Correlation Between Frontal Lobe Functions and Explicit and Implicit Stem Completion in Healthy Elderly

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The authors investigated the relationship between performance on neuropsychological tests, which were sensitive to medial-temporal and frontal lobe function, and implicit and explicit stem completion in a group of healthy elderly participants (mean age = 77.3 years). Several stem-completion conditions varying in the size of the search space and the specificity of the cues were included. Across conditions, performance on a frontal lobe sensitive test (word fluency) and on medial-temporal tests (California Verbal Learning Test; delayed recall) correlated with explicit stem completion. The correlations between frontal and medial-temporal test performance and implicit stem completion were weaker. However, a relationship was observed between frontal lobe functioning and stem completion when (a) the search space was large and the cues were constrained and (b) when the search space was limited and the cues were relatively unconstrained. Therefore, the role of the frontal lobes in implicit stem completion seems to be to detect bias resulting from prior study, and this involvement can only be revealed when the interaction between the size of the search space and the retrieval cues (a) makes bias detection necessary and (b) allows it to play a role. The stronger involvement of the frontal lobes in explicit stem completion likely reflects strategic retrieval processes, and the medial-temporal lobe involvement may be related to verification processes.

A major category of implicit memory is known as repetition priming. Memory on tests of repetition priming, such as word completion and perceptual identification, is revealed as facilitated task performance following prior exposure to the same stimuli. Numerous studies have demonstrated that performance on tests of repetition priming can be dissociated from performance on tests of explicit memory involving recall or recognition of target items. Demonstrations of dissociations have important neuropsychological implications in that they suggest distinct neural systems mediating performance on the two classes of tests (for a recent review, see Nyberg & Tulving, 1996).

One class of dissociation concerns differences as a function of chronological age, or developmental dissociations. A number of studies have shown that the difference in memory performance between young and older adults is more pronounced on recall and recognition tests than on tests of repetition priming (see Light, 1991; Moscovitch, 1982). The existence of developmental dissociations, however, does not mean that there are no age differences in repetition priming. In fact, there have been several findings of age differences favoring younger adults (for a review, see La Voie & Light, 1994).

There is evidence that age differences are more likely to be found on some repetition priming tests than on others. The word-stem completion test is an example of a test on which age differences are particularly likely to be observed. In this test, participants typically study a list of words and are later given word stems (the first three letters of words) to complete with the first words that come to mind. A meta-analysis of age differences in perceptual priming (La Voie & Light, 1994) revealed that word-stem completion was associated with a substantially higher effect size, signaling greater priming for younger than older adults, than tests such as perceptual identification and lexical decision. Similarly, a recent meta-analysis of priming in Alzheimer's disease (Meiran & Jelicic, 1995) showed a substantial advantage of controls over Alzheimer's patients on word-
stem completion, whereas the two groups exhibited comparable levels of priming on perceptual identification.

The suggestion by Gabrieli and colleagues (e.g., Gabrieli et al., 1994; Keane, Gabrieli, Fennema, Growdon, & Corkin, 1991) of a strong involvement of conceptual processes, in addition to perceptual processes (cf. Roediger, Weldon, & Challis, 1989; Tulving & Schacter, 1990), in stem-completion priming offers one hint as to why age differences are particularly likely to emerge on stem-completion tests. There are data suggesting that conceptual priming processes are more impaired in advanced age than are perceptual priming processes (Jelicic, Craik, & Moscovitch, in press).

A similar account was recently put forward by Winocur, Moscovitch, and Stuss (1996). Winocur et al. found significant positive correlations between performance on word-stem completion and on tests of frontal lobe function (cf. Davis et al., 1990). On the basis of this finding they suggested that word-stem completion, but not fragment completion or perceptual identification, has a frontally mediated strategic search component. Frontal lobe dysfunction in old age will impair this search component, thereby leading to impaired stem-completion priming.

Winocur et al. (1996) showed that unprimed stem completion performance was not correlated with frontal lobe function. This noteworthy finding suggested that the frontal lobes may not be related to the generation of simply any response but instead to selection of the primed response. In this sense, the frontal lobes can be thought of as picking up the bias in the word system that results from prior study. Although this view is in line with proposals that the frontal lobes may be related to a mechanism that controls and modulates memory (Metcalfe, 1993), there is little direct evidence that the relationship between frontal lobe function and stem-completion priming reflects some kind of bias detection. One purpose of the present study, therefore, was to address this issue.

