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Phonological Blocking During Picture Naming in Dementia of the Alzheimer Type

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Individuals with dementia of the Alzheimer type (DAT; $n = 53$, ages 55–91), healthy older adults ($n = 75$, ages 59–91), and younger adults ($n = 24$, ages 18–24) performed a word-primed picture-naming task. Word primes were neutral (*ready*), semantically or phonologically related, or unrelated to the correct picture name. All groups produced equivalent unrelated-word interference and semantic priming effects in response latencies. However, analysis of errors revealed a DAT-related increase of phonological blocking. The results suggest that picture-naming errors in DAT are due, at least in part, to a breakdown in access to phonological representations of object names as a consequence of reduced inhibitory control over other highly active alternatives.

Progressive impairment of lexicosemantic processing is an important aspect of one of three major aspects of cognitive processing declines associated with dementia of the Alzheimer type (DAT). Recent factor analytic results (Kanne, Balota, Storandt, McKeel, & Morris, 1998) found that, whereas individuals without DAT yielded a single undifferentiated factor on a battery of psychometric tests, the scores of a large sample of individuals with DAT yielded three global cognitive-decline factors of Cognitive Control, Memory/Lexical Processing, and Visuospatial Processing. These factors were related to the pattern of neuropathology in a subset of individuals who subsequently underwent an autopsy, indicating that regional cortical changes in frontal, temporal, and parietal cortices were related to declines in the Cognitive Control, Memory/Lexical Processing, and Visuospatial Processing factors, respectively.

DAT results in impaired performance on many lexical and semantic memory tasks (e.g., Lukatela, Malloy, Jenkins, & Cohen, 1998; R. G. Morris, 1996; Salmon, Butters, & Chan, 1999). For example, DAT-related changes in category fluency (e.g., Butters, Granholm, Salmon, Grant, & Wolfe, 1987) and semantic similarity judgments (e.g., Chan, Butters, & Salmon, 1997) are typically found early in the progression of DAT. Moreover, it has been generally recognized that the advanced stages of DAT often result in an anomia, which has led to the evaluation of standardized confrontation-naming tests such as the Boston Naming Test (BNT; e.g., Kaplan, Goodglass, & Weintraub, 1983) as potential diagnostic tools (e.g., Knesevich, LaBarge, & Edwards, 1986). The study of DAT-related declines in confrontation naming also has advantages with regard to better characterizing DAT-related declines in lexicosemantic processing (e.g., LaBarge, Balota, Storandt, & Smith, 1992; Lukatela et al., 1998). Object naming requires a range of cognitive processes, including perceptual, semantic, lexical, and phonological (e.g., Levelt et al., 1991). In addition, there is a rich literature on both primed and unprimed object naming in healthy younger and older adults (e.g., Bowles, 1994; Duchek, Balota, Faust, & Ferraro, 1995; Lupker, 1979; Vitkovitch & Humphreys, 1991), which can be used to motivate new ways of examining DAT-related changes in lexicosemantic processing. In the present study, we used a word-primed picture-naming task (e.g., Lupker & Williams, 1989) to probe for specific DAT-related breakdowns in semantic, lexical, and phonological processing during picture naming by varying prime–word and probe–picture relationships (e.g., semantic and phonological).

DAT and Picture Naming

Picture naming can be viewed as a lexicosemantic memory task that is implicit in nature and that involves access to a wide range of types of representations, including perceptual, semantic, lexical, and phonological (e.g., Levelt et al., 1991). This framework views picture naming as involving three interconnected networks for activating semantic information based on perceptual information, activating lexical representations based on semantic information, and activating the corresponding phonological information. Defi-

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cits in perceptual processing, semantic representation, and phonological access have all been proposed as underlying DAT-related deficits in picture naming.

Not only has the overall number of picture-naming errors been found to be related to global dementia severity (e.g., LaBarge et al., 1992; Skelton-Robinson & Jones, 1984), but also the analysis of DAT-related increases in picture-naming errors has produced a rich set of data on specific cognitive-processing declines in DAT (e.g., LaBarge et al., 1992; Lukatela et al., 1998). Although early studies found that individuals with DAT were more sensitive to variation in perceptual difficulty during confrontation naming (e.g., Kirshner, Webb, & Kelly, 1984; Shuttleworth & Huber, 1988), and some studies have reported DAT-related increases in the number of visual confusion errors (e.g., *cup* for *thimble;* Cormier, Margison, & Fisk, 1991), more recent work has implicated impaired phonological access and semantic representation. For example, Thompson-Schill, Gabrieli, and Fleischman (1999) manipulated the structural similarity of pictures and the word frequency of picture names and found that the influence of word frequency on naming errors was greater in the DAT group than in the healthy older group. By contrast, structural similarity influenced naming errors similarly for both groups. These results were consistent with a failure of word retrieval, rather than perceptual impairments, as a basis for DAT-related changes in confrontation naming. This view is consistent with studies of part–whole picture priming effects, which were shown to be perceptual in nature in healthy younger adults and found to be relatively preserved in adults with DAT (e.g., Gabrieli et al., 1994).

Most investigations of patterns of naming errors in DAT implicate breakdowns in semantic processing (e.g., Hodges, Salmon, & Butters, 1991; Lukatela et al., 1998). Individuals with DAT tend to produce more superordinate substitution errors, in which the category name is produced instead of the exemplar name, and they are more likely to substitute the name of another member of the same category. Semantic errors have been found to increase with dementia severity (e.g., LaBarge et al., 1992), and correspondences between errors for specific items across semantic tasks (including picture naming) have been reported for individuals with DAT (e.g., Hodges, Salmon, & Butters, 1992). These findings suggest that impairment in lexicosemantic processing underlies the picture-naming deficit in DAT. There is much current interest in better determining the source of this impairment (e.g., Astell & Harley, 1998; Auchterlonie, Phillips, & Chertkow, 2002).

