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Inhibitory Control during Sentence Comprehension in Individuals with Dementia of the Alzheimer Type

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Abstract

In two experiments we investigated the extent to which individuals with dementia of the Alzheimer type (OAT) manage the activation of contextually appropriate and inappropriate meanings of ambiguous words during sentence comprehension. OAT individuals and healthy older individuals read sentences that ended in ambiguous words and then determined if a test word fit the overall meaning of the sentence. Analysis of response latencies indicated that OAT individuals were less efficient than healthy older individuals at suppressing inappropriate meanings of ambiguous words not implied by sentence context, but enhanced appropriate meanings to the same extent, if not more, than healthy older adults. DAT individuals were also more likely to allow inappropriate information to actually drive responses (i.e., increased intrusion errors). Overall, the results are consistent with a growing number of studies demonstrating impairments in inhibitory control, with relative preservation offacilitatory processes, in DAT.

A decline in the ability of individuals with senile dementia of the Alzheimer type (DAT) to comprehend written and spoken language is one of severallanguage deficits documented in studies of language ability (e.g., Murdoch, Chenery, Wilks, & Boyle, 1987; Appell, Kertesz, & Fisman, 1982). While word naming abilities are relatively well preserved during the early stages of DAT, reading comprehension declines with dementia severity (Cummings, Houlihan, & Hill, 1986). The decline of language comprehension in DAT may be, in part, due to a disruption of retrieval from semantic memory (e.g., Nebes, Boller, & Holland, 1986; Nebes, Brady, & Huff, 1989) or to a degradation of the representations of concepts

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and words in semantic memory (e.g., Martin & Fedio, 1983; Chertkow, Bub, & Seidenberg, 1989; Gewirth &Shindler, 1984; Flicker,Ferris, Crook,&Bartus, 1987), or possibly, both (see Nebes, 1989, for a recent review). However, evidence is accumulating to suggest that individuals in the early stages of DAT also suffer from a loss in the efficiency of cognitive mechanisms responsible for the management of the activation of or accessibility to information on-line during comprehension. For example, Morris and Baddeley (1988; see also Helkala, Laulumaa, Soininen, & Riekkinen, 1989) argued that the memory impairment found in early DAT may in part be due to a deficit in working memory. More specifically, Morris and Baddeley argued that the Central Executive portion of working memory (Baddeley and Hitch, 1974) is "responsible for initiating and modulating the different mental processes associated with working memory and has a high degree of complexity which might make it especially vulnerable to the effects of dementia" (Morris & Baddeley, 1988, p. 284).

Several models of language comprehension have stressed the importance of the ability to manage information on-line during the comprehension process (e.g., Gernsbacher, 1990, 1991; Carpenter & Just, 1988; Hasher & Zacks, 1988; Kintsch, 1988). Gernsbacher (1990) has proposed that facilitatory and inhibitory mechanisms (enhancement and suppression, respectively) modulate the activation of information and that these mechanisms underlie the component processes involved in language comprehension. Individual differences in the efficiency of suppression mechanisms have been shown to underlie individual differences in comprehension skill among young adults (Gernsbacher, 1990; Gernsbacher & Faust, 1991b). Specifically, poorer comprehenders are less efficient than better comprehenders at suppressing contextually inappropriate information but are as able, if not more so, to effectively use context as a basis for enhancing appropriate information.

Similarly, Hasher and Zacks, and their colleagues have proposed that a decline in inhibitory processes with a relative preservation of facilitatory processes occurs during normal aging (1988; Connelly, Hasher, & Zacks, 1991; Hamm & Hasher, 1992; Hartman & Hasher, 1991; Hasher, Stoltzfus, Zacks, & Rypma, 1991; Stoltzfus, Hasher, Zacks, Ulivi, & Goldstein, 1993). They have argued that inhibitory processes play two important roles in language comprehension: (a) keeping inappropriate information from entering working memory and (b) deactivating inappropriate and no-longer-needed information that does become active in working memory. From this perspective, as inappropriate information becomes more activated it interferes with the processing of appropriate information and, in the extreme, can act to redirect the line of thought away from the intended goal path.

There is a growing body of work suggesting that a selective breakdown in inhibitory control may also play an important role in the cognitive changes during the early stages of DAT. Studies of intrusion and perseverative errors (e.g., Butters, Granholm, Salmon, Grant, & Wolfe, 1987; Shindler, Caplan, & Hier, 1984), of selective attention (e.g., Spieler, Balota, & Faust, 1994; Sullivan, Faust, & Balota, 1994), and of word reading (e.g., Balota & Duchek, 1991; Balota & Ferraro, 1993; Patterson, Grahm, & Hodges, 1994) have demonstrated that DAT individuals not only suffer from breakdowns in inhibitory processes responsible for deactivating partially active task irrelevant information, as assessed by correct response latencies, but that they also suffer from a marked increase in the likelihood that task irrelevant information will interfere with information processing to the point that it is allowed to actually drive a response (i.e., an intrusion error). It is unclear at this point if this increased tendency to produce intrusion errors reflects breakdowns in inhibitory control among DAT individuals that is different in kind from the breakdowns indicated by analyses of correct response latencies, or simply reflects breakdowns that differ in their extent. However, because DAT seems to result in a decreased ability to use inhibitory processes to deactivate partially active inappropriate information, and also in a decreased ability inhibit responses driven by inappropriate information, the inhibitory deficit associated with DAT can be thought of as a loss of efficiency in the control of inhibitory processes. We will use the term *inhibitory control* to emphasize the fact that the inhibitory deficit in DAT involves aspects of the control of inhibitory processes.

In the present paper we will examine the hypothesis that DAT individuals suffer from breakdowns in inhibitory control during sentence comprehension with a relative preservation of facilitatory processes. Before describing our experiments we will provide a brief review of selected studies consistent with the view that DAT individuals suffer from a selective breakdown in inhibitory control that results in both decreased use of inhibitory processes to deactivate inappropriate information and in increased intrusion errors.

FACILITATORY AND INHIBITORY PROCESSES IN DAT

Most studies have shown that the facilitation of the processing of words due to the processing of preceding words is relatively preserved in DAT (Nebes, 1989, 1992). For example, as compared to healthy older adults, DAT individuals show equivalent improvements when reactivating a previously presented word (i.e., repetition priming, e.g., Balota & Duchek, 1991; Moscovitch, Winocur,McLachlan, 1986). DAT individuals also produce normal, or even greater than normal, semantic priming effects (e.g., Balota & Duchek, 1991; Chertkow, Bub, & Seidenberg, 1989; Nebes et al., 1989). In a study designed to separate facilitatory and inhibitory semantic priming components Hartman (1991) found that while facilitatory processing of words was preserved in DAT individuals, the inhibitory component was not.

Nebes and Brady (1991) have reported results that suggest the facilitatory effects of prior sentence context upon the processing of words is relatively preserved in DAT. Nebes and Brady had participants verify whether or not a word formed a sensible completion to an incomplete sentence. They found that DAT individuals and healthy older adults showed equivalent facilitation of response latencies as the extent to which the context of the incomplete sentences constrained possible endings was increased.

In contrast with findings of normal facilitatory processes in DAT, there are a growing number of studies in several distinct areas suggesting that inhibitory processes may be impaired in DAT. For example, most researchers have found substantial increases in perseverative errors in DAT individuals (e.g., Butters et al. 1987; Fuld, Katzman, Davies, & Terry, 1982; Helkala et al., 1989; Jacobs, Troster, Butters, Salmon, & Cermak, 1990; Loewenstein, D'Elia, Guterman, Eisdorfer, Wilkie, LaRue, Mintzer, & Duara, 1991; Shindler et al., 1984; Troster, Salmon, McCullough, & Butters, 1989). Fuld et al. (1982)

administered a wide range of neuropsychological tests to a variety of patients and found that prior-item intrusions (i.e., a delayed repetition of the appropriate response to a previous item) were more prominent in DAT than in other dementias (e.g., Multiple Cerebral Infarct, Korsakoff). Both Butters et al. (1987) and Shindler et al. (1984) report that DAT individuals produced more prior-item intrusions than healthy older adults during tests of verbal fluency. In fact, Shindler et al. (1984) suggest that intrusion errors "... arise when subjects are unable to access correct responses from long-term memory and instead substitute erroneous responses selected from short-term memory." Butters et al. (1987) also reported that when asked to listen to and recall short stories, individuals with DAT were more likely than controls, or even equivalently demented individuals with Huntington's disease, to produce prior-story intrusions (i.e., ideas from a previously presented story). Sandson and Albert (1987) reviewed the literature on perseverative errors and have proposed that the prominent increases in these errors in DAT are due to an inability to inhibit information inappropriate to the task at hand.