Given that the frontal lobes are involved in selecting primed responses, it is to be expected that this involvement can vary depending on the retrieval conditions. Two factors that may determine the degree of involvement of this selection mechanism are the size of the search space and how constrained the cues are. If the search space is very small and the cue is constrained (has many letters in the stem), the role of the selection mechanism should be minimal. In this case, there is little competition between possible responses, and hence there is little need or role for bias detection. Similarly, if the search space is quite large and the cue is relatively unconstrained (has fewer letters specified), selection may play a minimal role. In this latter case, the situation may be too unconstrained for any bias to be detected. In contrast, the putative frontal bias detection mechanism should be most strongly involved when the interaction between cue constraints and the size of the search space provides an opportunity for it to play a role.

We tested the above predictions by varying (a) the number of letters that served as cues (two or three letters) and (b) the size of the search space. The latter manipulation was accomplished by varying the number of response alternatives the stems could elicit. Thus, four conditions were created in which two- or three-letter stems had either a small (3 or fewer) or large (10 or more) number of response alternatives. We also included a condition in which search space was constrained by limiting responses to words from a specific semantic category (animals) in a conceptual priming task.

We expected the lowest level of baseline performance and priming in the 2–10 condition (see Materials section) because the cues were minimal and the search space was too large for them to be effective. By comparison, in the 3–3 and animal priming conditions, the combination of high cue and limited search space constrained the number of possible responses. As a result, the target word should have a large probability of being elicited both at priming and in the baseline condition. In the 3–10 and 2–3 conditions, performance at baseline was expected to fall between these two extremes, and priming should surpass that in the 2–10 condition.

A second purpose of the present study was to investigate the relationship between frontal lobe function and explicit stem-completion performance. It is generally accepted that explicit stem completion has a conceptual component, but Winocur et al. (1996) did not find significant correlations between stem-cued recall performance and measures of frontal lobe function. The recall levels were relatively high, suggesting that the retrieval cues may have been sufficient to minimize the demand for strategic search, and Winocur et al. suggested that the frontal lobes are involved in explicit retrieval only when the cues are ineffective at specifying the target. This suggestion could be tested in the present study by examining the effect of manipulating the nature of the cues and the search space. Two-letter stems are poor retrieval cues (Park & Shaw, 1992). Given the variability in frontal lobe function in elderly people, the Winocur et al. suggestion predicts a relationship between frontal lobe function and recall performance for two-letter stems, and any other condition in which the interaction between the cues and the search space makes the retrieval difficult.

Finally, we studied the relationship between tests sensitive to medial–temporal functioning and explicit and implicit stem-completion performance. In line with previous findings (Winocur et al., 1996), we expected that performance on the neuropsychological measures of explicit memory would correlate with word-stem completion recall performance but not with performance on the implicit version of word-stem completion.

**Method**

**Participants**

A total of 39 participants were included in the study (mean age = 77.3 years; range = 66–87 years). All participants lived in their own homes, and they had a relatively high level of education (mean years of formal schooling = 13.6, range = 8–22). Participants were administered the vocabulary test of the Wechsler Adult Intelligence Scale, and only individuals scoring in the normal range or above were included (absolute mean score for the final sample = 49.4, range = 32–61).
Neuropsychological tests

Wisconsin Card Sorting Test (WCST). Participants sorted cards showing multidimensional drawings into different categories (cf. Milner, 1964). Total errors (WSTE) and perseverative errors (WSEP) are reported (Table 1).

Word Fluency. Participants orally generated words beginning with F, A, and S. One minute was allowed for each letter (cf. Borkowski, Benton, & Spreen, 1967). The total number of words produced in response to all three letters are reported in Table 1.

California Verbal Learning Test (CVLT). Four words from four different categories were read aloud in a mixed order (1 word per second). Immediately following the presentation, the participants freely recalled words in any order. This procedure was repeated five times (cf. Delis, Kramer, Kaplan, & Ober, 1987). The total number of words recalled across the five trials are reported in Table 1.