One issue of interest has been the extent to which DAT results in a general disruption of the organization and structure of semantic knowledge such that concepts, concept attributes, and the links between concepts are lost or degraded because of neural degeneration in critical cortical areas (e.g., Butters, Salmon, & Heindel, 1990; Grober, Buschke, Kawas, & Fuld, 1985; Smith, Faust, Beeman, Kennedy, & Perry, 1995). From this perspective, DAT-related declines in picture naming might be attributable to a breakdown in semantic networks responsible for spreading activation to lexical and phonological representations.

Another issue of interest has been the extent to which DAT results in breakdowns in inhibitory control mechanisms (e.g., Balota & Duchek, 1991; Balota & Faust, 2002; Chenery, 1996; Daum, Riesch, Sartori, & Birbaumer, 1996; Hartman, 1991; Kanne et al., 1998). A growing number of studies have found that both DAT (e.g., Balota & Duchek, 1991; Balota & Faust, 2002; Balota & Ferraro, 1993, 1996; Faust, Balota, Duchek, Gernsbacher, & Smith, 1997; Spieler, Balota, & Faust, 1996) and, to a lesser extent, healthy aging (e.g., Hasher & Zacks, 1988; Hasher, Zacks, & May, 1999; Zacks & Hasher, 1994) result in impairments in the ability to inhibit inappropriate or no-longer-relevant information. For example, Spieler et al. (1996) found modest age-related changes in Stroop interference in the response latencies of healthy older adults (compared with younger adults) and more marked DAT-related changes in Stroop interference (compared with healthy older adults) in error rates. The DAT group was impaired to the extent that they allowed the inappropriate information (i.e., the color name) to drive a response, whereas the healthy older adults were able to overcome this tendency, but at the cost of extra time.

The inhibitory deficit view suggests that individuals with DAT may experience increased interference during picture naming from semantic, lexical, and phonological representations that remain active following processing of prior stimuli. For example, enduring activation of inappropriate phonological representations from the previous trial might act to block retrieval of the appropriate phonological code for a lexical entry. Both the semantic deficit and attentional control views may have merit. Chenery, Murdoch, and Ingram (1996) used the BNT to assess confrontation-naming performance in DAT. On the basis of the results of their study, these researchers argued that early in the progression of DAT, declines in performance were best explained as being due to changes in attentional control and/or access processes and that later in the progression of DAT, declines in performance were best explained as being due to additional breakdowns in the structure of semantic memory.

As discussed above, the semantic deficit and inhibitory control explanations of picture-naming declines in DAT involve breakdowns either in the spread of activation processes in representational networks or in the control of no-longer-relevant activations in the same networks. Researchers can effectively explore these hypotheses by using priming methodology. Priming involves evaluation of the influence of processing prior stimuli (prime) on current target processing by systematically varying aspects of the prime, usually by varying aspects of the relationship between the prime and target items.

Primed Picture Naming

Word-primed picture naming involves assessing the effects of words of various types on the speed and accuracy of picture naming. The observed priming effect provides a window on the spreading of activation in the semantic, lexical, and phonological networks responsible for picture naming (e.g., Levelt et al., 1991). These processes are dynamic in that they unfold over time and are influenced (i.e., primed) by previously presented context (e.g., Jescheniak & Schriefers, 1998; Lupker, 1979; Meyer & Schriefers, 1991). Primes have been proposed to facilitate picture naming through mechanisms of spreading activation and to inhibit picture naming by activating inappropriate lexical entries that act to block access to appropriate lexical entries (e.g., Bowles, 1994; Wheeldon & Monsell, 1994). In this view, whether or not picture naming is speeded or slowed by a prime item depends on the dynamic interplay of facilitatory and interfering processes.

In the present study, we tested the predictions of the inhibitory deficit and semantic deficit explanations of DAT-related impairments in picture naming by using a visual word-primed picture-naming task. Three priming effects typically found in the literature are of interest to the present study (e.g., Lupker & Williams, 1989; Schriefers, Meyer, & Levelt, 1990; Sperber, McCauley, Ragain, & Weil, 1979; Starreveld & La Heij, 1996). First, unrelated word primes typically lead to slower picture-naming times (i.e., unrelated-word interference) in relation to a neutral control. Second, semantically related word primes produce slowed naming, compared with unrelated control primes, if presented within a brief time window surrounding presentation of the to-be-named picture (i.e., approximately ± 150 ms) but facilitate naming (i.e., semantic priming) if presented with a greater stimulus onset asynchrony. Third, word primes that are phonologically related to the picture name typically facilitate picture-naming times throughout a wide range of stimulus onset asynchronies (i.e., phonological priming).

The semantic deficit view (e.g., Butters et al., 1990; Grober et al., 1985; Smith et al., 1995) predicts that because of breakdowns within the semantic network as well as breakdowns in the connections from the semantic to the lexical network underlying picture naming, individuals with DAT should experience reduced semantic priming and reduced unrelated-word interference effects. The inhibitory deficit view (e.g., Balota & Duchek, 1991; Balota & Faust, 2002; Balota & Ferraro, 1993, 1996; Faust et al., 1997; Spieler et al., 1996) predicts that because of a declining ability to suppress inappropriate activations in the semantic, lexical, and phonological networks underlying picture naming, individuals with DAT should experience increased unrelated-word interference and either reduced phonological priming or, if the breakdowns in phonological networks are great enough, increased phonological interference.

Method

Participants

Fifty-three individuals with DAT and 75 healthy older adults were recruited from the Washington University Medical School Alzheimer's Disease Research Center (ADRC). The healthy older adults and the individuals with DAT were seen by a physician and completed a battery of psychometric tests approximately once a year. An additional 24 younger adults (age 25 or younger) were recruited from the Washington University community and paid $10 for their efforts. This was done to better equate the benefits that younger adults received from the testing with those that the healthy older adults and individuals with DAT received (e.g., occasional free lunches and free visits to a physician). The healthy older adults and the individuals with DAT were screened by a physician for neurologic, psychiatric, or medical disorders with the potential to cause dementia. The inclusionary and exclusionary criteria for a diagnosis of DAT have been described in detail elsewhere (e.g., J. C. Morris, McKeel, Fulling, Torack, & Berg, 1988) and conform to those outlined in the criteria of the National Institute of Neurological and Communications Disorders and Stroke—Alzheimer's Disease and Related Disorders Association (McKhann et al., 1984). Diagnostic accuracy for Alzheimer's disease has been reported to be high (e.g., 96%, with Alzheimer's disease confirmed in 102 of 106 consecutive autopsies in individuals with DAT; Berg & Morris, 1994) when these criteria are used. All participants were native speakers of English.