A study by Balota and Duchek (1991) provides evidence of a selective breakdown in inhibitory processes in DAT during lexical processing. In this study naming latency for the third of three sequentially presented words was recorded. Healthy older adults produced equivalent naming latencies for the Discordant condition (e.g., KIDNEY–ORGAN–PIANO) and for the Unrelated condition (e.g., KIDNEY–CEILING–PIANO), thereby indicating that the first word (e.g., KIDNEY) constrained the interpretation of the ambiguous second word (e.g., ORGAN) such that it no longer primed the third word (e.g., PIANO), which was related to the contextually inappropriate sense of the ambiguous word. On the other hand, DAT individuals were faster to name the third word (e.g., PIANO) in the Discordant condition than in the Unrelated condition, indicating that the contextually inappropriate interpretation of the second word (i.e., organ as a musical instrument) was not deactivated as it had been for the healthy older adults.

Several studies have demonstrated that the breakdown in inhibitory processing in DAT individuals may be seen not only as a breakdown in the time taken to reach a correct response in the face of partially activated inappropriate information, but may also manifest itself in an increased likelihood that inappropriate information will actually drive the response (i.e., an intrusion error). For instance, Sullivan et al. (1994) found a negative priming effect (i.e., a slowing to respond to a current target item due to the fact that it was a distractor in the preceding display, Tipper & Driver, 1988) for healthy older adults, but not for DAT individuals. However, there were little or no group differences in intrusion errors in this study. In contrast, Balota and Ferraro (1993; see also Patterson et al., 1994) found that DAT individuals produced more regularizations (i.e., a mispronunciation in accordance with spelling-to-sound rules, e.g., pronouncing PINT such that it rhymes with HINT) during word naming. Furthermore, the regularization effect increased with dementia severity. The increase in regularization errors indicates an increased probability that inappropriate information (in this case spelling-to-sound rules) will actually drive the pronunciation response. However, there were no group differences in the effects of exception words such as *pint* on response latencies.

Similarly, Spieler et al. (1994) found that DATindividuals' performance in the Stroop color naming task can be best characterized by increased reliance on inappropriate information (i.e., word identity rather than color name) to drive responses. Specifically, DAT individuals produced greater intrusion errors (i.e., naming the word when word and color are in conflict, e.g., RED written in blue), but when overall speed of responding was controlled for, DAT individuals were not slowed by conflicting word identity (i.e., Stroop interference) any more than healthy older adults. DAT individuals were, however, disproportionately faster to name the color of words when the color name and word identity matched (e.g., the word RED written in red) in comparison to a control condition where there was no relationship between word identity and color name (e.g., the word BAD written in red). Thus, DAT individuals differed from healthy older adults predominantly in the extent to which inappropriate information was allowed to drive responses.

SUMMARY

Current models of language comprehension have stressed the importance of on-line management of the activation of information (e.g., Gernsbacher, 1990, 1991; Carpenter & Just, 1988; Hasher & Zacks, 1988; Kintsch, 1988). Gernsbacher and Faust (1991a, 1991b) have argued that inhibition or suppression of inappropriate information is an important marker of comprehension skill among healthy younger adults. Similarly, Hasher and Zacks (1988) have proposed that breakdowns in the ability to suppress inappropriate information account for changes in comprehension processes with normal aging.

Given the prediction that suppression of inappropriate information is an important aspect of language comprehension (e.g., Gernsbacher, 1991; Hasher & Zacks, 1988), the obvious breakdowns in comprehension with DAT (e.g., Appell et al., 1982; Murdoch et al., 1987), and the growing number of studies demonstrating a selective impairment in inhibitory control in DAT (e.g., Balota & Duchek, 1991; Balota & Ferraro, 1993; Butters et al., 1987; Chertkow et al., 1989; Shindler et al., 1984; Helkala et al., 1989; Nebes, 1989; Spieler et al., 1994; Sullivan et al., 1994), the present paper will examine the hypothesis that DAT results in a selective breakdown in inhibitory control during sentence comprehension. Specifically, we will show that DAT individuals experience both a greater slowing in processing due to inappropriate information and a greater tendency to allow inappropriate information to drive responses than do healthy older adults. We will also show that these effects are not attributable to an inability on the part DAT individuals to appreciate context, by demonstrating that they can use contexts with strong biases to facilitate comprehension processing.

EXPERIMENT I

A major challenge to text comprehension comes from the widespread lexical ambiguities present in language. Many words have multiple associations (e.g., *apple* is associated with picking fruit from a tree, or baking a pie), and many words are ambiguous in that they have multiple distinct meanings (e.g., *spade* can be a digging tool or a playing card suit). Thus, it is likely that during reading, information that is inappropriate given the preceding context may become active and interfere with comprehension. In this case, comprehension skill

(Gernsbacher, 1990, 1991; Gernsbacher & Faust, 1991a, b) will depend upon efficient inhibition of contextually inappropriate information.

To test the hypothesis that DAT individuals suffer from a breakdown suppression mechanisms we used a paradigm developed by Gernsbacher, Varner, and Faust (1990, Experiment 4; see Table 1). In this task, participants read a sentence (e.g., She liked the rose) and then received a test word (e.g., FLOWER). Their task was to verify whether or not the test word matched the overall meaning of the sentence (i.e., context verification). On half of the trials the test word did not match the meaning of the sentence. On half of those trials, the last word of the sentence was an ambiguous word (e.g., He dug with the *spade*). The test word on those trials was related to one meaning of the ambiguous word; however, it was not the meaning implied by the sentence (e.g., ACE).

The slower participants were to reject the test words (e.g., ACE) following sentences containing a sentence-final ambiguous word (e.g., He dug with the *spade*), in relation their speed to reject test words following sentences containing an unrelated sentence-final word (e.g., He dug with the *shovel*), the more active the inappropriate senses of the sentence-final ambiguous words must have been. Thus, the difference in response latencies in these two conditions provides a measure of how much the inappropriate senses of the sentence-final ambiguous words interfered with comprehension processes.

Method

Subjects—A total of 19 DAT individuals and 16 healthy older adults participated. Eleven OAT individuals were recruited from the Alzheimer's Assessment Clinic at Good Samaritan Hospital and Medical Center (Portland, OR). An additional 8 DAT individuals were recruited from the Washington University Medical School Alzheimer's Disease Research Center (ADRC, St. Louis MO). OAT individuals were screened for depression, severe hypertension, reversible dementias, Parkinson's disease, and any other disorder that could affect cognitive performance. lnclusionary and exclusionary criteria for OAT conform to those outlined by the National Institute of Neurological and Communicative Disorders and Stroke/Alzheimer's Disease and Related Disorders Association (NINCDS-ADRDA) Work Group (McKhann et al., 1984). In all cases, the diagnosis of OAT was performed by a board certified physician, and in the case of DAT individuals from the Washington University ADRC, a second physician confirmed the diagnosis after a review of a video tape of the clinical assessment. The 16 healthy older adults had no prior history of alcohol abuse, neurological problems, or significant health problems and were recruited from the Portland community.

Only those DAT individuals scoring less than 25 on the MMSE and successfully completing another study requiring relative preservation of word naming abilities were tested with the present task. Two DAT individuals were unable to perform the task and did not complete the study. Data from an additional three DAT individuals was removed due to an overall error rate above our predetermined rate of 30%. All healthy older adults completed the task and met the error rate criterion.