Delayed recall. A list of 10 familiar words was visually presented (each word was written in black on white index cards and shown to the participants at a rate of 2 s per word). At study, the participants were instructed to try to remember the words for a subsequent test. Following a 60-s retention interval, during which participants counted backwards by threes from a three-digit number, the participants freely recalled words in any order. This procedure was repeated three times with different lists. The average number of recalled words across the three trials is reported in Table 1.

Memory Tests

Materials. Fifteen 20-item lists were constructed with 20-word list and instructed to try to remember as many words as possible for a later unspecified memory test. In the primed and unprimed word-stem completion conditions, participants were instructed to complete word stems written on a response sheet with the first word that came to mind. For the animal lists, they were instructed to complete the stems with the first animal name that came to mind. In the recall condition, participants were instructed to complete word stems written on a response sheet with words from the prior study list.

Results

The performance levels in the different word-stem completion and recall conditions are summarized in Table 2. It is evident that the word-stem completion scores were higher than the baseline performance in all conditions. The priming effect was statistically evaluated with one-tailed t tests and was found to be reliable in all conditions (all ts > 4.0, all ps < .001).

The correlation coefficients between neuropsychological test performance and priming measures on the stem-completion tests are shown in Table 3. In line with previous findings (Winocur et al., 1996), baseline scores did not correlate strongly with neuropsychological test performance. The only significant correlation, between word fluency performance and baseline completion rate, occurred in the animal condition.

With a few exceptions, word-stem completion was generally weakly correlated with neuropsychological test performance. In line with our predictions, word fluency performance was significantly correlated with priming in the 3–10 condition and showed a trend toward significant (p < .10) correlation with priming in the 2–3 condition. The baseline completion rates in these conditions did not correlate with word fluency performance, suggesting that the significant correlation indeed reflects a relationship between priming and word fluency. Moreover, WCST performance (total as well as perseverative errors) correlated significantly with priming in the animal condition, whereas the correlation

Table 2
Mean Proportions of Correct Completions on Baseline, Word-Stem Completion, and Word-Stem Cued Recall as a Function of Condition

<table>
<thead>
<tr>
<th>Measure</th>
<th>3-10</th>
<th>2-10</th>
<th>3-3</th>
<th>2-3</th>
<th>Animal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>.15</td>
<td>.05</td>
<td>.67</td>
<td>.32</td>
<td>.83</td>
</tr>
<tr>
<td>SD</td>
<td>.10</td>
<td>.05</td>
<td>.09</td>
<td>.14</td>
<td>.11</td>
</tr>
<tr>
<td>WSC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>.30</td>
<td>.11</td>
<td>.80</td>
<td>.49</td>
<td>.90</td>
</tr>
<tr>
<td>SD</td>
<td>.13</td>
<td>.08</td>
<td>.10</td>
<td>.19</td>
<td>.08</td>
</tr>
<tr>
<td>WSCR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>.39</td>
<td>.13</td>
<td>.82</td>
<td>.48</td>
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<tr>
<td>SD</td>
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<td>.09</td>
<td>.11</td>
<td>.18</td>
<td>.09</td>
</tr>
</tbody>
</table>

Note. 3-10 = 3-letter stems with a minimum of 10 completions; 2-10 = 2-letter stems with a minimum of 10 completions; 3-3 = 3-letter stems with a maximum of 3 completions; 2-3 = 2-letter stems with a maximum of 3 completions; Animal = 3-letter stems with a minimum of 10 completions that were to be completed with the name of an animal.
Table 3
Pearson Correlations Between Neuropsychological Test Performance and Baseline, Word-Stem Completion (WSC), and Word-Stem Cued Recall (WSCR) as a Function of Condition

