Word Stem Priming in Unilateral Stroke Patients: Word Type and Laterality Effects

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We explored word type and lesion laterality effects in visual word stem completion priming. Participants were 24 stroke patients (12 left, 12 right) and 11 non-brain damaged, medical controls. Participants studied 32 threatening and 32 nonthreatening words and completed cued recall and word stem priming tasks (Mathews, Mogg, May, & Eysenck, 1989). Stroke groups had lower cued recall than controls and the right hemisphere damaged group was lower in cued recall than the left. Word type did not affect cued recall. Groups were comparable in word stem priming, and there was a word type effect such that more nonthreatening than threatening words were produced. No laterality effects were found in word stem priming. Implications for models of how words are processed during word stem priming are discussed. © 1997 National Academy of Neuropsychology

Implicit memory refers to the facilitative effect of prior stimulus exposure on subsequent processing of the same stimulus even when participants are not required or able to recollect the prior exposure (Keane, Gabrieli, Fennema, Growdon, & Corkin, 1991; Schacter, Chiu, & Ochsner, 1993). This is in contrast to explicit memory which refers to conscious, intentional recall of previously presented stimuli. A dissociation between implicit and explicit memory has been demonstrated in both normal and brain damaged samples. Warrington and Weiskrantz (1974) compared normal and amnesic participants and found that while amnesic participants performed significantly worse on explicit recall tasks, they were comparable to normals in implicit memory. This finding has been replicated in a variety of normal, neurologic, and psychiatric populations (Danion, Willard-Schoeder, Zimmermann, Grange, Schlienger, & Singer, 1991; Keane et al., 1991; Marsolek, Kosslyn, & Squire, 1992; Mathews et al., 1989; Schacter et al., 1993).

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Word stem completion priming tasks are commonly used to study implicit memory (Schacter et al., 1993). For example, in a typical word stem priming experiment, participants are presented with a list of words on which they perform a processing task during a study phase (e.g., rating the pleasantness of each word). In a later test phase, they are given word stems of three initial letters. Each word stem has several possible completions, only one of which would produce a word from the previous list. Participants are asked to complete the word stems with the first word that comes to mind and are not informed that any of the word stems are from the previous list. Priming is demonstrated when participants produce completions consistent with words that were previously presented.

A distinction can be made between perceptually and conceptually-driven priming tasks (Schacter et al., 1993; Srinivas & Roediger, 1991). In perceptually-driven tasks, priming is based on the match between the physical features of the study and test stimuli. In contrast, priming in conceptually-driven tasks is based on the match between the semantic aspects of the study and test stimuli.

There has been debate in the literature on the degree to which tasks such as word stem completion are perceptually or conceptually-driven. Schacter has argued that word stem completion is largely perceptually-driven (Schacter, 1990; Schacter et al., 1993), however, evidence from studies of priming in Alzheimer’s patients suggests this may not be the case. The degree of priming in Alzheimer’s patients varies with the type of priming task. For example, Alzheimer’s patients have shown normal priming effects on incomplete-picture and word identification tasks but reduced priming on word stem completion tasks (Keane et al., 1991).

The dissociation seen in Alzheimer’s patients may be understandable in terms of the differing processes underlying perceptual and conceptual priming. Tulving and Schacter (1990) proposed that a presemantic perceptual representation system (PRS) underlies perceptual priming. The PRS for visual word forms contains modality specific information about word form and structure, but not meaning (Schacter et al., 1993). The PRS appears to be identical to Gabrieli’s (cited in Keane et al., 1991) “structural-perceptual memory system.” Gabrieli further suggested that a lexical-semantic system, which is part of semantic memory, supports conceptual priming. Reduced word stem completion performance may occur in Alzheimer’s disease patients because this task includes a conceptual component which poses difficulty for them.

The current study examined two issues related to the nature and lateralization of word stem priming. The first issue was the impact of word type on word stem priming. Using threatening and nontargeting stimuli, word type effects on word stem priming have been reported in anxiety disordered participants (Mathews et al., 1989; Zeitlin & McNally, 1991). Mathews et al.’s (1989) normal controls primed more nontargeting words while their anxious participants showed a trend towards greater priming of threatening words. Similarly, Zeitlin and McNally (1991) reported a word type effect in post-traumatic stress disordered participants who primed more combat words than positive, neutral, or social threat words.