The healthy older adults had a mean age of 70.4 years (*SD* = 7.8) and a mean education of 14.5 years (*SD* = 2.2), while the DAT group had a mean age of 72.9 years (*SD* = 8.5) and a mean education of 14.7 years (*SD* = 2.5). The two groups did not differ significantly on either mean age or education. The Mini Mental Exam Scores for the DAT individuals ranged from 18 to 24, indicating mild to moderate dementia levels, with a mean MMSE score of 20.9 (*SD* = 2.0) that was significantly lower than the mean for the healthy older adults (29.5, *SD* = .9; $F(l, 28) = 237.65$, $p < .001$). In addition to the MMSE, dementia severity for each DAT individual recruited from the Washington University ADRC was staged in accordance with the Washington University Clinical Dementia Rating (CDR) scale (Morris, 1993). According to this scale, a score of 0 indicates no dementia; a score of .5 indicates very mild, or "Questionable," dementia; a score of 1 indicates "Mild" dementia; and a score of 2 indicates "Moderate" dementia. All of these OAT individuals had CDR scores of 1.0, except one person who had a CDR score of 2.0.

Materials and design—The materials employed were identical to those of Gernsbacher et al (1990, Experiment4; see Table 1). Eighty ambiguous words with two meanings of relatively equal frequency were each matched with two sentences which differed only in their final word. In one sentence, the final word was an ambiguous word (e.g., "He dug with the *spade*"); in the other sentence, the final word was a different, unambiguous word that was semantically comparable, though not necessarily synonymous (e.g., "He dug with the *shovel*"). Finally, there was a unique test word for each of the 80 ambiguous words. Each test word represented the meaning of the ambiguous word that was *not* captured in the sentence. For example, the test word *ACE* followed the sentence, "He dug with the spade." The test words were also unrelated to the sentences when the semantically comparable, unambiguous words were the final words (e.g., the test word ACE is unrelated to the sentence. "He dug with the shovel"). All sentences were four or five words long and consisted of simple vocabulary.

There were also 80 filler sentences. These sentences were identical in structure to experimental sentences. Thirty-seven of the 80 filler trials contained ambiguous words. However, these filler sentences differed from the experimental sentences because their test words were related to the sentences' meaning. For example, the sentence "She liked the rose" was followed by the test word *FLOWER*.

Counterbalancing of our materials was accomplished by manipulating two variables. First, for each experimental sentence, half the DAT individuals and half the healthy older adults were presented with the ambiguous word as the final word of the sentence (e.g., He dug with the spade), and the other half were presented with the semantically comparable, unambiguous word as the final word (e.g., He dug with the shovel). Second, for each experimental sentence, half the participants of each group were presented with the test word after a short delay (100 msec), and half were presented with it after a long delay (1000 msec). Thus, the counterbalancing of these two variables yielded four between-subjects material sets.

Procedure—For all healthy older adults and the DAT individuals recruited from Good Samaritan Hospital stimuli were presented by an Apple lie computer on a standard color monitor with a viewing distance of 1/3 to 2/3 m. Participants responded by pressing one of two micro-switch keys with the index and middle fingers of their dominant hand to produce responses. Response latencies were timed to the nearest millisecond using a Mountain Clock internal clock. For the DAT individuals recruited from the Washington University ADRC, stimuli were presented by an IBM 386 clone computer on a standard VGA monitor. Response latencies were timed to the nearest millisecond using an assembly routine that reprogrammed an internal chip to cycle at greater than 1000 Hz. Font size, font color, and the viewing distance were the same for the two computers. The task was explained to participants verbally and an example of a "yes" and a "no" trial was presented. The facts that "this is a judgment task," and that there is "no absolute right or wrong answer," were stressed. Participants were told that "We want you to answer as quickly as you can" and that "We just want you to answer according to whether you think there is a relationship between the overall meaning of the sentence and the word based on your first impression." Participants performed eight practice trials and were then given a chance to ask questions. Participants expressing any doubt regarding their understanding of the task performed an additional eight practice trials. Overall task time was approximately 35-40 min, in which there were three short breaks.

Each trial began with a warning signal, which was a plus sign that appeared for 850 msec in the center of the screen. Then, each sentence was presented, one word at a time, in the center of the screen, with each successive word replacing the previous one. Each word's presentation duration was a function of its number of characters plus a constant. The constant was 500 msec, and the function was 100 msec per character. The interval between words was 150 msec. The presentation rate for the words contained in the sentences was based upon the reading abilities of two mildly demented DAT individuals who did not participate in the experiment. After the offset of the final word in each sentence, the test word appeared either I 00 msec later (short delay) or 1000 msec later (long delay). Each test word was capitalized and flanked by a space and two asterisks, for example: **ACE**. The test words remained on the screen until the participants responded or until 15 sec elapsed, but a response limit was set at 10 sec. No feedback was given as to correctness or response latency. The intertrial interval was 4000 msec.

Results and Discussion

The overall mean error rate, computed using both experimental (i.e., *no* responses) and filler trials (i.e., *yes* response) was .13 (*SD* = .075; range, .04 to .26) for the DAT individuals, and .04 (*SD* = .023; range, .01 to .11) for the healthy older adults. Thus, the DAT individuals were clearly able to comprehend the sentences well enough to compare effectively the overall meaning of the sentence with the test word.

Response latencies—Errors comprised 15.6 and 3.5% of experimental trials for DAT individuals and healthy older adults, respectively, and were removed from the analysis of response latencies. Then responses faster than 100 msec, or slower than 10 sec, were removed from the data, resulting in removal of 1.5% of the experimental trials for the DAT individuals and removal of less than 0.05% of the experimental trials for healthy older adults. Using the remaining correct responses, we calculated the mean and *SD* for each participant, removing outliers more extreme than 2.5 *SD*s from the mean. This procedure resulted in the removal of an additional 2.9 and 2.5% of experimental trials for DAT and healthy older individuals respectively. Thus, a total of 4.4 and 2.5% of experimental response latencies were removed as outliers for the DAT and healthy older individuals, respectively.

Table 2 presents the mean and standard deviation of participants' mean response latencies, median response latencies, and error rates for the experimental trials. DAT individuals, overall, were slower to reject test words that did not fit the overall meaning of the sentences (F(l, 28) = 34.96, p <, 001, and F(1, 28) = 32.82, $p < .001$,for means and medians, respectively). All participants were somewhat faster to reject test words following the long, rather than the short, delay; however, this difference did not reach significance (F(1,28) = 3.07, $p = .091$,and F(1,28) = 1.98, $p = .170$, for means and medians, respectively).

To assess the influence of inappropriate information, we computed an interference measure by subtracting each participant's mean (median) response latency to reject test words like *ACE* after unambiguous words (e.g., *shovel*) from their mean response latency to reject test words like *ACE* after ambiguous words (e.g., *spade*). To the extent that the contextually inappropriate meaning of the ambiguous word is active and interferes with performance on the task of context verification, we would expect the interference measure to be reliably greater than zero. Thus, the interference difference score is an estimate of the activation of the inappropriate senses of the sentence-final ambiguous words. We also computed interference scores for medians. Figure 1 displays the amount interference that the DAT and healthy older individuals experienced, collapsed across the two delay intervals, for both means and medians.

Overall, interference from inappropriate information was greater than zero (F(1, 28) = 52.90, $p < .001$, and F(l, 28) = 21.40, $p < .001$, for means and medians, respectively). As illustrated in Fig. 1, both the DAT (F(l, 13) = 32.49, $p < .001$, and F(1, 13) = 8.18, $p = .013$, for means and medians, respectively) and the healthy older individuals (F(1, 15) = 21.48, $p < .001$, F(l, 15) = 19.58, $p = .001$, for means and medians, respectively) experienced a significant amount of interference. Furthermore, there was a significant group by interference interaction for means (F(l, 28) = 9.33, $p = .005$), but not for medians (F(l, 28) = .52, $p = .476$). There was no effect of delay interval for either group, and none of the interactions containing delay interval were significant (all Fs < 1).

The results suggest that the contextually inappropriate meanings of the ambiguous words were highly active for each group, both shortly (100 msec) after reading the ambiguous words, and after a longer delay (1000 msec). Thus, there is no evidence in the response latency results that either group was able to reliably suppress the inappropriate information across delay. Finally, the DAT individuals experienced more interference overall than did the healthy older adults for mean response latency, but not median response latency. This result is consistent with the notion that DAT individuals are less efficient at suppressing contextually inappropriate meanings of ambiguous words than are healthy older individuals. However, because means are more sensitive to skewing than are medians, it appears that the decrease in suppression efficiency with DAT results mainly in a greater proportion of responses in the tail of the response latency distribution for the ambiguous word conditions (i.e., increased skewing), rather than a shift in the central tendency of the distributions.