<table>
<thead>
<tr>
<th>Measure</th>
<th>Condition</th>
<th>3-10</th>
<th>2-10</th>
<th>3-3</th>
<th>2-3</th>
<th>Animal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>FAS</td>
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<td>.05</td>
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<td>.27</td>
<td>.04</td>
<td>.35*</td>
</tr>
<tr>
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<td>.04</td>
<td>.05</td>
<td>.00</td>
<td>-.25</td>
<td>.07</td>
</tr>
<tr>
<td>CVLT</td>
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<td>-.08</td>
<td>-.19</td>
<td>.11</td>
<td>.09</td>
<td>-.06</td>
</tr>
<tr>
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<td>.12</td>
<td>-.30</td>
<td>-.17</td>
<td>-.25</td>
<td>-.01</td>
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<td>WCTE</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>.30</td>
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</tr>
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<td>.15</td>
<td>.16</td>
<td>.25</td>
</tr>
<tr>
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<td>.07</td>
<td>.04</td>
<td>.23</td>
<td>.22</td>
</tr>
<tr>
<td>WCPE</td>
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<td>-.20</td>
<td>.13</td>
<td>-.04</td>
<td>-.45*</td>
</tr>
<tr>
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<td>-.17</td>
<td>.08</td>
<td>.00</td>
<td>-.44*</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAS</td>
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<td>.38*</td>
<td>.44*</td>
<td>.28</td>
<td>.52*</td>
<td>.47*</td>
</tr>
<tr>
<td>DR</td>
<td></td>
<td>.36*</td>
<td>.00</td>
<td>.30</td>
<td>.30</td>
<td>.05</td>
</tr>
<tr>
<td>CVLT</td>
<td></td>
<td>.03</td>
<td>.19</td>
<td>.04</td>
<td>.32</td>
<td>.34*</td>
</tr>
<tr>
<td>WCPE</td>
<td></td>
<td>.00</td>
<td>-.21</td>
<td>-.21</td>
<td>-.02</td>
<td>-.03</td>
</tr>
<tr>
<td>WCTE</td>
<td></td>
<td>-.03</td>
<td>-.19</td>
<td>-.17</td>
<td>-.04</td>
<td>.02</td>
</tr>
</tbody>
</table>

Note. FAS = word fluency; DR = delayed recall; CVLT = California Verbal Learning Test; WCPE = perseverative errors on Wisconsin Card Sorting Test; WCTE = total errors on Wisconsin Card Sorting Test.

*p < .05.

between WSPE and priming in the 3–10 condition just missed statistical significance (p < .10).

The strongest correlations between neuropsychological and stem-completion performance were observed in the explicit condition. Word fluency scores were significantly correlated with performance in four of the five conditions and showed a trend toward significant correlation (p < .10) with performance in the fifth condition (3–3). Furthermore, in line with our expectations, there were generally substantial positive correlations between at least one of the neuropsychological tests of explicit memory (CVLT, delayed recall) and recall of word-stem completion. Delayed recall showed a significant correlation with word-stem completion recall in the 3–10 condition, and correlations with word-stem completion recall approached significance in the 2–3 and 3–3 conditions (p < .10). The correlation between CVLT and word-stem completion recall was significant in the animal condition and approached significance in the 2–3 condition (p < .10).

Discussion

The main finding of this study was that a neuropsychological measure of frontal lobe functioning (word fluency) was correlated with both explicit and implicit stem-completion performance. On the basis of previous proposals that frontal involvement in implicit stem completion indicates some kind of bias detection mechanism (Winocur et al., 1996), we predicted a stronger relationship between word fluency and stem-completion priming when the interaction between cue constraints and the size of the search space provided an opportunity for such a mechanism to play a role.

The results supported this prediction by showing a significant relationship in the 3–10 condition and a marginally significant relationship in the 2–3 condition. In the former condition, the specification of three letters in the cue constrained the search and detection processes in the larger search space. In the latter condition, although the search space was quite limited, the less constrained cue made search and detection processes critical. Hence, in both of these conditions, there should have been a need for some kind of bias detection, and, at the same time, the retrieval conditions should have been constrained enough for it to show up. In contrast, in the 3–3 and animal conditions, which were heavily constrained in terms of number of letters specified in the cues as well as the search space, there should have been less need for bias detection. Finally, in the 2–10 condition, the retrieval condition may have been too unconstrained for the bias from the prior study episode to be detected.