These latter two studies suggest that more than just visual orthographic information is processed during word stem priming. In order for the emotional valence of the words to impact priming, the meaning of the stimuli must have been accessed or processed. This further supports the notion proposed by Keane et al. (1991) that word stem priming may include a semantic or conceptual component.

The second issue examined in this study was the laterality of priming effects. Marsolek et al. (1992) compared priming effects for stimuli presented in the left vs. right visual half-fields. A left visual half-field (right hemisphere) advantage was found for word stem priming when modality of presentation and letter case remained constant across study and test phases. In contrast, no laterality effects were found when study and test stimuli differed
TABLE 1
Means and Standard Deviations for Participant Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Left Hemisphere</th>
<th>Right Hemisphere</th>
<th>Medical Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>M 72</td>
<td>M 64</td>
<td>M 60</td>
</tr>
<tr>
<td></td>
<td>(10.34)</td>
<td>(14.39)</td>
<td>(11.84)</td>
</tr>
<tr>
<td>Education</td>
<td>M 13</td>
<td>M 14</td>
<td>M 15</td>
</tr>
<tr>
<td></td>
<td>(3.58)</td>
<td>(2.35)</td>
<td>(2.53)</td>
</tr>
<tr>
<td>Gender</td>
<td>6 Male</td>
<td>7 Male</td>
<td>2 Male</td>
</tr>
<tr>
<td></td>
<td>6 Female</td>
<td>5 Female</td>
<td>9 Female</td>
</tr>
</tbody>
</table>

in letter case. For explicit cued recall, no right hemisphere advantage was obtained. A reduction in blood flow to the right extrastriate cortex also has been found during visual word stem priming (Squire, Ojemann, Miezin, Petersen, Videen, & Raichle, 1992).

These results with normal participants suggest a right hemisphere advantage for visual word stem priming. The right hemisphere superiority may reflect processing of the words as visual orthographic units by the PRS, which presumably would also be located in the right hemisphere. Clearly, the perceptual aspects of word stem priming are emphasized in these studies with normal subjects. This contrasts with recent research with brain damaged samples that has emphasized both perceptual and conceptual aspects of word stem priming. Further exploration of these issues, particularly in unilateral brain damaged participants, may be useful in determining the extent to which word stem priming is associated with the right hemisphere.

In the present study, we further explored the effect of word type and hemispheric lateralization on priming. Specifically, we examined word stem completion of threatening and nonthreatening words in unilateral stroke patients and non-brain damaged, medical controls. We hypothesized that:

1. Both left and right hemisphere stroke participants would be impaired in cued recall compared to medical controls.
2. A word type effect would be found in word stem priming (i.e., a difference in the amount of priming of threatening and nonthreatening words).
3. Right hemisphere stroke participants would show less word stem priming than left hemisphere stroke or medical control participants.

METHOD

Participants

Table 1 summarizes the demographic characteristics of the three groups of participants (left hemisphere stroke—LHS, right hemisphere stroke—RHS, and medical controls—MC). All participants were inpatients at a rehabilitation center located in a large Southeastern United States medical school. Participants were selected based on the following criteria: at least a 9th grade education, reported right-handedness, English as a first language, and no history or current symptoms of aphasia as determined by their admittingphysiatrist. The stroke groups contained approximately equivalent numbers of males and females, while the control group had more females than males. In addition, medical controls had to show no evidence of brain damage in their routine medical admission examinations. Controls consisted of amputees and patients with orthopedic or spinal cord injuries. Consequently, gender differences in explicit and implicit memory were only examined in the stroke patients.
A one-way analysis of variance revealed a difference among groups in age, \( F (2, 32) = 3.26, p = .05 \), but not education, \( F (2, 32) = .997 \). Newman-Keuls post-hoc analysis showed that the LHS group was significantly older than the MC group. Consequently age was used as a covariate in subsequent data analyses.

Medical records were reviewed by the authors to obtain diagnostic and lesion lateralization and localization data. Lesion lateralization data were available for all stroke participants and all had clearly lateralized lesions. Lesion localization data were available from written CT scan and EEG reports for 14 of the 24 stroke participants. Four of the left hemisphere participants had multiple brain lesions compared to three of the right hemisphere participants. Cortical areas that were damaged included frontal (three participants), temporal (five participants), parietal (seven participants), and occipital (one participant) lobes. Subcortical areas damaged included the thalamus (two participants), basal ganglia (two participants), internal capsule (two participants), and centrum semiovale (one participant). Hence, the groups appeared to be representative of the general stroke population. Controls had no evidence of brain damage in routine medical admission examinations and consisted of amputees and patients with orthopedic or spinal cord injuries.