To better evaluate the hypothesis that adding conflicting inappropriate information (i.e., by adding ambiguous words to the sentences) results in a greater proportion of responses falling in the positive tail of the distribution (i.e., greater positive skewing), we computed the skew of each individuals response latency distribution in each experimental condition using the formula based upon the differences between means and medians (Glass & Hopkins, 1984, p. 68). As the results depicted in Fig. 1 indicate, there was a group by sentence type interaction in the skew measure ($F(1, 28) = 7.86$, $p = .009$). This interaction is presented in Fig. 2. Adding conflicting inappropriate information, that is, adding sentence-final ambiguous words, resulted in significantly more skewing of the response distribution for DAT individuals ($F(1, 13) = 5.95$, $p = .030$), but a trend toward less skewing for the healthy older adults ($F(1, 15) = 1.36$, $p = .261$).

The results presented in Fig. 2 are consistent with the hypothesis that DAT individuals are less efficient at suppressing inappropriate information during sentence comprehension than are healthy older adults. The decrease in efficiency presumably causes a greater proportion of responses to fall in the positive tail of the distribution, that is, greater positive skewing, rather than a shift in the central tendencies of the distribution.

Errors—We analyzed error rates to evaluate the hypothesis that DAT results in an increased tendency to allow inappropriate information to drive responses. Overall, DAT individuals produced more errors than did healthy older adults ($F(1, 28) = 23.95$, $p < 0.001$). All participants made fewer errors after the long delay (1000 msec) than after the short (100 msec) delay ($F(1, 28) = 4.72$, $p = .038$). However, group and delay did not interact ($F(1,28) = .62$, $p = .437$).

We computed a measure of interference for errors, analogous to the one depicted in Fig. 1, by subtracting the participants' proportion of failures to reject test words like *ACE* after ambiguous words *(spade)* from the proportion of failures to reject test words like *ACE* after unambiguous words *(shovel)*. To the extent that the contextually inappropriate meaning of the ambiguous word is active, and is allowed to drive the response, we would expect that participants will fail to reject a test word like *ACE* after an ambiguous word *(spade)* more often than after an unambiguous word *(shovel)*. Note that if the error rate interference effect mirrors the reaction time interference effect described above, differences in error rates will be in opposition to a speed/accuracy tradeoff (i.e., for conditions with slower reaction times, more errors are predicted).

It should also be noted that the interference difference score for errors can be thought of as an estimate of intrusion errors due to competition from inappropriate senses of sentence-final ambiguous words corrected for overall errors. Because in the Unambiguous condition there is no relationship between the sentence-final unambiguous word and the test word, errors to reject the test word in the Unambiguous condition are not directly attributable to the activation of inappropriate information associated with the sentence-final word; they are simple processing errors. However, this is not the case in the Ambiguous condition. Here errors may be either simple processing errors or intrusion errors due to the activation of inappropriate senses of sentence-final ambiguous words. Thus, the difference in errors between these two conditions is an estimate of intrusion errors with simple processing errors removed.

The results of the error interference measures (error differential) are presented in Fig. 3. Both the DAT individuals ($F(1, 13) = 21.15$, $p < .001$) and the healthy older adults ($F(1, 15) = 3.50$, $p = .081$) experience significant interference as measured by differences in error rates. In addition, the DAT individuals experienced more interference than the healthy older individuals ($F(1, 28) = 11.65$, $p = .002$). There was no reliable main effect of delay interval, but there was a reliable interaction between delay interval and group ($F(1, 28) = 9.47$, $p = .005$). As illustrated in Fig. 3, immediately after the healthy older individuals read the ambiguous words, they experienced a significant amount of error interference ($F(1, 15) = 8.41$, $p < .01$). This suggests that at the short delay (100 msec), the inappropriate meanings were highly activated. However, after the 1000-msec-long delay, the healthy older individuals were no longer experiencing a reliable amount of error interference ($F(1, 15) = 1.45$, $p > .25$). This suggests that the inappropriate meanings had become considerably less activated. The OAT individuals also experienced a significant amount of error interference at the short delay ($F(1, 13) = 10.18$, $p < .01$). However, unlike the healthy older individuals, the OAT individuals experienced even more error interference after the long delay ($F(1, 13) = 5.64$, $p = .034$).

Thus, the error rate results are consistent with the view that DAT results in an increased probability that inappropriate information that is in conflict with appropriate information will drive responses (i.e., increased intrusion errors). An inspection of Fig. 3 shows that this increase is quite dramatic in our data. Furthermore, intrusion errors increase over time for the DAT individuals, but decrease for the healthy older adults.

The results of Experiment 1 suggest that DAT individuals are less efficient than healthy older individuals at suppressing contextually inappropriate meanings of ambiguous words. They experience greater interference from contextually inappropriate meanings, in both reaction times and in error rates, than do healthy older individuals. While the reaction time interference measure did not vary over time for either group, the error rate results suggest that the healthy older individuals were able to suppress the contextually inappropriate meanings over time, while the DAT individuals allowed inappropriate information increasingly to drive responses as the delay interval increased. Furthermore, while both DAT individuals and healthy older adults produced equivalent interference from inappropriate information when shifts in the central tendency of latency distributions were emphasized (i.e., medians), conflicting inappropriate information resulted in a skewing effect in the latency distributions for DAT, but not healthy older individuals. These results are what would be expected if DAT individuals experience a loss in the reliability or efficiency of inhibitory processes rather than a general decrement in inhibitory capacity. A general decrement in inhibitory capacity would predict greater shifts in the central tendency of latency distributions with DAT, which was not the case. What we did find was an increase in the proportion of relatively long response latencies due to the addition of potentially conflicting inappropriate information, indicating a more probabilistic breakdown in inhibition with DAT.

EXPERIMENT 2

It is possible that the greater overall reaction time and error rate interference experienced by the DAT individuals in Experiment 1 was due to a decreased ability to comprehend context per se. If DAT individuals were unable to represent effectively sentential context, then one might expect that they would suffer greater interference from contextually inappropriate meanings of ambiguous words because of their inability to use poorly represented context as a basis for discriminating between appropriate and inappropriate meanings. Previous studies have suggested that DAT individuals do have a decreased ability to use context to disambiguate words (Balota & Duchek, 1991; Cushman & Caine, 1987; Kempler, Curtiss, & Jackson, 1987). An impoverished representation of context may have caused less suppression of inappropriate meanings for DAT individuals than for healthy older individuals who presumably can effectively use context as a basis to suppress contextually inappropriate meanings.

It is also possible that individuals with DAT may suffer from slowed word recognition processes. If this is so, then perhaps DAT individuals were still in the process of accessing meanings, both appropriate and inappropriate (Swinney, 1979), of the sentence final ambiguous words during the 900 msec between the immediate and the delayed intervals. Thus, facilitatory processes associated with word recognition may have masked what was an otherwise normal suppression mechanism. Such a scenario may well have been responsible for the observed trend toward more interference over time for the DAT individuals.

Both of the above alternatives were explored in Experiment 2. We employed the task and stimuli used by Gernsbacher and Faust (1991a, Experiment 4; see Table 1) to examine the extent to which DAT individuals could take advantage of biases in context to facilitate or enhance contextually appropriate meanings of ambiguous words. As in Experiment 1, participants read sentences and test words and then determined if the test word was related to the overall meaning of the sentence. We compared how long it took participants to confirm that a word (e.g., GARDEN) fits the overall meaning of a biased context sentence (e.g., She dug with the *spade*.) versus an unbiased context sentence (e.g., She picked up the *spade*). Gernsbacher and Faust (1991a, Experiment 4) have previously found that more- and less-skilled young adult comprehenders experienced a significant amount of facilitation, both after a short (100 msec) and a long (1000 msec) delay. In fact, neither group differed in terms of facilitation over time, and the less skilled comprehenders had a greater facilitation of response latency. Furthermore, other researchers have also found that less-skilled comprehenders benefit more from bias in sentence context than do more-skilled comprehenders (Perfetti & Roth, 1981).