Dementia severity for each individual with DAT recruited from the Washington University Medical School ADRC was staged in accordance with the Washington University Clinical Dementia Rating Scale (Hughes, Berg, Danziger, Coben, & Martin, 1982; J. C. Morris, 1993). According to this scale, a score of 0 indicates no cognitive impairment, a score of 0.5 indicates very mild dementia, a score of 1 indicates mild dementia, and a score of 2 indicates moderate dementia. At the Washington University Medical School ADRC, a Clinical Dementia Rating Scale score of 0.5 has been found to accurately indicate the earliest stages of DAT (J. C. Morris et al., 1991).

Because it has become common in the literature on cognitive changes in healthy older adults for researchers to distinguish between younger-old and older-old adults by using a threshold of approximately 80 years of age (e.g., Balota & Ferraro, 1996; Faust, Balota, & Spieler, 2001), we split our healthy older adult group into two subgroups with age 80 as a cutoff. The younger adults (ages ≤ 25) had a mean age of 20.4 years ($n = 24$, $SD = 1.8$), the healthy younger-old adults (ages 59–79) had a mean age of 70.8 years ($n = 40$, $SD = 6.0$), the healthy older-old adults (ages 80–93) had a mean age of 85.7 years ($n = 35$, $SD = 3.8$), the individuals with very mild DAT (ages 55–91) had a mean age of 76.3 years ($n = 31$, $SD = 8.9$), and the individuals with mild DAT (ages 61–86) had a mean age of 76.7 years ($n = 22$, $SD = 5.8$).

Psychometric Test Performance

In addition to participating in the experimental task, all of the individuals with DAT and all of the healthy older adults recruited from the ADRC participated in a 2-hr battery of psychometric tests as part of a larger longitudinal study of cognitive performance in DAT. Further details on the full set of tests administered in the battery are available elsewhere (see Rubin et al., 1998). We chose tests to be reported in the present study that were a subset of those reported in previously published articles from our group (e.g., Balota & Ferraro, 1996; Faust & Balota, 1997) and that focused on language, memory, and intelligence (see Table 1). The main purpose for reporting these results was to document memory and intellectual declines in the DAT group. We should note that some participants did not finish some of the tasks; therefore, sample size varied somewhat across tasks. Memory was assessed with the Associates subscale (paired-associates learning) and the Logical Memory subscale (surface-level story memory) of the Wechsler Memory Scale (Wechsler & Stone, 1973). Measures of general intelligence were assessed with the Information and Digit Symbol subtests of the Wechsler Adult Intelligence Scale (Wechsler, 1955). Participants also completed the Word Fluency Test (Thurstone & Thurstone, 1949), in which they were required to name as many words as possible beginning with a specified letter (*p* or *s*) in a 60-s interval, and the BNT (Kaplan et al., 1983). As shown in Table 1, the DAT group performed more poorly than the healthy older group on all tests. Because the younger adults were recruited from another source, they did not participate in the psychometric battery.

The BNT results are of particular relevance in that they showed a clear decline in confrontation naming with age and dementia severity. Three planned Bonferroni-corrected *t* tests ($\alpha = .017$) revealed that, on average, the older-old adults scored below the younger-old adults, $t(73) = 3.18$, $p = .002$; the adults with very mild DAT scored below the adults with mild DAT, $t(49) = 4.53$, $p < .001$; and the adults with very mild DAT scored below the younger-old adults, $t(68) = 3.95$, $p < .001$.

Apparatus

All stimuli for the experimental task were presented on an IBM AT-compatible computer with a standard 14-in. (35.56-cm) VGA monitor and fitted with a VGA graphics card. Participants viewed the monitor at an approximate distance of 60 cm. Naming latency for each word and picture was measured with a microphone attached to a Gebrands Model G1341T voice-operated relay that was interfaced with the parallel port of the computer. Verbal responses were recorded on audiotape so that errors could be marked in each participant's data file.

Table 1
Means and Standard Deviations of Age, Education, and Scores on Selected Psychometric Tests for Healthy Older Adults and Individuals With DAT

Psychometric test	Younger-old ($n = 40$) *M*	*SD*	Older-old ($n = 35$) *M*	*SD*	Very mild DAT ($n = 30$) *M*	*SD*	Mild DAT ($n = 21$) *M*	*SD*	*F*	*df*s
Wechsler Memory Scale										
Associates[a]	15.98	3.41	12.40	3.05	9.78	3.61	6.67	1.04	44.17*	3, 119
Logical Memory	9.99	2.61	8.06	2.51	5.31	3.55	1.79	0.68	50.19*	3, 122
Wechsler Adult Intelligence Scale										
Information	22.74	3.78	20.54	3.78	16.17	4.65	10.14	2.97	54.92*	3, 122
Digit Symbol[b]	48.31	10.64	38.83	9.50	33.72	10.99	25.39	10.56	24.01*	3, 120
Word Fluency Test	31.78	10.46	29.28	9.95	23.48	8.67	18.04	7.90	11.58*	3, 122
Boston Naming Test	55.85	4.26	52.40	5.13	48.72	10.30	35.83	9.56	36.44*	3, 122

Note. DAT = dementia of the Alzheimer type.
[a] This test included 18 individuals with mild DAT. [b] This test included 19 individuals with mild DAT.
* $p < .01$.

Materials

Three hundred line drawings of common objects were chosen from Snodgrass and Vanderwart's (1980) norms and from Biederman, Blickle, Teitelbaum, and Klatsky (1988). These line drawings were digitized, printed in booklets, and presented to a sample of 20 healthy older adults recruited from the Washington University Department of Psychology healthy older adult participant pool. These pilot participants provided written names of each of the objects depicted. One hundred pictures with the highest exact naming consistency (all at 80% or above) were chosen as experimental stimuli, and the correct name for each object was defined as the exact name most frequently provided. An additional 16 pictures with relatively high naming consistency were chosen as practice stimuli. See Appendix A on the Web at http://dx.doi.org/10.1037/0894-4105.18.3.526.supp for a full list of picture targets and word primes. Each of the experimental pictures was assigned a semantically related word prime, a phonological word prime that overlapped with the correct picture name in the first two to three phonemes (e.g., *mouth* and *mouse*), and a semantically and phonologically unrelated word prime.