**Measures**

**Word list stimuli.** Three word sets (designated A, B, and C) developed by Mathews et al. (1989) were used in the current study. Each word set consisted of 64 words, including 32 threatening (e.g., “mutilated,” “ridicule”) and 32 nonthreatening (e.g., “confident,” “scarf”) words. Each word had a unique stem (i.e., the first three letters of the word). The three word sets were matched for word frequency, word length, and the number of alternative words that could be generated for each stem. The complete word sets are available in Mathews et al., (1989).

**Mood measures.** The participants’ levels of depression and anxiety were measured to control for possible influence of mood state on memory. The Beck Depression Inventory (BDI) (Beck & Steer, 1987) and the state portion of the State-Trait Anxiety Inventory (STAI) (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) were administered orally. To make the instructions for these measures consistent, participants were asked to indicate their anxiety and depression symptoms based on their feelings within the past week and including the day of the experimental procedures.

**Procedure**

The study and memory test procedures developed by Mathews et al. (1989) were modified as described below for use with our medical population. All procedures were individually administered.

**Study phase.** Participants from each group were randomly assigned to word sets A, B, or C. The 64 words in the set were presented via computer, one word at a time. Each word appeared in the center of the screen for a 10-second interval. To obviate any potential influence of differing visuoperceptual ability, the experimenter read the word aloud while participants read the word silently. Participants rated the word for pleasantness on a 1–5 scale, with 1 corresponding to extremely unpleasant and 5 to extremely pleasant. Responses were recorded by the experimenter. Two practice trials using non-set words were presented prior to the study trials.
Memory test phase. Following the study phase, participants performed a 2-minute filler task (detecting target numbers and shapes on a page). Participants then completed cued recall (explicit memory) and word stem priming (implicit memory) tasks in counterbalanced order, separated by the same 2-minute filler task.

In the cued recall task participants were presented with 32 word stems, one at a time, for half of the study phase words. Participants were instructed to complete these stems by recalling words they had rated for pleasantness during the study phase. In contrast, the priming task utilized 64 word stems, 32 from the remaining half of the study phase words and 32 control word stems. (Control word stems were based on words that had not been viewed during the study phase). Participants were told to respond with the first word that came to mind. Specifically, if the presented set was A and the cued recall task used half of list A, then the priming task used the other half of A and an equal number of control words from one of the other sets (B or C).

In both memory tasks, word stems were presented by the computer in a fixed random order, one at a time, for a 10-second interval. Participants read the word stems silently while the experimenter read the individual letters of the stems aloud and recorded all responses. Letter case was kept constant across study and test phases. Subject responses were considered correct if the root of their response word was the same as the target word.

RESULTS

Mood State

Mean STAI scores for the LHS, RHS, and MC groups were 36.83 (SD = 11.27), 46.60 (SD = 16.14), and 35.60 (SD = 8.54). The corresponding mean BDI scores for these groups were 10.58 (SD = 6.37), 17.50 (SD = 15.13), and 6.18 (SD = 3.97). A one-way analysis of variance revealed no significant difference among groups in state anxiety, $F(2,29) = 2.82$. Groups did differ, however, in BDI scores, $F(2,32) = 3.86$, $p = .03$, with Newman-Keuls post-hoc analysis showing that the right hemisphere group reported higher levels of depression than the medical controls ($p = .026$). The LHS and RHS groups did not differ significantly from each other in level of depression. The BDI score was used (in addition to age) as a covariate in all subsequent group comparisons to control for any influence of mood on memory.

Study Task

To verify that words were initially processed by each group, we examined the number of words participants failed to rate within the 10-second time limit. Mean words missed by the LHS, RHS, and MC groups were .92 (SD = 1.68), 1.25 (SD = 1.82), and .27 (SD = .90). Groups did not differ significantly, $F(2,30) = .16$, on this variable. Consistent with previous research using this task (Mathews et al., 1989), threatening words ($M = 1.54$, $SD = .55$) were rated as significantly less pleasant, $t (34) = 26.59$, $p < .001$, than nonthreatening words ($M = 4.03$, $SD = .33$). Groups did not differ significantly in their pleasantness ratings of threatening, $F(2,30) = .33$, or nonthreatening, $F(2,30) = 1.98$ words.