It is also interesting to note at this point that the results of Experiment 2 will add converging evidence to the hypothesis that DAT results in an increased likelihood that responses will be inappropriately driven under conditions where different sources of information are in conflict. For the experimental trials in Experiment 2, context was either consistent with the same response as the relationship between the sentence-final word and test word (i.e., the *Related response*) or did not bias a response. Therefore, we did not expect to find a context bias by group interaction in Experiment 2 as we did in Experiment 1.

Method

Subjects—Eight DAT individuals and 19 healthy older adults were recruited from the Alzheimer's Assessment Clinic at Good Samaritan Hospital and Medical Center (Portland, OR). An additional 5 DAT individuals were recruited from the Washington University Medical School ADRC. All subject selection criteria were the same as in Experiment 1. All but one of the DAT individuals were able to complete the task. Two DAT individuals and 3 healthy older adults were excluded due to high overall error rates (>30%). Therefore, their data were not analyzed. Finally, one DAT individual was dropped for responding nearly twice as slow as the average OAT individual (i.e., a mean of nearly 6000 msec). Thus, data from 9 OAT individuals and 16 healthy older adults was obtained for analysis. Two of the OAT and 3 of the healthy older individuals also participated in Experiment 1. The average time between testing sessions was 7.7 months with test intervals ranging from 4 to 10.5 months.

The healthy older adults had a mean age of 65.9 years (SD = 5.3) and a mean education of 14.8 years (SD = 2.2), while the OAT group had a mean age of 70.9 years (SD = 10.1) and a mean education of 13.0 years (SD = 1.4). The two groups did not differ significantly on their mean age, but did differ in education (F(l, 23) = 4.66, p = .041). The mean Mini Mental Exam Score for the OAT individuals was 21.4 (SD = 3.28), which was significantly lower than the mean for the healthy older adults (29 .3, SD = 1.12; F(l, 16) = 46.57, p < 001). However, MMSE scores were unavailable for seven of the healthy older adults.

Materials and design—The materials employed were a subset of those employed by Gernsbacher and Faust (1991, Experiment 4; see Table 1). Sixty ambiguous words with two predominant meanings of relatively equal frequency were each matched with two sentences which differed in their verbs. In one sentence, the verb was biased toward one meaning of the ambiguous word (e.g., *He dug with the spade*); in the other sentence, the verb was neutral (e.g., *He picked up the spade*). We also selected a test word for each of the 60 ambiguous words. Each test word was related to the meaning of the ambiguous word that was implied by the biased verb. For example, the test word *GARDEN* was selected for the sentence *He dug with the spade*. The test words were also related to the sentences when the neutral verbs replaced the biased verbs (e.g., *GARDEN* is also related to *He picked up the spade*). All sentences were four to seven words long and were composed of relatively simple vocabulary.

We also constructed 60 filler sentences. These sentences were identical in structure to the experimental sentences, and the final words for all were ambiguous words. However, these filler sentences differed from the experimental sentences because their test words were unrelated to their sentences' meaning (i.e., participants should respond “no” to these test words). For example, we followed the filler sentence *She liked the rose* with the test word *STAND*.

We counterbalanced our materials by manipulating two variables. First, for each experimental sentence, half the participants were presented with the biasing verb as the final word of the sentence, and the other half were presented with the neutral verb. Second, for each experimental sentence, half the participants of each group were presented with the test word after a short delay (100 msec), and half were presented with it after a long delay (1000 msec). By counterbalancing these two variables, we created four between-subjects material sets. Participants were assigned at random to each material set.

It may appear from the examples used above, and in Table 1, that the materials used in Experiment 2 were nearly identical to those of Experiment 1. However, this was not the case, only 37 of the 120 test words (30.8%) used in Experiment l were also used in Experiment 2, and only 16 of these were experimental trials. Furthermore, only 13 of 240 sentences (5.4%) used in Experiment 2 were also used in Experiment I, and only 5 of a possible 120 (4.2%) experimental sentences were repeats. The overlap in materials was therefore minimal, and given the relatively small numbers of individuals participating in both experiments (2 of 9 DAT individuals and 3 of 16 healthy older adults) and the length of time between testing sessions (7.7 months, on average) it seems reasonable to include data from these repeat subjects.

Procedure—The procedure and apparatus were identical to those employed in Experiment 1.

Results and Discussion

Response latencies—Errors comprised 18.5 and 16.5% of the experimental trials for DAT individuals and healthy older adults, respectively, and were removed from the analysis of response latencies. Then responses faster than 100 msec, or slower than 10 sec, were removed from the data, resulting in removal of .3% of the experimental trials for the DAT individuals and removal of less than .05% of the experimental trials for healthy older adults. Using the remaining correct responses, we calculated the mean and *SD* for each participant, removing outliers more extreme than 2.5 *SD*s from the mean. This procedure resulted in the removal of an additional 2.4 and 2.9% of experimental trials for DAT and healthy older individuals respectively. Thus, a total of 2.43 and 2.9% of experimental response latencies were removed as outliers for the DAT and healthy older individuals, respectively.

Table 3 presents the mean of participants’ mean response latencies, median response latencies, and error rates for the experimental trials. Overall, DAT individuals were slower to accept test words that fit the overall meaning of the sentences ($F(1, 23) = 45.49$, $p < .001$, and $F(1, 23) = 40.35$, $p < .001$ for means and medians, respectively). All participants were somewhat faster to accept test words following the long, rather than the short delay; however, this difference did not reach significance ($F(1, 23) = 3.80$, $p = .063$, and $F(1, 23) = 3.29$, $p = .083$, for means and medians, respectively). Furthermore, none of the interactions containing the delay interval factor were significant.

To assess the facilitatory effects of context upon the processing of the appropriate senses of the sentence-final ambiguous words, we computed a facilitation measure by subtracting each participant's mean (median) response latency to accept test words (e.g., *GARDEN*) following

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sentences with biasing verbs (e.g., He *dug with* the spade) from their mean (median) latency to accept the same test words following sentences with neutral verbs (e.g., He *picked up* the spade). To the extent that the meaning of the ambiguous word biased by the preceding sentential context is active we would expect performance on the task of context verification to be facilitated. Figure 4 displays the amount of facilitation the DAT and healthy older individuals experienced at the two delay intervals.

The facilitation measure was, overall, reliably greater than zero (F(l, 23) = 60.88, p < .001, and F(1,23) = 51.37, p < .001, for means and medians, respectively), with the DAT individuals experiencing greater facilitation than the healthy older adults (F(l, 23) = 16.61, p < .001, and F(l, 23) = 10.65, p = .003, for means and medians, respectively). Neither the effect of delay interval, nor the interaction of group and delay interval, were significant (all Fs < 1.30). This suggests that the contextually appropriate meanings of the ambiguous words were highly active for each group, both after a short (100 msec) delay and after a long (1000 msec) delay.

As can be seen in Fig. 4, the mean and median response latencies produced similar facilitation estimates. Furthermore, we computed the skew of each individuals response latency distribution in each experimental condition using the formula based upon the differences between means and medians (Glass & Hopkins, 1984, p. 68). Only the effect of sentence type was significant (F(l, 23) = 5.21, p = .032), with more biased sentences producing more positive skew. More importantly, there were no differential effects of skewing across groups as there were in Experiment 1.

The results indicate a relative preservation of the ability of DAT individuals to use context to enhance, or facilitate, the processing of contextually appropriate senses of ambiguous words during comprehension. In fact, the response latency results suggest that DAT individuals benefited more from context than did healthy older adults. Note that previous studies employing virtually the same stimuli, at moderately different reading rates, with young adults have found a pattern of greater facilitation effects for less-skilled versus more-skilled comprehenders, but no increase over time in facilitation (Gernsbacher & Faust, 1991a).

