BRIEF REPORTS

Selection demands versus association strength in the verb generation task

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Neuroimaging and neuropsychological data from Thompson-Schill and colleagues (Thompson-Schill, D'Esposito, Aguirre, & Farah, 1997; Thompson-Schill et al., 1998) showed that in the verb generation task, the left inferior frontal gyrus (left IFG) was more involved in a high-selection condition, in which the noun had two verb responses of equal association strength, than in a low-selection condition, in which the noun had only one strongly associated verb. They proposed that the left IFG was involved in selecting semantic information from competing alternatives. The present study compared verb generation in two high-selection conditions that varied in the association strength of the most frequently produced verbs. The results from neurally intact participants and a patient with a lesion that included the left IFG indicated that association strength between nouns and the most frequently produced verb, rather than competition during verb selection, affected verb generation. The degree of involvement of the left IFG may depend on the difficulty of verb retrieval as reflected in association strength.

The verb generation task has been widely used in behavioral and neuroimaging research to study the retrieval of semantic information. In this task, participants are presented with a concrete noun and are asked to supply a semantically appropriate verb (e.g., *broom* → “sweep”). In neuroimaging studies, areas in the left inferior frontal gyrus (IFG) have often been found to be activated during verb generation and other semantic tasks (e.g., Poldrack et al., 1999), leading some researchers to propose that the left IFG is responsible for the retrieval of semantic information (e.g., Badre & Wagner, 2002; see also Anderson, Qin, Sohn, Stenger, & Carter, 2003). However, Thompson-Schill and colleagues have suggested that it is not the retrieval of semantic knowledge per se but selection among competing alternatives that is associated with left IFG activity (Thompson-Schill, D'Esposito, Aguirre, & Farah, 1997; Thompson-Schill et al., 1998).

In testing the selection hypothesis, Thompson-Schill et al. (1997) compared neural activation for high- and low-selection conditions for three semantic tasks. For example, in their comparison task, the low-selection condition involved making judgments of words' global semantic similarity, whereas the high-selection condition involved making judgments of words' similarity on a particular feature. In order to create the high- and low-selection conditions in their verb generation task, Thompson-Schill et al.

(1997) obtained norms for verb generation in a pretest. Nouns in the low-selection condition were those for which there was one dominant response; specifically, the ratio of the most frequent to the second most frequent verb was 4.0 or greater. Those in the high-selection condition had ratios that were 3.0 or less, indicating that the top two responses were fairly equal in frequency. The results showed that a common region in the left IFG was more activated in high- than in low-selection conditions across their three semantic tasks. In addition, a subsequent study by Thompson-Schill et al. (1998) found that patients with lesions in left IFG had difficulty producing verbs in the high- but not in the low-selection condition.

Other findings, however, have called into question the selection account of these findings. Results from Wagner, Paré-Blagoev, Clark, and Poldrack (2001) raised the possibility that, in the comparison task, weaker association strength between cues and targets in high- than in low-selection conditions may have been the source of the greater activation in left IFG. The present study investigated a similar possibility with regard to the verb generation task. The design of the verb generation task in the Thompson-Schill studies (Thompson-Schill et al., 1997; Thompson-Schill et al., 1998) only took into account the relative frequencies of the two most frequent verbs, and not the absolute value of the association strength between the nouns and verbs. (Association strength can be operationally defined by the proportion of individuals producing a particular verb response.) A check of the stimuli in the Thompson-Schill studies against our verb generation norms (see the Method section) showed that the mean association strength for the most frequently produced verb

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was .43 for the high-selection stimuli and .72 for the low-selection stimuli, a difference that was highly significant [$t(45) = 6.39, p < .0001$].¹ Thus, the greater activity in left IFG in the imaging study and the patients' poorer performance in the high-selection condition could have resulted from the relative difficulty of retrieving a verb in this condition, because the most frequently produced verbs had low association strength relative to those in the low-selection condition.

The association strength hypothesis would fit with Wagner and colleagues' (Badre & Wagner, 2002; Wagner et al., 2001) proposal that prefrontal cortex is involved in controlled but not in automatic semantic retrieval. If the verbs in the high-selection condition have a weaker association strength with the noun, more effort would be required for retrieval, making it a controlled process. In the low-selection condition, the one dominant verb response is strongly associated with the noun, thus rendering retrieval more automatic. This hypothesized role of the left IFG in controlled retrieval could explain the poor patient performance and the greater left IFG activation found in the high-selection condition.²

It should be noted, however, that an fMRI study of verb generation by Barch, Braver, Sabb, and Noll (2000) provided some evidence against an association strength explanation. These researchers examined low- versus high-selection conditions and the prepotency of the responses produced (i.e., whether participants produced the verb with the strongest association strength or some other verb). In the left IFG, they found greater activation for the high- than for the low-selection condition but obtained no effect of prepotency.³ However, it is highly likely that their high- and low-selection manipulation, like that of Thompson-Schill et al. (1997), confounded competition with association strength of the most frequent response. The effect of prepotency of produced responses may have provided a relatively weaker test of association strength, because there would be fewer observations for the non-prepotent responses. On the basis of their null result for prepotency, the authors suggested that only the number of competitors rather than their association strength was relevant to IFG activation. This conclusion was contradicted, however, by the findings of Wagner et al. (2001), which did show an effect of association strength on activation in left IFG.