Cued Recall

The mean number of threatening and nonthreatening words recalled by each group are presented in Table 2. A 3 (group) x 2 (word type) analysis of covariance (using age and BDI scores as covariates) revealed a statistically significant main effect for group, $F(2,30) = 4.76$, $p = .02$. Newman-Keuls post-hoc analysis showed that all three groups differed significantly
from each other in cued recall ($p < .04$), with the MC group recalling the most words, followed by the LHS group, and lastly the RHS group. No statistically significant word type effect was found, $F(1,30) = 1.52$, indicating that stimulus emotional valence did not influence cued recall. The group X word type interaction effect also was not significant, $F(2,30) = 1.02$.

**Word Stem Priming**

The mean number of threatening and nonthreatening words produced by each group during the word stem priming task are presented in Table 3. Also included are the number of threatening and nonthreatening words produced that matched the nonpresented control words. Priming rates for the left hemisphere, right hemisphere, and medical control groups were 22%, 15%, and 20%. Paired t-tests demonstrated a significant priming effect for each group. In other words, more completed word stems corresponded to study phase words than to nonpresented control words. For LHS participants, $t(10) = 5.75, p = .001$, for the RHS group, $t(10) = 4.61, p = .001$, and for the MC group, $t(9) = 3.46, p = .006$.

To explore word type effects in priming, a 3 (group) X 2 (word type) analysis of covariance (using age and BDI) was performed with number of words primed as the dependent variable. Results showed no main effect for group, $F(2,30) = 1.78$, but there was a main effect for word type, $F(1,30) = 8.66, p = .006$, such that more nonthreatening than threatening words were primed. No significant interaction between group and word type was found, $F(2,30) = 2.62$.

**Gender**

Analysis of covariance (using age and BDI) revealed no effect of gender in either the cued recall [$F(1,20) = 0.61$] or word stem priming [$F(1,20) = 0.04$] performance of the stroke participants. Meaningful analysis of gender differences in the control participants was not possible due to the disproportionate number of male and female controls.

**DISCUSSION**

In the current study, participants with unilateral right or left-sided strokes showed lower explicit cued recall performance compared to medical controls who were not brain damaged. This finding confirms our first hypothesis that patients with lateralized lesions would be impaired in cued recall. Right hemisphere stroke participants unexpectedly showed lower cued recall performance compared to left hemisphere stroke participants. This could be due to our subject selection procedure. Right hemisphere participants may have had more extensive brain damage compared to the left hemisphere participants since we eliminated participants with aphasia due to the verbal demands of the experimental tasks.
All groups in the current study showed a significant priming effect on the word stem completion task. The current study thus replicates the dissociation between explicit and implicit memory that has been demonstrated in normal, psychiatric, and other neurologic samples and the finding that brain damage impairs cued recall but does not typically impair word stem priming (Danion et al., 1991; Keane et al., 1991; Marsolek et al., 1992; Matthews et al., 1989; Schacter et al., 1993).

A significant word type effect in priming was found, thus supporting our second hypothesis. More nonthreatening than threatening words were produced during the priming task across groups. This finding cannot be attributed to differences in word frequency or length as the word lists were balanced on these factors. As the threat value of the words was conveyed only by their meaning, our results and previous reports (Mathews et al., 1989; Zeitlin & McNally, 1991) suggest that semantic information is processed during word stem priming.

These results, therefore, shed light on the nature of word stem priming tasks. If word stem priming is mediated by an exclusively presemantic perceptual representation system (Schacter et al., 1993), then an effect of word type would not be found. Word stem priming tasks must be influenced by the output of additional systems that process meaning.

Our findings are consistent with reports of a dissociation between perceptual priming tasks (e.g., incomplete picture or word identification) and word stem priming in Alzheimer’s disease samples (Keane et al., 1991). More recent research (Winocur, Moscovitch, & Stuss, 1996) also demonstrated a dissociation between the more perceptually-based word fragment completion task and word stem priming. The latter dissociation was hypothesized to arise because generative search strategies influence word stem priming more than they influence purely perceptual priming tasks.