Errors—The overall error rates were quite a bit higher in Experiment 2 than in Experiment 1. DAT individuals produced an overall error rate of 18.5% for Experiment 2 and 15.6% for Experiment 1, while the healthy older adults produced 16.5 and 3.5% for Experiments 1 and 2, respectively. It is of some concern that the overall error rates were as high as they were for the control group in Experiment 2. However, as a comparison of Tables 2 and 3 shows that the error rates were elevated only for the Unbiased sentences of Experiment 2. The healthy older adults produced similar error rates for the Ambiguous condition of Experiment 1 and the Biased condition of Experiment 2. This is understandable because, as an examination of Table 1 shows, both of the conditions contained sentences which strongly biased a single interpretation of the sentence-final ambiguous word. The control group yielded 5.9% errors for the Biased sentences, but yielded 27.1% errors for the Unbiased sentences. The Unbiased sentences were designed to provide little basis for disambiguation of the sentence-final ambiguous word. It is likely, then, that subjects would often choose the sense of the sentence-final ambiguous word that was *not* related to the subsequent test word. Thus, the Unbiased trials often required switching to the alternative interpretation selected against under time pressure and were simply more difficult. The elevated error rates for the healthy older adults in Experiment 2, as compared to those in Experiment 1, can therefore be readily explained by the inherent difficulty of the Unbiased condition. It is also worth noting that the DAT individuals produced the same pattern of elevated errors for the Unbiased sentences.

The question of interest in the error analysis is whether the elimination of the conflict between context and semantic relatedness would cause a reduction in the group by sentence type interaction in error rates present in Experiment 1 (see Fig. 3). Overall, DAT individuals produced only slightly more errors than did healthy older adults. However, this trend was not significant ($F(1, 23) = .12$, $p = .733$). There was also a trend for all participants to make fewer errors after the long delay (1000 msec) than after the short (100 msec) delay ($F(1, 23) = 3.78$, $p < .064$). Furthermore, delay interval did not interact with any other factor (all Fs < 1.00).

We computed a measure of facilitation for errors by subtracting each participant's proportion of failures to accept test words (e.g., *GARDEN*) following sentences with a biasing verb (e.g., He *dug with* a spade) from the proportion of failures to accept test words following sentences with neutral verbs (e.g., He *picked up* the spade). To the extent that the contextually appropriate meaning of the ambiguous word was active, we would expect more facilitation in error rates. Note that if the error rate facilitation effect mirrors the reaction time facilitation effect described above, differences in error rates will be in opposition to a speed/accuracy tradeoff (i.e., for conditions with slower reaction times, more errors are predicted).

The results of the error facilitation measure (error differential) are presented in the far right of Fig. 4. The results of the error facilitation measure differ in interesting ways from the response latency facilitation results depicted in the left and central portions of Fig. 4. While there was an overall error facilitation effect ($F(1, 23) = 95.32$, $p < .001$), there was no difference in the amount of error facilitation between the two subject groups, no time interval effect, and no interaction between group and time interval (all Fs < 1). Thus, there was no group by sentence type interaction in Experiment 2 as there was in Experiment 1. The results support the hypothesis that informational conflict results in a greater likelihood that DAT individuals' responses will be inappropriately driven in that removing such conflict resulted in a disappearance of the group by sentence type interaction in error rates.

Overall, the results of both response and error facilitation measures suggest that both DAT and healthy older individuals can exploit contextual constraints to enhance the activation of contextually appropriate meanings of ambiguous words. The response latency facilitation results are also consistent with the notion that under some conditions DAT individuals may benefit more from enhancement mechanisms than do healthy older individuals. Additionally, the relative preservation of DAT individuals' ability to use context to enhance appropriate senses of ambiguous words in Experiment 2 suggests that the breakdowns in inhibitory control observed in Experiment 1 cannot be explained by a breakdown in DAT individuals' ability to appreciate context per se.

GENERAL DISCUSSION

The results of Experiment 1 demonstrated that, as compared to healthy older adults, DAT individuals suffered from breakdowns in inhibitory control during sentence comprehension that were reflected: (a) in an increased proportion of relatively slow response latencies due to interference from contextually inappropriate information and also (b) in an increased tendency for responses to be driven by contextually inappropriate information (i.e., increased intrusion errors). The results of Experiment 2 demonstrated that the breakdowns in inhibitory control observed in Experiment 1 were not due to a decrease in the ability to appreciate context on the part of DAT individuals. Both DAT individuals and healthy older adults were clearly able to use context to enhance contextually appropriate information. In fact, in terms of response latency, DAT individuals benefited more from context than did healthy older adults. Overall, the results are consistent with breakdowns in inhibitory control in DAT during sentence comprehension, in the face of a relative preservation of facilitatory processes. We shall now tum to the interpretation of these results.

Efficiency of Inhibitory Processes

In Experiment 1, participants read sentences that ended in sentence-final ambiguous words, and the amount of interference from the activation of the contextually inappropriate senses of the sentence-final ambiguous words was probed. DAT individuals experienced more interference, as measured in mean response latencies, than did healthy older adults. The increased sensitivity of DAT individuals to interference from inappropriate information resulted in DAT individuals producing a greater proportion of slow responses when the test word was related to the contextually inappropriate sense of the sentence-final ambiguous word. Healthy older adults, on the other hand, did not produce a greater proportion of slow responses due to inappropriate information. In addition, DAT individuals' responses were driven by inappropriate information (i.e., intrusion errors) more often than were the responses of healthy older adults. These results indicate that the breakdowns in inhibitory control in DAT during sentence comprehension involve changes in the reliability or efficiency of inhibition, rather than a general breakdown in inhibition.

If DAT individuals experienced a general breakdown in inhibition, then inappropriate information should have caused a shift in the central tendency of latency distributions in comparison to a control condition. However, both healthy older adults and DAT individuals produced equivalent interference effects in median response latencies, indicating that any general breakdown in inhibition was attributable to age and not to DAT. Alternatively, if DAT individuals experienced a breakdown in the efficiency of inhibition that is not attributable to age, then inappropriate information would be expected to cause greater positive skewing for DAT individuals than for healthy older adults. Thus, the fact that we found a greater proportion of slow responses (i.e., increased positive skewing) due to inappropriate information for DAT, but not for healthy older individuals, supports the conclusion that DAT results in a decrease in inhibitory efficiency. Further support for this idea comes from the marked increase in intrusion errors for DAT individuals over healthy older adults, which are consistent with periodic severe breakdowns in inhibitory control.

Inhibition and Control

One way of understanding the reduction in suppression efficiency in DAT is to view inhibitory processes as a unitary construct. From this perspective, DAT and healthy older adults possess suppression mechanisms that are, on average, equally effective, but that are simply less reliable. An alternative approach postulates a separation of inhibitory mechanisms from control mechanisms responsible for detecting and dealing with conflicting information. By conceptually separating inhibitory mechanisms from attention-like control mechanisms, shifts in the central tendency of latency distributions are attributed to the effectiveness of suppression mechanisms, and increases in positive skew are attributed to the reliability of control mechanisms. Such a perspective gains support from the fact that inappropriate information caused an increase in the positive skew in the latency distributions of the DAT, but not the healthy older adults, while both groups showed equivalent shifts in the central tendency.

Therefore, proposing a separation of inhibitory processing into inhibitory and control components, leads to the conclusion that our results support a breakdown in the control component in DAT. Our results are also consistent with studies of working memory function in DAT which have argued for breakdowns in the Central Executive component of working memory (Morris & Baddeley, 1988; Helkala et al., 1989). Finally, DAT individuals in our study demonstrated an impaired ability to manage the activation of information on-line during sentence comprehension, a result consistent with recent theories of language comprehension (Gernsbacher, 1990, 1991; Gernsbacher & Faust, 1991; Hasher & Zacks, 1988).

Intrusion Errors and Enhancement of Inappropriate Information

At first glance it appears that the dramatic increase in intrusion errors with DAT should provide a clear distinction between normal aging and DAT. However, studies of normal aging often find increased intrusion errors (e.g., Cohen, 1988; Winthorpe & Rabbitt, 1988). Thus, the increases in intrusion errors seen the present study may reflect the pattern expected if DAT results in an acceleration of normal aging, at least in terms of inhibitory processes.

An alternative explanation of the increased intrusion errors observed in Experiment 1 comes from the notion that DAT individuals might actively enhance (i.e., further activate) inappropriate information. The error rate analysis (see Fig. 3), and to a lesser extent the mean latency analysis (see Table 2), of Experiment 1 indicated that inappropriate meanings of ambiguous words continued to become more active over time for individuals with DAT, while the opposite was true for healthy older individuals. One reason this might be the case is that DAT individuals may occasionally actively enhance contextually inappropriate information. To the extent that inappropriate information is occasionally enhanced, then inappropriate information would be expected to actually drive the response more often, leading to increased intrusion errors. Thus, the evidence for inappropriate enhancement in

DAT individuals provides a possible explanation for the increased intrusion errors in DAT individuals in Experiment 1.