In order to further examine the selection versus association strength interpretations of the verb generation results, we replicated Thompson-Schill's (Thompson-Schill et al., 1997; Thompson-Schill et al., 1998) design, but added a third condition in which there were two verb responses of relatively equal strength for a noun, both of which had high association strength (e.g., door-open, door-close). Thus, the three conditions were (1) high selection, high association (e.g., door-open, door-close); (2) high selection, low association (e.g., rug-roll, rug-lay); and (3) low selection (e.g., apple-eat). If the difficulties in the high-selection condition demonstrated in the Thompson-Schill studies were caused by selection demands, we would expect no difference between the two

high-selection conditions; both should be more difficult than the low-selection condition. On the other hand, if the difficulties in Thompson-Schill and colleagues' high-selection conditions were due to low association strength between the verb response and the target noun, we should find that retrieval in the high-selection, low-association condition is more difficult than in either the high-selection, high-association condition or the low-selection (high association) condition, with no difference between the latter two conditions.

METHOD

Participants

The verb generation task was administered to 10 Rice undergraduate students (who participated to satisfy a course requirement), 10 older control participants, and a patient, M.L., who had an infarction that included the left IFG. M.L. and the older controls were paid \$8.00/h for participation. The older controls were age- and education-matched with patient M.L. Their ages ranged from 55 to 75 years, and they had at least a high school education, with most having at least some college education. All participants were native English speakers.

Patient M.L. is a right-handed male, 63 years old at the time of testing, who suffered a left hemisphere cerebrovascular accident in 1990. Computerized tomography scan indicated an infarction involving the left frontal and parietal operculum, with atrophy in the left temporal lobe and mild diffuse atrophy. M.L. had completed 2 years of college. He has excellent single-word processing on standardized tests but has been identified as having a semantic short-term memory deficit (Martin & He, 2004). Recently, Hamilton and Martin (2005) reported that M.L. had great difficulty with inhibition tasks in the verbal domain (e.g., a standard Stroop task) but not in the nonverbal domain (e.g., an antisaccade task). To the extent that selection involves inhibition of competitors, one might predict that M.L. would be highly sensitive to selection demands.

Materials

Fifteen nouns in each of the three conditions were selected based on the data from a pretest in which 71 Rice University undergraduate participants generated verbs to 250 nouns. Fifteen nouns with a selection ratio of first to second verb frequency greater than 4.0 were chosen for the low-selection condition, and 30 nouns with a ratio of 2.0 or less were chosen for the two high-selection conditions. The items for the two high-selection conditions were chosen such that the association strength for the dominant response was .20 (14/71) or less for the high-selection, low-association condition and .28 (20/71) or greater for the high-selection, high-association condition. Table 1 presents the mean selection ratios and association strengths for the three conditions, along with mean values for relevant characteristics of the noun cues. As indicated in the table, nouns in the three conditions were well matched for both spoken and written frequency, word length in letters and syllables, and neighborhood size (based on *N* count; Coltheart, Davelaar, Jonasson, & Besner, 1977). To rule out the possibility that the nouns might differ in terms of the strengths of nonverb competitors, we examined the strength of the highest nonverb response for each noun and the average strength of all responses that were higher than the first verb for each noun (based on the University of South Florida Free Association Norms; Nelson, McEvoy, & Schreiber, 1998). These nonverb strengths were also well matched across conditions.

Procedure

On each trial, a fixation point was presented for 1,000 msec, followed by a randomly selected noun belonging to one of the three conditions. The noun was presented auditorily and visually such that

Table 1
Mean Values for Properties of Noun Cues in Each Condition

Property	High Selection, Low Association	High Selection, High Association	Low Selection
Selection ratio	1.44	1.53	12.70
Association strength	.15	.48	.63
Log written-word frequency ^a	1.53 (58.40)	1.43 (53.80)	1.42 (81.90)
Log spoken-word frequency ^b	.93 (22.00)	1.03 (22.70)	1.13 (73.30)
Letter length	4.90	4.70	5.10
Syllable length	1.30	1.50	1.50
Neighborhood size ^c	5.20	4.80	4.90
Highest nonverb assoc. strength ^d	.29	.31	.30
Mean nonverb assoc. strength after 1st verb ^{d,e}	.11	.19	.12

^aFrom Francis and Kučera (1982); the means of the raw frequencies are in parentheses. ^bFrom Brown (1984); the means of the raw frequencies are in parentheses. ^c*N* count (Coltheart et al., 1977). ^dFrom South Florida word association norms (Nelson et al., 1998). ^eIncludes all responses with association strengths higher than the first verb response for each noun.