Taken together, these findings provide a basis for understanding frontal involvement in primed stem completion. This involvement is not "strategic" in the sense traditionally associated with frontal lobe functioning, in that the search process is not guided by conscious strategies. Nevertheless, there is an overriding supervisory role of the frontal lobes in eliciting cue-appropriate responses and in monitoring and detection. With regard to understanding the mechanisms involved, it is useful to contrast the role of the frontal lobes in stem-completion priming with their lack of involvement in fragment completion (see Winocur et al., 1996). In fragment completion, the randomly organized letter cues afford little opportunity for directed search in the lexicon, and priming is based on perceptual matching in which one response fits the fragment. By comparison, because initial stems provide a good entry into the lexicon, tests of stem completion recruit frontal lobe involvement in implementing the process that elicits a range of possible candidates from the lexicon. Because the various possibilities compete with each other, the frontal lobes also may be necessary for establishing priorities for response selection, based on levels of activation. Priming raises the level of activation, giving the studied item a high priority (see Postle & Corkin, 1996, for a similar view of stem-completion priming). This frontally mediated process of response selection may be further enhanced by inhibitory mechanisms that reduce the likelihood of responding with competing words. This view is consistent with previous findings of frontal lobe involvement in implicit tasks (Grafton, Hazeltine, & Ivry, 1995; Mayes & Gooding, 1989; Shallice, 1982). These processes are most effective when the combination of letter-cue constraints and search space is conducive to frontal lobe involvement, as in the 3–10 and possibly 2–3 conditions. When cues are highly constraining and the search space is small (i.e., Condition 3–3), there is no need for further frontal contribution, and performance on stem completion resembles that of fragment completion. When search space is very large (i.e., Condition 2–10), far too many candidates become available so that even frontal lobe
involvement is not helpful in establishing priorities among them. The idea that the interaction of cue constraints determines the degree of frontal involvement predicts that the level of priming should be low when the search space is large and the cue information is limited. Our results supported this prediction by showing significantly lower priming in the 2–10 condition than in three of the four conditions. (The only exception was for the animal condition, which may be related to the high baseline level in this condition.)

In demonstrating that cue constraints and number of response alternatives determine the degree of frontal involvement in stem completion, the present results have implications for other paradigms. Following our interpretation of these results, we would predict similar effects for word-fragment completion if there were multiple, rather than single, solutions to the fragment. A recent finding by J. Gabrieli (personal communication, June 1996), involving divided attention and word-fragment completion, provides direct support for this idea. Because of their strategic nature, frontal lobe functions demand attentional resources. Consequently, dividing attention at study should affect performance on tasks dependent on frontal lobe involvement, but not on those that do not. Consistent with our prediction, Gabrieli found that priming on a word-fragment completion test was reduced by dividing attention at study for fragments with multiple solutions, but not for those with a unique solution. To be fully in line with our predictions, comparable results should be obtained when attention is divided at test. The latter prediction has yet to be tested.

It should be noted that all the frontally mediated processes discussed above occur at a nonconscious level both at search and at retrieval. On the other hand, frontal involvement on explicit tests differs from that on implicit tests in two ways. In explicit tests, (a) the initial search and subsequent monitoring of available responses is under conscious guidance, and (b) possible responses are compared not with activated items in the lexicon but with contextually bound episodic memory records elicited from the medial temporal lobes. (See Nyberg et al., 1996, for direct evidence of increased activation in medial temporal lobes during episodic memory retrieval.) As a result, the relationship between frontal lobe test performance and explicit stem completion was substantial in all conditions. As with implicit stem completion, frontal involvement in explicit stem completion may be related to bias detection but, as indicated above, with regard to episodic memory records rather than items from the lexicon. The generally stronger correlations between word fluency and stem-cued recall suggest that the relationship also reflects an additional component. In keeping with previous proposals, we argue that this component may be related to consciously controlled, strategic search processes (e.g., Moscovitch, 1992).1

The finding of a strong relationship between word fluency and explicit stem completion is not in line with the Winocur et al. (1996) finding that word fluency and explicit stem completion were not correlated. However, as noted in the introduction, Winocur et al. proposed that the frontal lobes are involved in explicit retrieval only when the retrieval cues are inadequate (cf. Moscovitch, 1992). A comparison of the performance levels for the three-letter stem conditions in the present study (explicit baseline score = .24 and .15) and the corresponding score in the Winocur et al. study (.38) shows that the performance was markedly lower in the present experiment. At the same time, the performance levels on the standard tests of explicit retrieval (CVLT, delayed response) were almost identical in the two studies. This suggests that the recall test was more difficult in the present study and, consequently, may have involved more strategic search processes.