Enhancement of inappropriate information provides an explanation of the increase in intrusion errors in DAT in Experiment 1 that is consistent with the results of the context verification task. While it is not clear that this explanation will work for intrusion errors due to inappropriate information across a number of tasks, the results of Spieler et al. (1994) provide converging evidence. Spieler et al. did not include a delay interval manipulation, but did find that DAT individuals' performance in the Stroop color naming task can be best characterized by increased reliance on inappropriate information (i.e., word identity rather than color name) to drive responses. DAT individuals differed from healthy older adults (a) in the extent to which inappropriate information was allowed to drive responses (i.e., increased intrusion errors) and (b) in the amount of facilitation of response latencies due to the to-be-ignored word identities. Thus, there may be a relationship in DAT between inappropriate facilitation of inappropriate information and intrusion errors.

Relative Preservation of Facilitation

The context verification task was used in Experiment 2 to estimate the activation of contextually appropriate senses of sentence-final ambiguous words. There was no sign that DAT individuals suffered from an impaired ability to enhance the activation of appropriate information. There was no difference between the groups in facilitation as estimated by errors, and DAT individuals actually experienced greater facilitation in response latency measures. Thus, the breakdowns in inhibitory control of contextually inappropriate information observed for DAT individuals (in Experiment 1) were obtained in the presence of relatively preserved facilitation of contextually appropriate information (in Experiment 2). The results of Experiment 2 demonstrated that the results of Experiment 1 are not attributable to slower comprehension processing or to an inability to use context to affect the processing of sentence-final ambiguous words.

DAT and Comprehension

As discussed in the Introduction, previous research has indicated that degradation of semantic representation (Martin & Fedio, 1983; Chertkow, Bub, & Seidenberg, 1989) and also disruption of retrieval processes (Nebes, Boller, & Holland, 1986; Nebes et al., 1989) underlie impairments of language function in DAT. Our results provide evidence for an additional mechanism underlying breakdowns in language comprehension in DAT (Cummings et al., 1986). We found evidence of a specific breakdown in retrieval processes during sentence comprehension in DAT such that inappropriate information is not suppressed as efficiently and is allowed to drive comprehension of the goal path a greater proportion of the time. To the extent that inappropriate information remains highly active, it will be harder for processes involved in mapping incoming information onto existing mental structures to retrieve appropriate information, and therefore building an appropriately structured mental representation of the text will suffer (Gernsbacher, 1990, 1991).

A number of studies have indicated that DAT individuals have a decreased ability to use context to disambiguate words (Balota & Duchek, 1991; Cushman & Caine, 1987; Kempler et al., 1987). We have also found that DAT individuals can take advantage of contextual constraints to enhance the appropriate meanings of ambiguous words. This finding is consistent with Nebes and Brady (1991) who have reported that DAT individuals can capitalize on the amount of context provided by incomplete sentences to evaluate how well an additional word “completes” the sentence. Thus, our results suggest that the decreased ability to use context to disambiguate words in DAT reported in the literature is due to a specific deficit in the ability to suppress the contextually inappropriate sense of ambiguous words.

Inhibition and Comprehension

Gernsbacher (1990) has proposed that facilitatory and inhibitory mechanisms modulate the activation of information, and that these mechanisms underlie the component processes involved in language comprehension. Gernsbacher and Faust (1991a) found that individual differences in the efficiency of inhibitory, but not facilitatory, mechanisms were related to individual differences in comprehension skill among young adults. Similarly, Hasher and Zacks (1988) have proposed that a decline in inhibitory processes with a relative preservation of facilitatory processes explains age related changes in language comprehension. Our results provide converging evidence that changes in inhibitory processes underlying sentence comprehension, in the absence of changes in facilitatory processes, can result in impaired comprehension abilities. On this view suppression of inappropriate or irrelevant information is an important aspect of the management of limited processing resources on-line during comprehension.

Local versus Global Cortical Integrity and Inhibition

One important way in which theories of cognitive neuroscience vary is in how distributed elementary cognitive operations are proposed to be (Mesulam, 1990; Posner, Petersen, Fox, & Raichle, 1988). Parasuraman and Nestor (1993) have recently argued for the possibility that “... some cognitive operations operate normally in the AD brain because they are subserved by localized neural modules that are not affected markedly by pathological processes that affect communication *between* modules.” They base this argument on the results of several recent studies indicating that the pathology in DAT is regionally systematic (Damasio, Van Hoesen, & Hyman, 1990; Kemper, 1984) and can be characterized as a disconnection syndrome in which corticocortical connections are particularly disrupted (Morrison, Hof, Campbell, DeLima, Voigt, Bouras, Cox, & Young, 1990).

We would like to finish with the speculation that the hypothesis that DAT results in impairments in inhibitory control with a relative preservation of facilitatory processing maps nicely onto the observation that DAT can be characterized as a disconnection syndrome. There is a long tradition in cognitive psychology to view a good portion of facilitatory processes as being relatively automatic, while inhibitory processes are usually thought of as controlled (Posner & Snyder, 1975). Thus, we speculate that DAT individuals may experience a relative preservation of facilitation in the face of marked deficits in inhibitory control due to the fact that the neural underpinnings of such processing tends to be more localized than that for inhibitory control processes.

CONCLUSION

Our results are consistent with a growing body of work suggesting that a selective breakdown in inhibitory processes, with a relative preservation of facilitatory processes, may play an important role in the cognitive changes during the early stages of DAT (e.g., Balota & Duchek, 1991; Butters et al., 1987; Spieler et al., 1994; Sullivan et al., 1994). We have added to this work by noting that, in sentence comprehension at least, the breakdown in inhibitory processing can be characterized as a change in efficiency, rather than an across the board decrement in inhibitory processing.

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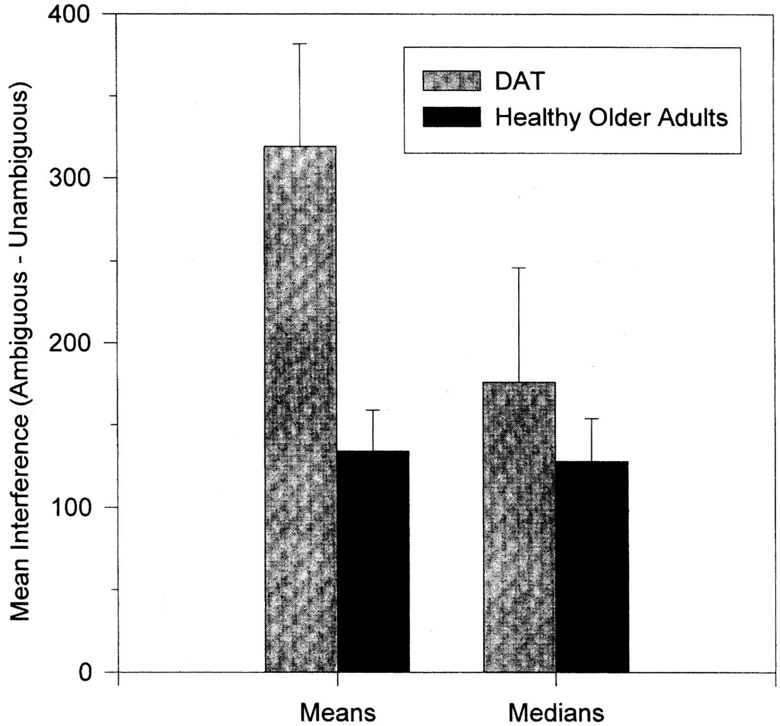

FIG. 1.

Interference, mean (median) response latency for the inappropriate minus the mean (median) response latency for the appropriate condition as a function of group in Experiment 1.