With two exceptions (i.e., *calendar* and *tobacco*), all word primes were English words of three to eight letters and one to two syllables and were of moderate to high frequency (i.e., frequency ≥ 10 per million in the Kučera & Francis, 1967, norms). Four stimulus lists were created by taking the 100 experimental pictures, randomly assigning 25% of the pictures to each of four possible prime conditions (i.e., semantic, phonological, unrelated, and a neutral prime condition in which the word *ready* was presented), and then counterbalancing prime type across lists. The resultant lists contained exactly one presentation of each to-be-named picture, and across lists, each to-be-named picture was preceded equally often by each type of prime. Sixteen practice trials were created by assigning semantic word primes to 4 pictures, assigning phonological word primes to 4 pictures, assigning unrelated word primes to 4 pictures, and assigning the word prime *ready* to 4 pictures.

Procedure

Upon being scheduled for yearly psychometric testing, individuals with DAT and healthy older adults were recruited for participation in the current study. Every effort was made to schedule the testing for the present project either during a separate block of time on the same day or within a few days following psychometric testing. All individuals with DAT and healthy older participants were tested in the present study within 8 weeks of their latest psychometric testing. All participants completed a battery of two naming tasks consisting first of the picture-naming task used in the present study, followed by a word-naming task used in another project (Faust et al., 2001). None of the object names used in the word-naming study were used in the present picture-naming task. Total testing time was 1–1.5 hr per participant, including all breaks, testing, and practice intervals.

The task was explained verbally to participants. Participants were instructed to "name each word prime and picture target aloud into the microphone as fast as you can while making only a few errors." Participants completed 16 practice trials, followed by two blocks of 50 experimental trials separated by a minimum (i.e., participants chose when they wished to resume) 30-s rest break. Each block took approximately 4 min. Within the prior 12-month period, none of the individuals with DAT or the healthy older adults had participated in other studies that included reaction time (RT) and computer presentation of stimuli.

A centrally presented white box (approximately 10 cm [width] × 7.5 cm [height]) with a blue border was displayed against a dark background throughout a block of trials. Picture stimuli were scaled to comfortably fit this box. Pictures ranged from 3 to 8 cm in width and from 3 to 6 cm in height, with each picture having approximately 1.5–2 cm from each edge to the border of the white box along its longest (i.e., vertical or horizontal) axis. A standard (i.e., Turbo Pascal) serif font was used for word primes, with each letter being presented in a 1.2-cm (height) × 0.8-cm (width) box. Thus, words ranged from 2.4 to 7.2 cm in width. All words and pictures were centered both vertically and horizontally within the white presentation box.

Each trial began with the presentation of a ready signal, consisting of three plus signs with intervening spaces, for 300 ms in the center of the square, followed by a blank square again for 400 ms. The prime word was then presented, centered horizontally and vertically in the white box, until 250 ms after detection of a vocal response, followed by the blank square for 500 ms. The target picture was then presented until 250 ms after detection of a vocal response. Thus, the response–stimulus interval was 750 ms. Following the response to the target picture, the blank white box was presented for a 1,500-ms intertrial interval. A time-out deadline of 5,000 ms was imposed for each word prime and picture target. If the participant did not respond within this time interval, an error was recorded, the stimulus was removed, and the task was continued.

Results

We first identified naming errors as trials in which (a) no response was made prior to the 5,000-ms time-out, (b) the response was not fluent or contained extra vocalizations (e.g., "uhm"), or (c) a fluent response other than the predefined correct picture name was produced. The resultant error rates are listed in Table 2 as a function of prime type and group. We then computed an overall mean and standard deviation for each participant and removed any responses more than 2.5 standard deviations from each participant's overall mean. Trials defined as outliers and removed from the response latency analyses were not counted as incorrect unless they met one of the three criteria listed above. The amount of latencies removed because of this procedure was overall quite low (2.6%). The amount of latencies removed was equivalent across groups: 2.7%, 2.8%, 2.5%, 2.6%, and 2.4%, for the young, younger-old, older-old, very mild DAT, and mild DAT groups, respectively. The amount of latencies removed was also equivalent across conditions: 2.4%, 2.1%, 2.7%, and 3.3%, for the semantic, neutral, unrelated, and phonological primes, respectively. Using the remaining correct responses, we calculated the mean naming latency for each participant in each experimental condition (see Table 2) and submitted these values to a 5 (group: young, younger-old, older-old, very mild DAT, or mild DAT) × 4 (prime type: neutral, unrelated, semantic, or phonological) mixed-model analysis of variance (ANOVA), in which prime type was a within-participants factor.

Response Latency

The main effect of group was significant, $F(4, 147) = 16.28$, $p < .001$, indicating that the groups differed in overall speed of correctly naming the pictures (M = 786, 923, 1,018, 986, and 1,078 ms for the young, younger-old, older-old, very mild DAT, and mild DAT groups, respectively). A Tukey post hoc procedure revealed a significant influence of age on overall RT (i.e., younger-old adults were slower than young adults and faster than older-old adults; $ps < .05$) and a significant influence of dementia (i.e., adults with very mild DAT were slower than younger-old adults and faster than adults with mild DAT; $ps < .05$). The main effect of prime type was significant, $F(3, 441) = 20.93$, $p < .001$, indicating that significant priming effects were present (M = 934, 979, 940, and 981 ms for the neutral, unrelated, semantic, and phonological prime types, respectively). There was no Group × Prime Type interaction ($F < 1.2$). As discussed in the introduction, three priming effects were of interest: (a) unrelated-word interference, (b) semantic priming, and (c) phonological priming.