Hence, there is converging evidence that the brain utilizes more than just perceptual information during word stem priming. The results of our study add further support to the notion that word stem priming tasks have a conceptual component. Implicit memory in general, and word stem priming in particular, need to be reconceptualized to include the role of semantic processing and search strategies.

Conversely, it has been argued that the apparent role of semantic information in priming is actually due to contamination by explicit recall (Schacter, Alpert, Savage, Rauch, & Albert, 1996). On word stem completion tasks, participants may explicitly recall study list words, thereby inflating the number of words produced during priming. For example, Squire et al. (1992) reported greater than 70% priming of studied words. Priming rates tend to be lower when encoding tasks are designed to decrease the likelihood of contamination by explicit
memory. For example, Schacter et al. (1996) reported priming rates of 30% when participants performed a nonsemantic encoding task. Although we used a semantic encoding task, our priming rates (e.g., an average of 19% across groups) were even lower than those reported by these latter researchers. Therefore, it seems unlikely that explicit memory contamination occurred.

One question that arises from our results is why no word type effect, based on emotional valence, was evident in cued recall performance. Few studies have examined the effect of emotional valence in cued recall vs. word stem priming. Of those that have examined this issue, some have found a word type effect for both (e.g., Zeitlin & McNally, 1991), while others have found the effect only in priming (Mathews et al., 1989). Our finding of a word type effect in priming, but not cued recall, supports our contention that our word stem completion task was not contaminated by explicit memory.

It can be hypothesized that a word type effect occurred in priming, but not cued recall, in our study because some aspect of the procedure made it more likely for participants to initiate lexical-semantic processing during priming. It should be noted, however, that participants performed the same processing task for all words during the study phase and had no way of knowing which words would later be used in the cued vs. primed conditions. Therefore, it is unlikely that differential processing of the words would have occurred.

A simpler explanation of the lack of a word type effect in cued recall may lie in the type and amount of semantic information available during priming vs. cued recall. Previous studies suggest that at most a limited amount of semantic information is available during priming (Schachter et al., 1993). If more complete semantic information is available to guide cued recall, stimulus emotional valence may not be a prominent factor in performance. Emotional valence may, however, assume a greater role during priming because other semantic information is not available.

This is similar to the proposal by Winocur et al. (1996) of a role for generative search strategies in priming. They found a correlation between presumed tests of frontal lobe function and implicit but not explicit word stem completion. These investigators argue that strategic processes, presumably mediated in the frontal lobe, can become operative in either explicit or implicit memory when access to a memory trace is not automatic. Applying this argument to our results would lead to the conclusion that the word type effect in priming reflects the activation of strategic processes, because the word stems were not sufficient to permit automatic access to memory traces. In contrast, word stems may have provided sufficient cues to permit memory traces to be directly accessed during cued recall.

Our results did not support our third hypothesis that right hemisphere stroke participants would show less word stem priming as there was no significant difference among groups on this task. This hypothesis was based on previous reports of a right hemisphere advantage for form-specific word stem priming in normal participants (Marsolek et al., 1992; Squire et al., 1992). Our findings, therefore, do not appear to support the notion of a right hemisphere advantage for this type of priming task in brain damaged participants.

The lack of a hemisphere effect could indicate that right hemisphere areas specifically involved in word stem priming were spared in our stroke sample. Recent studies suggest a possible association of priming with specific brain regions; perceptual priming with the occipital lobe (Schacter et al., 1996; Squire et al., 1992) and nonperceptual (e.g., conceptual) priming with the frontal lobe (Winocur et al., 1996) or possibly with the hippocampus (Squire et al., 1992). Since precise localization data were not available for many of our stroke patients, we can only speculate that areas critical to word stem priming may have been spared in our sample.

In summary, the current investigation demonstrated a word type effect in priming in unilateral stroke patients and added support to the hypothesis that one particular priming task,
word stem completion, includes both perceptually and conceptually-driven components. Investigation of word type effects in other priming tasks may further clarify the nature of the systems that process semantic information during priming. Limitations of the current study include a relatively small sample size and lack of precise lesion localization data for all participants. Hence, replication of the current results is needed. A more complete understanding of the lateralization and localization of the processing systems involved in priming is likely to come from studying patients having clearly established lesion localizations. In particular, participants with focal occipital, frontal, or hippocampal lesions should be included in future studies.

REFERENCES