The finding of correlations between word fluency and word-stem completion and recall of word-stem completion suggests that, at least under certain conditions, both explicit and implicit stem completion rely on the integrity of the frontal lobes. It is important to point out, though, that the many experimental (e.g., Graf & Mandler, 1984), statistical (e.g., Hayman & Tulving, 1989), and neurological (e.g., Graf, Squire, & Mandler, 1984) dissociations between explicit and implicit word completion suggest the additional involvement of distinct brain regions. Implicit stem completion may additionally engage a structural–perceptual system involving the occipital lobes (cf. Keane et al., 1991; Squire et al., 1992). Explicit stem completion may additionally rely on a recollection system involving, as suggested above, medial–temporal brain regions. Support for this comes from the present finding of stronger correlations of neuropsychological tests of medial–temporal functioning with explicit stem completion than with implicit stem completion. A similar pattern of results was reported by Winocur et al. (1996).

The present results are consistent with other studies that demonstrated a significant correlation between stem-completion priming in the elderly (Winocur et al., 1996) and in various patient populations (Borkowski, Benton, & Spreen, 1967; Davis et al., 1990). A prediction that follows from these findings is that patients with discrete frontal lobe lesions should exhibit below-normal levels of priming on a stem-completion task. In fact, Shimamura, Gershberg, Jurica, Mangels, and Knight (1992) found normal priming on such a task in a group of patients with focal lesions in the frontal lobes, and similar results have been reported for patients with Parkinson's or Huntington's disease who were thought to have frontal lobe damage. This apparent discrepancy may relate, in some cases, to procedural variations and, in others, to lack of information regarding relationships between stem completion and performance on standard frontal lobe tests.

Another interesting possibility is suggested by evidence

1 The relationship between explicit and implicit stem completion in the present experiment was weak. However, one significant correlation was observed in the 2–10 condition (p < .05). Performance in the explicit version of this condition was uncorrelated with the standard tests of explicit retrieval. Together, these observations indicate that participants may have relied on implicit retrieval strategies in both the implicit and explicit conditions. Possibly, this is because two-letter stems are very poor cues to guide explicit retrieval (cf. Park & Shaw, 1992).
that, following damage to frontal lobes, functions associated with the affected area may be taken over by other brain regions. Buckner and colleagues (Buckner, Petersen, Ojemann, et al., 1995; Buckner, Petersen, & Raichle, 1995) found activation in left prefrontal cortex in stem-completion tasks that resembled the priming tasks used in the present study and in the Winocur et al. (1996) study. Buckner, Corbetta, Schatz, Raichle, and Petersen (1996) followed their observations by investigating a patient who, following an ischemic stroke, suffered damage to the left frontal area involved in stem-completion performance. The patient, although impaired on other tests of frontal lobe function, performed normally on stem completion. Using positron emission tomography, the investigators found increased activation in a preserved part of the right prefrontal cortex that is not normally activated during word-stem completion. This evidence suggests that, following damage to frontal lobe regions, some tasks may be performed by adopting strategies that are controlled elsewhere in the brain or that a compensatory mechanism for recovering lost functions may be built into other brain regions. With respect to stem completion, it may be that these adjustments occur only in cases of relatively severe damage; structural changes associated with normal aging may not be sufficient to trigger compensatory mechanisms for performing this task, leaving the older individual to resort to preferred, but impaired, strategies. Although speculative, this notion is consistent with other evidence that relatively intact brain regions are recruited to take over cognitive functions that are lost as a result of damage in other brain areas (Cabeza et al., 1996; Grady et al., 1994).

In conclusion, the present study strengthens the case for an involvement of the frontal lobes in implicit stem completion (Keane et al., 1991; Mayes & Gooding, 1989; Winocur et al., 1996), and it suggests that the role of the frontal lobes in implicit stem completion is related to detection of bias in the word system resulting from the prior study episode. Thus, findings of greater facilitation on stem completion of younger than older adults do not necessarily reflect an impaired perceptual system for the elderly. Instead, such findings may reflect an age-related impairment of frontally mediated processes that are critical for successful task performance.

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Received January 3, 1996
Revision received June 11, 1996
Accepted June 11, 1996