We created difference scores from the mean latencies for each individual for each of the priming effects of interest, and we submitted each difference score to a separate one-way ANOVA. Unrelated-word interference was assessed by subtracting the mean neutral latency from the mean unrelated latency (i.e., positive values indicate interference), semantic priming was assessed by subtracting the mean unrelated latency from the mean semantic latency (i.e., negative values indicate facilitation), and phonological priming was assessed by subtracting the mean unrelated latency from the mean phonological latency (i.e., negative values indicate facilitation). Figure 1 depicts these mean priming effects as a function of prime type and group.

Overall, participants were slower to name pictures following the neutral (i.e., *ready*) primes than the unrelated primes (i.e., unrelated-word interference), $F(1, 151) = 44.30$, $p < .001$. Participants were also faster to name pictures following a semantic prime than following an unrelated prime (i.e., semantic priming), $F(1, 151) = 29.59$, $p < .001$. However, there was no significant phonological priming effect ($F < 1$). There were no main effects of group for any of the three priming conditions ($Fs < 1.6$, $ps > .18$), and Tukey post hoc procedures revealed no pairwise differences among any of the groups for any of the priming measures. We evaluated priming effects for each group separately using

Table 2
Means and Standard Deviations of Naming Latencies (RTs) and Percentages of Errors as a Function of Prime Type and Group

	Prime type							
	Neutral		Unrelated		Semantic		Phonological	
Group and Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Younger adults (n = 24)								
RT (ms)	766	98	795	118	790	111	791	111
% errors	8.7	5.7	8.8	4.9	12.7	10.0	10.8	8.2
Younger-old (n = 40)								
RT (ms)	889	112	948	138	912	140	943	160
% errors	12.2	6.8	12.2	8.7	12.9	9.3	12.8	11.4
Older-old (n = 35)								
RT (ms)	1,002	159	1,029	180	990	152	1,053	155
% errors	15.7	9.1	15.9	10.6	17.3	9.0	19.7	10.3
Very mild DAT (n = 31)								
RT (ms)	961	149	1,017	163	954	154	1,013	183
% errors	18.5	13.2	17.7	10.6	16.3	10.3	23.3	14.2
Mild DAT (n = 22)								
RT (ms)	1,052	163	1,106	161	1,053	165	1,102	152
% errors	30.5	12.7	26.0	11.6	29.1	11.8	38.2	15.4

Note. Table 2 includes 2 additional participants for whom psychometric results were not available and who were not included in Table 1. RT = reaction time; DAT = dementia of the Alzheimer type.

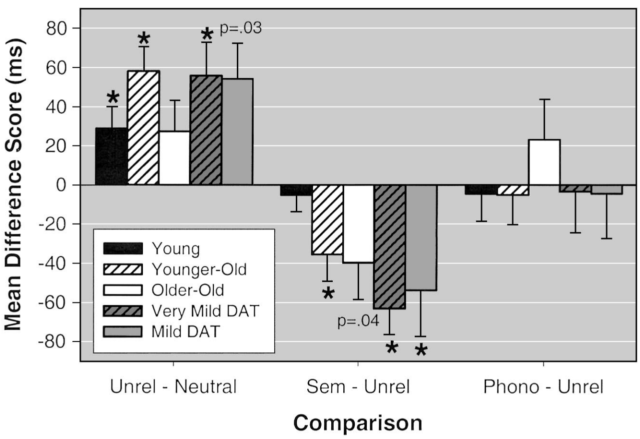

Figure 1. Mean difference scores computed from untransformed reaction times (RTs) as a function of group for three comparisons of interest. The left-most group depicts unrelated-word interference (mean RT for unrelated primes minus mean RT for neutral primes), with more positive values indicating greater unrelated-word interference. The middle group depicts semantic priming (mean RT for semantic primes minus mean RT for unrelated primes), with more negative values indicating greater semantic priming. The right-most group depicts phonological priming (mean RT for phonological primes minus mean RT for unrelated primes), with more negative values indicating greater phonological priming. Error bars represent standard errors of the means. DAT = dementia of the Alzheimer type; Unrel = unrelated; Sem = semantic; Phono = phonological. $*p < .02$.

Bonferroni-corrected t tests (familywise $\alpha = .10$ for each set of five tests for each priming measure; per-comparison αs = .02). The asterisks in Figure 1 indicate significant effects yielded by this procedure. As can be seen in Figure 1, whereas all groups produced unrelated-word interference effects of a similar magnitude, only the young, younger-old, and very mild DAT groups produced significant unrelated-word interference effects and significant semantic priming, and none of the groups produced significant phonological priming. To control for group differences in overall speed of response, we transformed mean RTs to z scores as recommended by Faust, Balota, Spieler, and Ferraro (1999) and repeated the analysis of priming scores. As can be seen from comparison of Figure B1 (see Appendix B on the Web at http://dx.doi.org/10.1037/0894-4105.18.3.526.supp) and Figure 1, the pattern of results for z-scaled priming scores did not differ substantially from that for unscaled RTs.

Error Rates

Percentages of errors in fluently producing the expected name prior to the 5,000-ms time-out (see Table 2) were submitted to a 5 (group) × 4 (prime type) mixed-model ANOVA. The main effect of group was significant, $F(4, 147) = 22.02$, $p < .001$, indicating that the groups differed in overall rate of picture-naming errors (M = 10.3%, 12.5%, 17.1%, 18.9%, and 31.0% for the young, younger-old, older-old, very mild DAT, and mild DAT groups, respectively). A Tukey post hoc procedure revealed a significant influence of age on overall error rates (i.e., younger-old adults produced fewer errors than older-old adults; $p < .05$) and a significant influence of dementia (i.e., adults with very mild DAT produced more errors than younger-old adults and fewer errors than adults with mild DAT; $ps < .05$). The main effect of prime type was significant, $F(3, 441) = 13.14$, $p < .001$ (M = 16.4%, 15.6%, 16.9%, and 19.9% for the neutral, unrelated, semantic, and phonological prime types, respectively). The Group × Prime Type interaction was significant, $F(12, 441) = 2.89$, $p = .001$, indicating that the pattern of priming effects varied across groups. To examine this pattern in more detail, we performed separate analyses of each priming effect.

