants, AD patients possibly could not minimize the effect of automatically activated information, and the activation achieved by unattended primes resulted in crosstalk between attended and unattended channels. This crosstalk could occur even though patients may have initially directed their attention accurately. According to this scenario, some time after the presentation of the prime but before the participant responded to the target, selected and unselected semantic information became activated to a similar degree and were available to influence target processing.

Activation of selected and unselected semantic information might occur for at least two reasons. First, if the peak activation level of all semantic information was higher than normal in AD patients (McGlinchey-Berroth, Milberg, & Grande, 1995), then the likelihood increases that irrelevant semantic activation will rise above some criterion level or threshold sufficient to influence processing of the target. Increasing gain or overall level of signal to noise is a frequent cause of interference or crosstalk in many information systems

¹ Notice that although the difference in response latency for targets preceded by unattended primes in comparison with unrelated primes did not differ reliably from zero in the NC participants, the direction of error was such that response latencies for targets preceded by unattended primes were slightly faster than these for targets preceded by unrelated primes. Thus the absolute difference between the two conditions was minimized.

(e.g., computer lines, electronic amplifiers, and tape recorders). It is quite possible that a cholinergic deficit, observed in AD patients, may result in analogous increases in neural activation levels (Hasselmo, 1994; Hasselmo & Bower, 1993). It is critical to point out that increasing the overall activation level or gain of semantic information may produce such crosstalk even if selective attentional processes are intact.

A second reason for the increased likelihood of crosstalk between selected and unselected sources of semantic information may be that AD participants are impaired in processes that follow the initial selection of items. DeSchepper and Treisman (1996) noted that participants maintain representations of selected and unselected information that are bound with a separate representation of the action associated with it (i.e., that it was selected or unselected). They reported that participants may lose access to this latter representation or "action tag" without losing access to the representations of the stimuli per se. It is possible, therefore, that AD patients do not form, bind, or maintain a representation of the initial act of selection long enough to differentially affect performance of the target even though their selection action was initially successful.

The identification of the precise mechanism responsible for the observed impairment awaits further experimentation; however, this study clearly demonstrates that AD patients' deficits in selective attention greatly impact the nature of their semantic information processing. Thus, as Posner (1980) suggested, it is reasonable to assume that the mechanisms and component processes utilized in orienting and attending to external stimuli can similarly be involved in orienting within the semantic memory system. The inability of patients to ignore distracting information that was demonstrated in this study, in conjunction with impairments in the ability to disengage and shift attentional resources demonstrated by Parasuraman et al. (1992), can be used to explain some common errors made by AD patients. On tasks such as confrontation naming, AD patients commonly generate items that are semantically related to the desired item (Bayles & Boone, 1982; Hodges, Salmon, & Butters, 1990). For example, when attempting to name a bench, an AD patient might respond with associated items of higher frequency or saliency such as *furniture, sofa, seat, or chair*. In the current framework, these errors could be explained by AD patients' intact ability to exhaustively activate all relevant associates in semantic memory and their concurrent inability to ignore competing representations, in this case items of higher frequency or saliency in semantic memory. In normal participants, these competing representations, although perhaps reaching a relatively higher level of activation, may not lead to errors because participants can quickly disengage from the incorrect associate and shift to another associate. This scenario leaves open the possibility that AD patients may be aware that they have produced an error but cannot correct themselves because of difficulty in releasing from the incorrect associate. This may be more obviously seen in the high rate of perseverations in these patients (see Lezak, 1995).

These same constructs may be useful in explaining the decreased performance on verbal fluency tasks by patients with AD (Chertkow & Bub, 1990; Martin & Fedio, 1983; Ober et

al., 1986). Consider that when given a category name, normal participants activate a cohort of semantic associates and select each item in turn to correctly determine its inclusion or exclusion in the desired category. Like NC participants, AD patients also activate a semantic cohort, but unlike normal participants, they cannot flexibly shift their focus within the cohort to produce unique associates.

This account implies that if given enough time, patients may be able to disengage and shift attention between semantic associates until a correct associate is engaged. However, activation levels of semantic representations peak and are available for only a brief period of time before they decay. Thus, functionally allowing patients more time may still not allow for normal performance. In fact, we have recently reported that activation of semantic representations may reach asymptotic levels faster with a subsequently more rapid decay in AD (McGlinchey-Berroth et al., 1995). Consequently, providing AD patients with more time to shift attention would likely not produce a more normal pattern of performance.

In conclusion, a deficit in selective attention can be used to account for decreased performance on some language tasks in patients diagnosed with AD. This, of course, is not intended to suggest that patients with AD do not have a primary deficit in language function or that a deficit in selective attention can be used solely to account for such deficits. Rather, we suggest that impairments in attention may interact with language function to produce symptoms that are more far reaching than might be speculated on the sole basis of an impairment in language function. As has been demonstrated, it is indeed critical in the study of cognitive deficits in AD to consider that deficits in one cognitive domain may likely result from a conjunction of deficits in multiple cognitive systems.

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