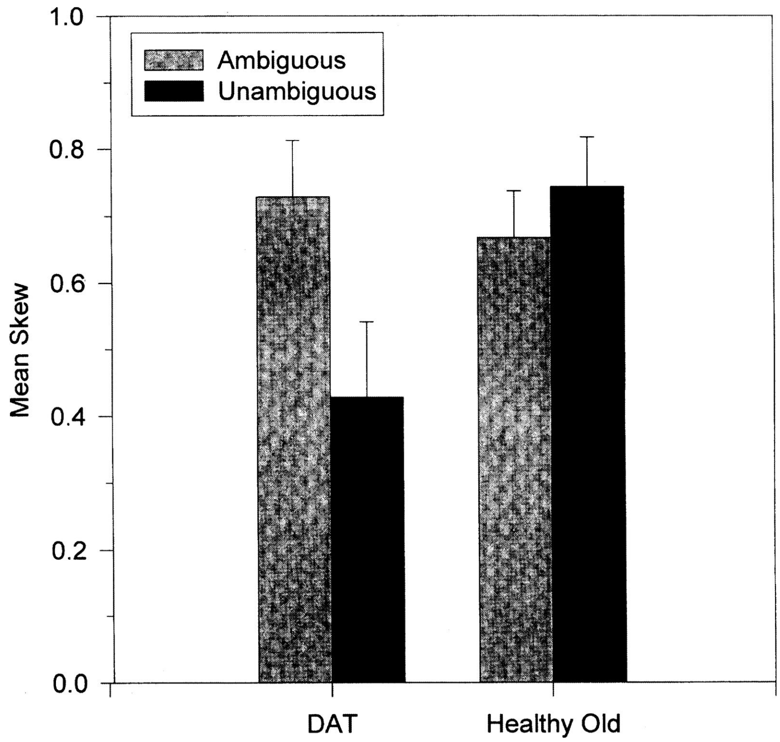

FIG. 2.
Mean of the skew of individual participants' response latency distributions, as a function of sentence type and group, in Experiment 1.

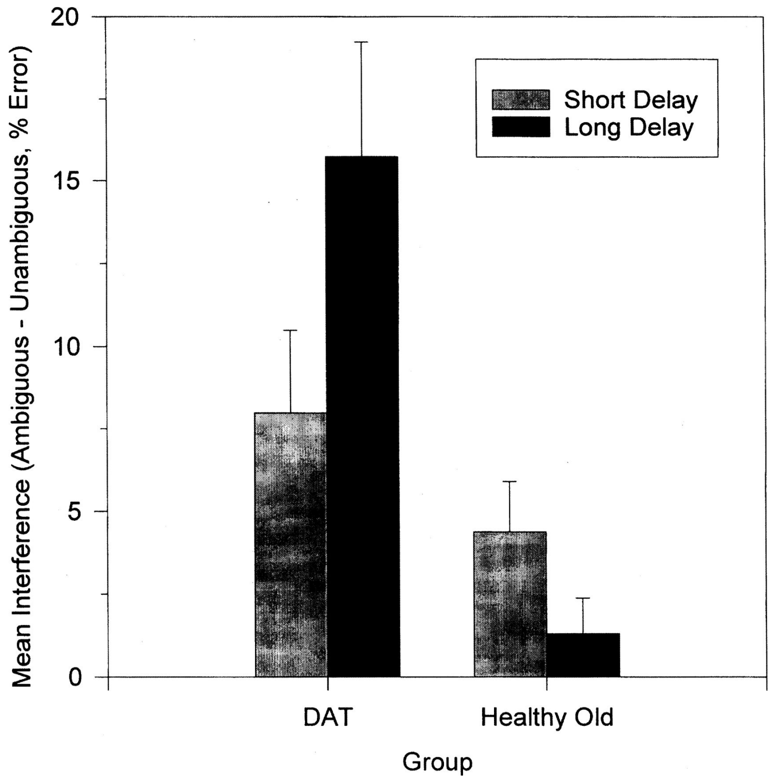

FIG. 3.

Interference, proportion error for the ambiguous minus the proportion error for the unambiguous condition, as a function of interstimulus interval (100 or 1000 msec), and group, in Experiment 1.

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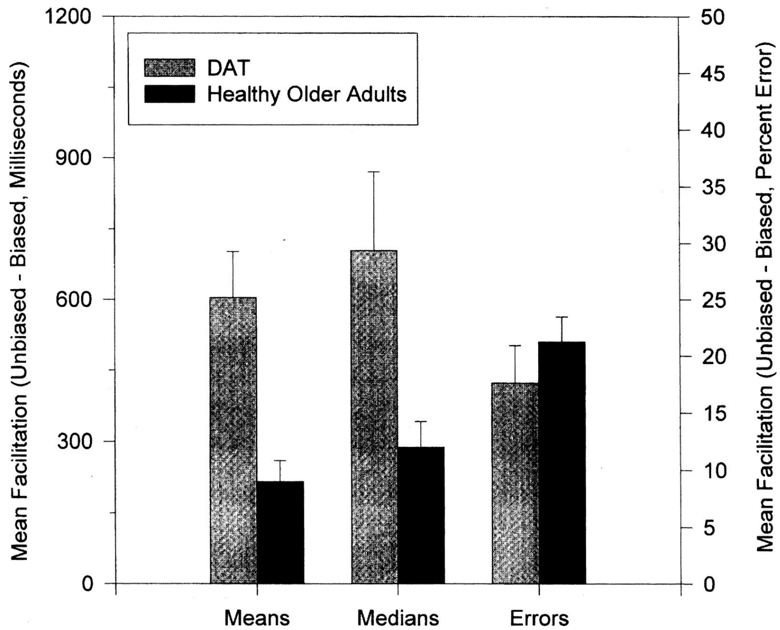

FIG. 4.

Interference, mean (median or percentage error) response latency for the unbiased minus the mean (median or percentage error) response latency for the biased condition as a function of group in Experiment 2.

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TABLE 1

Examples of Experimental Sentences and Test Words, and Filler Sentences and Test Words, from Experiments 1 and 2

Condition	**Sentence**	**Test word**
Experiment 1[a]		
Ambiguous	He dug with the *spade*	ACE
Unambiguous	He dug with the *shovel*	ACE
Filler	She liked the *rose*	FLOWER
Experiment 2[a]		
Biased	He dug with the *spade*	GARDEN
Unbiased	He picked up the *spade*	GARDEN
Filler	She picked up the *rose*	STAND

[a] Task is to judge relatedness, all or none, of test words and the overall meaning of sentences.

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TABLE 2

Means and Standard Deviations of Participants' Mean Response Latencies, Median Response Latencies, and Error Rates in Experiment 1

	Test interval			
	Short (100 msec)		**Long (1000 msec)**	
Group	**Ambiguous**[a]	**Unambiguous**	**Ambiguous**	**Unambiguous**
DAT group				
Means	3091 (998)[b]	2800 (1076)	2981 (1041)	2635 (868)
Medians	2798 (900)	2632 (1048)	2745 (1038)	2559 (854)
Error rates[c]	18.8 (12.9)	10.9 (9.6)	19.5 (12.2)	3.8 (4.4)
Control group				
Means	1472 (296)	1327 (275)	1430 (274)	1307 (308)
Medians	1385 (283)	1265 (276)	1331 (288)	1195 (273)
Error rates[c]	6.3 (5.0)	1.9 (3.6)	3.2 (4.1)	1.9 (3.1)

[a]Sentence-final word.

[b]Values in parentheses are standard deviations.

[c]Percentage errors.

TABLE 3

Means and Standard Deviations of Participants' Mean Response Latencies, Median Response Latencies, and Error Rates in Experiment 2

	Test interval			
	Short (100 msec)		Long (1000 msec)	
Group	**Biased**[a]	**Unbaised**	**Baised**	**Unbaised**
DAT group				
Means	3167 (821)[b]	3690 (1011)	3062 (706)	3745 (942)
Medians	2804 (704)	3406 (1039)	2726 (719)	3531 (1060)
Error rates[c]	10.1 (9.5)	28.6 (14.8)	7.2 (6.2)	23.9 (10.0)
Control group				
Means	1541 (537)	1783 (561)	1441 (488)	1632 (561)
Medians	1397 (441)	1748 (511)	1330 (495)	1555 (536)
Error rates[c]	6.7 (9.1)	29.2 (14.7)	5.0 (4.5)	25.0 (9.9)

[a]Bias of context in relation to sentence–final word.

[b]Values in parentheses are standard deviations.

[c]Percentage errors.