Priming effects. We used the percentage of errors for each participant to create difference scores for each of the priming effects of interest and submitted each priming effect to a separate one-way ANOVA. Unrelated-word interference was assessed by subtracting the percentage of neutral errors from the percentage of unrelated errors (i.e., positive values indicate interference), semantic priming was assessed by subtracting the percentage of unrelated errors from the percentage of semantic errors (i.e., negative values indicate facilitation), and phonological priming was assessed by subtracting the percentage of unrelated errors from the percentage of phonological errors (i.e., negative values indicate facilitation).

Overall, there were no significant unrelated-word interference or semantic priming effects in error rates ($Fs < 1.5$, $ps > .20$). However, participants did produce more picture-naming errors on average when the pictures were preceded by a phonological prime than when the pictures were preceded by an unrelated prime. This phonological blocking effect varied significantly across groups (see the left side of Figure 2), $F(4, 147) = 4.91$, $p = .001$. Tukey post hoc comparisons revealed that the mild DAT group produced a significantly larger phonological blocking effect than any of the other groups ($ps < .05$). Bonferroni-corrected t tests (familywise $\alpha = .10$ for each set of five tests for each priming measure; per-comparison αs = .02) revealed that only the mild DAT and very mild DAT groups produced significant phonological blocking (indicated by asterisks in Figure 2). Because of concerns that group differences in overall error rate might have contributed to the finding of a DAT-related increase in phonological blocking, we divided the phonological difference score for each individual by his or her proportion of errors in the unrelated prime condition. This procedure resulted in 4 younger adults and 1 younger-old adult being dropped from this analysis because of a division-by-zero problem. As can be seen on the right side of Figure 2, the results for the healthy older adult groups and the DAT groups were qualitatively similar.

The two appreciable differences (see left and right sides of Figure 2) were that the proportion change measure had much more error variation and that the younger adult phonological blocking effect, although still not statistically significant, was much larger in relation to the phonological blocking effect of the other groups. We attribute this finding to the fact that 4 younger adults were dropped and that this rescaling was somewhat inappropriate for younger adults because so many of them were so near to floor in proportion of errors. We should also note that with the increased measurement error in the proportion change measure (right side of Figure 2), the statistical power was reduced, and the groups did not differ in an omnibus ANOVA. However, the DAT groups still produced significant phonological blocking, whereas the younger-old group did not. On the basis of these results, it appears that the DAT-related increase in phonological blocking was not solely attributable to group differences in error rates.

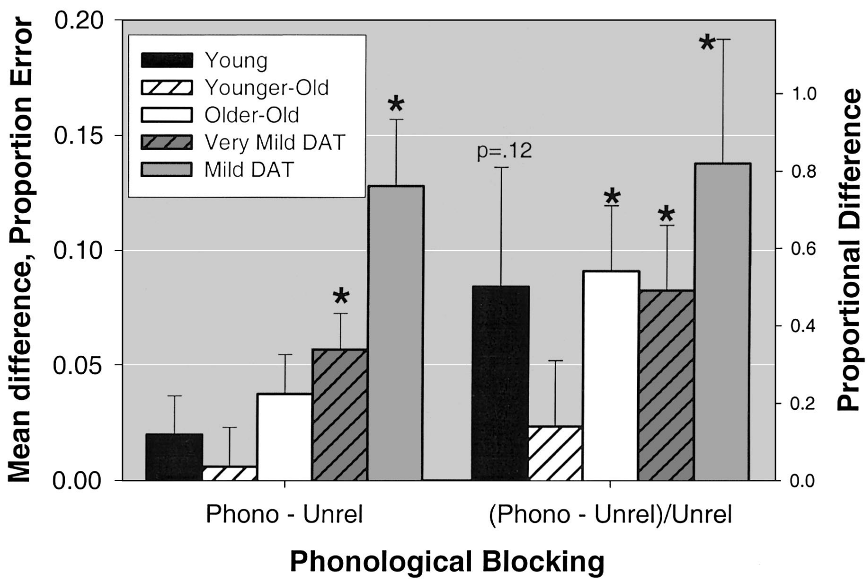

Figure 2. Mean phonological blocking (interference) effects in proportion of error as a function of group. The left-most group depicts phonological interference (proportion of error for phonological primes minus proportion of error for unrelated primes), with more positive values indicating greater phonological interference. The right-most group depicts the same phonological effects as a proportion of change in relation to the unrelated condition (proportion of error for unrelated primes minus proportion of error for neutral primes, with the difference divided by the proportion of error for the unrelated primes). Error bars represent standard errors of the means. DAT = dementia of the Alzheimer type; Phono = phonological; Unrel = unrelated. $^*p < .02$.

Breakdown of phonological interference effects by error type for DAT. In an attempt to uncover any specific sources of the phonological interference effect observed in the very mild and mild DAT groups, we combined both groups and categorized their errors as the following types: (a) timing problem (responses longer than the 5,000-ms time-out deadline or no response), (b) redirected responses (responses that were technically correct but that were not the response expected on the basis of norms for that item), (c) incorrect responses (indications of not knowing the correct name of the item, empty responses such as "uhm" or "ah," or clearly incorrect responses), or (d) intrusion errors (responses that, although incorrect, were semantically related either to the target picture or to the prime word). A phonological interference effect was constructed for each error type for each individual with DAT by subtracting the appropriate proportion of error for the unrelated condition from the proportion of error for the phonological condition. The results are presented in Figure 3.

Significant phonological interference effects were found for the timing problems, $M = .007$, $t(52) = 2.133$, $p = .038$; for the incorrect responses, $M = .048$, $t(52) = 3.067$, $p = .003$; and for the intrusion errors, $M = .016$, $t(52) = 2.474$, $p = .017$. The phonological interference effect for the redirection errors, although not significant, was marginal, $M = .014$, $t(52) = 1.995$, $p = .051$.

Phonological Blocking and BNT Scores

Of the six psychometric test scores reported for the healthy older adults and the individuals with DAT (see Table 1), overall proportion of errors on the primed picture-naming test was correlated most strongly with scores on the BNT, $r(124) = -.767$, $p < .001$, when both healthy older adults and individuals with DAT were included. Correlations ranged from $-.354$ to $-.599$ for the other five tests (see Table 1). The correlation between proportion of total errors on the primed picture-naming test and the BNT scores was stronger for the DAT group, $r(49) = -.823$, $p < .001$, than for the healthy older adults, $r(73) = -.506$, $p < .001$, by a Fisher's r-to-z transformation, $z = 3.27$, $p < .001$.

To assess whether phonological interference effects could explain a unique incremental portion of scores on the BNT for

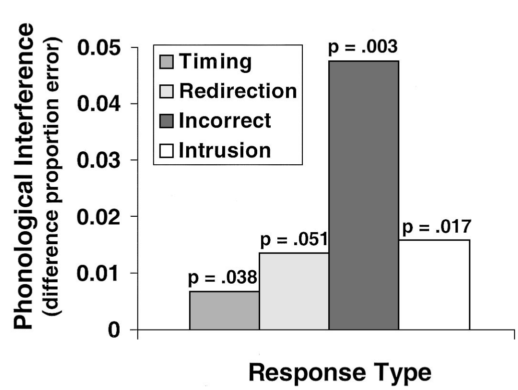

Figure 3. Mean phonological difference scores (proportion of error for phonological primes minus proportion of error for unrelated primes) computed from proportion of error as a function of response type for all dementia of the Alzheimer type groups combined. See text for definition of response types.

individuals with DAT, we computed the partial correlation between proportion of errors in the phonological condition and scores on the BNT, with proportion of errors in the unrelated condition removed, at $pr(48) = -.291$, $p = .041$. This result indicates that errors in the phonological primed condition were significantly related to BNT scores even when the portion of variability in BNT scores that could be predicted from proportion of errors in the unrelated condition was removed from consideration.

Discussion

The results of this study provide further documentation of age- and DAT-related declines in picture-naming efficiency (e.g., Albert, Heller, & Milberg, 1988; Bowles, 1994; Duchek et al., 1995; LaBarge et al., 1992; Lukatela et al., 1998). Picture naming was slower overall and more error prone with age and DAT. With respect to primed picture naming, the response latency results demonstrated much consistency across groups. The response latency results yielded robust unrelated-word interference and semantic priming effects that, with the possible exception of semantic priming for the young group, were equivalent across groups. By contrast, the error rate results failed to yield significant priming effects of any type for any of the groups, with the exception of significant phonological interference (i.e., phonological blocking) in the very mild and mild DAT groups. This DAT-related increase in errors following phonological primes was predictive of BNT scores for individuals with DAT above and beyond that portion of the variability in BNT scores that could be predicted by the errors in the unrelated (control) prime condition, which indicates that phonological blocking is a component of picture-naming deficits in DAT.

The results suggest that individuals with DAT, but not healthy older adults, experienced a decline in the ability to overcome the blocking effects of inappropriately activated, phonologically similar lexical items when attempting to access the target picture name. The analysis of error types (see Figure 3) indicated that this DAT-related phonological blocking effect was relatively nonspecific in that it included a range of subeffects, from a total blocking of a response that was related to the picture or word, to a partial blocking that led either to the production of an incorrect response that was semantically related to the prime or target or to a correct but infrequent name, to an increased likelihood of a slowed latency to produce the correct name (i.e., time-outs).

The finding of a DAT-related increase in phonological blocking but not in unrelated-word interference provides support for a bounded inhibitory deficit account (e.g., Balota & Faust, 2002; Faust et al., 1997; Spieler et al., 1996). In this account, individuals with DAT experience a relatively specific deficit in the ability to exert inhibitory control over previously activated phonological representations, leading to increased blocking of access to phonological representations during picture naming (see Figure 2). The results indicate that healthy older adults and individuals with DAT were equally able to exert inhibitory control over semantic, lexical, and phonological information activated during processing of the unrelated word primes (see Figure 1). Therefore, the inhibitory deficit appears to be specific to situations in which the inappropriate competitor is phonologically similar to the correct response, suggesting interference at the stage in which phonological codes are being assembled to drive motor output. This pattern of results is consistent with recent work by Balota and Ferraro (e.g., 1993, 1996) indicating that DAT results in a specific phonological processing deficit. Balota and Ferraro (1993) found that individuals with DAT were more likely to mispronounce exception words (e.g., “pint”) according to the most frequent spelling-to-sound correspondences (e.g., pronouncing “pint” as if it rhymed with “hint,” “mint,” or “lint”). This result suggests a problem with exerting inhibitory control over the spelling-to-sound processing pathway during word naming. The present results do not directly address the issue of the possibility of other sources of deficits in phonological access in DAT. For example, Taylor and Burke (2002) recently suggested that an age-related degradation in the connections from lexical to phonological networks in healthy older adults results in a perhaps milder deficit in top-down phonological access during picture naming. The present study was not designed to directly address this hypothesis in DAT.

Several studies have found that picture-naming deficits in individuals with DAT are more pronounced for low-frequency picture names (e.g., Thompson-Schill et al., 1999; Tippett & Farah, 1994), a result consistent with later lexical access processes. Astell and Harley (1998) compared picture-naming and word–picture matching task performance in individuals with DAT and healthy older adults by using the same items across tasks. The DAT group produced significantly more naming errors that were semantically related to the correct target item. The DAT-related impairment was reduced in the word–picture matching task, indicating a relative preservation of conceptual representations activated by the pictures. These results suggest that individuals with DAT experienced a specific deficit in accessing phonological representations, resulting in an increased likelihood of choosing an alternative from a set of active, semantically related lexical items. Further support for this hypothesis comes from a recent study by Chosak (2000), who analyzed a large database of BNT scores produced by individuals with DAT and individuals with dementia caused by cerebral vascular dementia using a general processing tree model that allows for estimation of parameters for perceptual, semantic, and lexical processes. Although there were no significant differences between the DAT and cerebral vascular dementia groups in terms of traditional statistical tests, this procedure successfully differentiated these groups on the basis of the lexical access and phonological realization parameters in the model.

No support was found for the semantic deficit view of DAT picture-naming declines. In contrast to the decreased semantic priming and unrelated-word interference effects in the DAT groups that are predicted by this view, we found that healthy older adults and individuals with DAT produced equivalent semantic priming and unrelated-word interference effects in response latencies (see Figure 1). The present findings do not rule out subtle semantic deficits that might be detected with other tasks requiring more controlled and explicit retrieval from semantic memory than does picture naming. It may also be the case that semantic deficits increase with DAT severity, having a sizable impact on cognitive processes only at later stages of DAT. For example, using the BNT, Chenery et al. (1996) found evidence that early in the progression of DAT, declines in performance were due to changes in attentional control and/or access processes and that later in the progression of DAT, declines in performance were best explained as being due to additional breakdowns in the structure of semantic memory. The present study used DAT individuals in the earlier stages (i.e., very mild to mild dementia) in the progression, which may have contributed to the lack of findings on semantic deficits.

Burke, MacKay, and colleagues (e.g., Burke, Mackay, Worthley, & Wade, 1991; James & Burke, 2000; Rastle & Burke, 1996) have proposed that age-related increases in retrieval failures such as word-finding problems during conversation and the *tip-of-the-tongue phenomenon* (i.e., a temporary inability to retrieve information from memory accompanied by a sense that the information is actually in memory; e.g., Brown & McNeill, 1966) are due to problems with the transmission of information across semantic, lexical, and phonological networks. Taylor and Burke (2002) recently extended this framework to the domain of picture naming. They suggested that there is a general, broad, and diffuse degradation of semantic, lexical, and phonological networks with age but that the lexicosemantic links to phonological networks are most affected by such degradation because this portion of the system is less richly interconnected. Taylor and Burke found evidence for an age-related decrease in top-down lexicosemantic priming of phonological representations but for preserved stimulus-driven semantic and phonological priming effects during a word-primed picture-naming task. There was no evidence of an age-related increase in phonological blocking reported in the Taylor and Burke study.

The present results are consistent with those of Taylor and Burke (2002) in that healthy older adults were overall more error prone in picture naming but produced equivalent unrelated-word interference and only a nonsignificant trend toward phonological blocking in the older-old group. Because the design of the present study did not include priming conditions designed to assess top-down priming from the lexicosemantic level to the phonological level (see Taylor & Burke, 2002, for a discussion of how this might be done), our results are not directly relevant to the specific predictions of the transmission deficit hypothesis as it relates to cognitive aging.

The finding of equivalent unrelated-word–prime interference with age also fails to add positive support to the claims of a general inhibitory breakdown with age (e.g., Hasher et al., 1999; Zacks & Hasher, 1994). Younger and healthy older adults were equally able to exert inhibitory control over inappropriate information associated with unrelated primes. However, the nonsignificant trend toward increased phonological interference in the older-old group suggests that there may be a more specific age-related decline in inhibitory control at work during picture naming. This view is supported by the results of Duchek et al. (1995), who used a task in which participants had to verify a semantic relationship between two successively presented objects while ignoring a word related to the first object. These researchers reported evidence of an age-related breakdown in inhibitory mechanisms during picture recognition. Further study is needed to determine whether there is a small and difficult-to-detect increase in phonological blocking with age during picture naming.

It is becoming clear that the hypothesis of a general inhibitory control deficit does not hold for either healthy aging or DAT. For example, although studies of Stroop color naming (Spieler et al., 1996), the antisaccade task (Butler, Zacks, & Henderson, 1999), recovery from garden path sentences (Hartman & Hasher, 1991; May, Zacks, Hasher, & Multhaup, 1999), and directed forgetting (Zacks & Hasher, 1994), among others, have demonstrated age-related decrements in inhibitory control, studies of other aspects of inhibitory control have not shown consistent age-related declines. Studies of negative priming (i.e., a slowing of response when participants are asked to attend to a previously ignored item; e.g., Sullivan & Faust, 1993; Sullivan, Faust, & Balota, 1995) and inhibition of return (i.e., a slowing of response when participants are asked to attend to a location or object that was previously attended to; e.g., Faust & Balota, 1997; Hartley & Kieley, 1995) have failed to yield consistent age-related declines in these inhibitory mechanisms. Similarly, whereas studies of sentence comprehension and homograph priming (e.g., Balota & Duchek, 1991; Faust et al., 1997), Stroop color naming (e.g., Spieler et al., 1996), and phonological processing (e.g., Balota & Ferraro, 1993, 1996), as well as the present study, have all demonstrated DAT-related declines in inhibitory control, other studies have failed to find DAT-related inhibitory deficits. For example, Faust and Balota found equivalent inhibition of return, and the present study found equivalent unrelated-word–prime interference effects in adults with DAT as opposed to healthy older adults.

Given that a general inhibitory breakdown hypothesis probably does not hold for aging or for DAT, it becomes important for researchers to modify the inhibitory deficit models for each group to take into account the observed pattern of age- and DAT-related changes in inhibitory control. Balota and Faust (2002) recently suggested that declines in inhibition associated with DAT seem to center around attentional control mechanisms that are responsible for maintenance of goals in working memory, selection of a relevant subset of information under conditions in which irrelevant information is active, and selection of relevant behavioral responses in situations with several active alternatives. This proposal bears some resemblance to proposals that the anterior portion of the brain contains an attentional network responsible for executive attention (e.g., Posner & DiGirolamo, 1998).

In conclusion, the present results suggest that the picture-naming deficit in DAT is at least in part due to a decline in inhibitory control over phonological output processes related to the phonological realization of conceptual information (e.g., Balota & Ferraro, 1993, 1996). These results, along with other studies in the literature, suggest that increased semantic circumlocutions during picture naming in individuals with DAT might be due to an increased likelihood that semantically interrelated alternative lexical items that are activated during the initial stage of lexical access will be chosen following phonological blocking of the correct lexical item. The results are also consistent with more general claims regarding DAT-related breakdowns in inhibitory cognitive mechanisms (e.g., Faust et al., 1997; Spieler et al., 1996) that are associated with executive attention (e.g., Balota & Faust, 2002).

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