the onset over the computer speakers was simultaneous with the onset on the computer screen.⁴ The participants were instructed to generate a verb associated with the noun on each trial as quickly as possible. The target word remained on the screen until the participant's voice triggered the voice key. Eight practice trials were administered. Instructions were repeated whenever the participants made an inappropriate response (e.g., a noun or adjective). The experiment was run with the PsyScope program (Cohen, MacWhinney, Flatt, & Provost, 1993), and the reaction time for the production of each verb was recorded. All responses were tape recorded for later transcribing. A response was considered to be correct if it had a verb entry in the Francis and Kučera (1982) word frequency norms and the verb sense had some semantic relation to the noun. Errors were classified into three types: (1) microphone failed to trigger by voice onset or was triggered by other nonverbal noises, (2) nonverb responses (adjectives, prepositions, nouns, etc.), or (3) no response.

The voice key was not used with M.L. because he often produced "um" or other extraneous noises prior to producing a verb. Instead, his responses were tape recorded and digitized later in order to score onset latency. For M.L., the target nouns remained on the screen until he had finished his response, at which point the experimenter pressed a key to advance to the next trial. If he had not made a response 10 sec after stimulus onset or if he generated a nonverb response, we reminded him of the task again by asking "What do you do with a ____?" or "What does a ____ do?" and waited until he made a verb response or indicated that he wanted to go to the next trial.

RESULTS

Mean reaction times (RTs) for the different conditions by participant group are shown in Table 2. In the RT analyses, only RTs for correct responses were included.

Young Participants

The young participants made very few errors (<1%), and thus error rates were not analyzed. In the RT analysis, data points that were more than ± 2.5 standard deviations from the mean for each participant for each condition were excluded. The main effect of condition was significant in the analyses by participants and by items [$F_1(2,27) = 4.81$, $MS_e = 156,957$, $p < .05$; $F_2(2,42) = 11.29$, $MS_e = 132,809$, $p < .0005$]. Pairwise comparisons of the three conditions revealed that RTs in the high-selection, low-association condition ($M = 1,654$ msec) were significantly longer than in the high-selection, high-association condition ($M = 1,168$ msec) [$t_1(9) = 2.38$, $p < .05$, 95% confidence interval (CI) of 24~947 msec; $t_2(28) = 3.71$, $p < .005$, 95% CI of 253~875 msec] and in the low-selection condition ($M = 1,189$ msec) [$t_1(9) = 2.37$, $p < .05$, 95% CI of 21~909 msec; $t_2(28) = 3.35$, $p < .005$, 95% CI of 206~854 msec]. Contrary to the prediction based on the role of selection from competitors, we found no significant difference between the RTs for the high-selection, high-association condition and the low-selection condition [$t_1(9) = -0.5$, $p = .628$, 95% CI of -112~71 msec; $t_2(28) = -0.47$, $p = .638$, 95% CI of -180~112 msec].⁵

For each condition, the first and second most frequent responses were produced by the following percentages of participants: for high-selection, low-association, 30% and 15%; for high-selection, high-association, 57% and 29%; for low-selection, 64% and 18%. Thus, despite the

Table 2
Mean Reaction Times (RTs, in Milliseconds) for the Three Experimental Conditions for Young Participants, Older Controls, and Patient M.L.

Condition	Young Participants		Older Controls		M.L.*
	All Correct Responses	Most Frequent Verb	All Correct Responses	Most Frequent Verb	All Correct Responses**
High selection, low association	1,654	1,517	3,736	4,145	5,893
High selection, high association	1,168	1,147	2,449	2,268	1,326
Low selection	1,189	1,149	2,093	1,868	1,316

*Geometric means are reported for M.L. **RTs for the most frequent verb are not reported for M.L. because the means would be based on few responses after eliminating responses of less frequent verbs.

small number of participants in this experiment versus the norming study, the relative proportions were replicated fairly well. It might be argued that response latencies should be included only for those responses that matched the most frequently produced verb in our norms because those would most directly reflect the predicted effects of competition, particularly for the low-selection condition. Table 2 also shows the mean reaction times for only the most frequently produced verbs. As can be seen in the table, including only these responses resulted in somewhat faster mean reaction times overall but did not change the pattern of results.

Older Controls

Reaction times. Although RTs for the older controls were substantially longer than those for undergraduate participants, we found the same pattern of means.

In determining outliers, first RTs greater than 10 sec were excluded. Then those responses more than ± 2.5 standard deviations from the mean per participant per condition were eliminated. The main effect of condition was significant in both the subject and item analyses [$F_1(2,27) = 6.97$, $MS_e = 1,071,609$, $p = .003$; $F_2(2,42) = 12.85$, $MS_e = 1,666,908$, $p < .005$]. RTs in the high-selection, low-association condition ($M = 3,736$ msec) were significantly longer than those in the high-selection, high-association condition ($M = 2,449$ msec) [$t_1(9) = 4.07$, $p < .01$, 95% CI of 572~2,001 msec; $t_2(28) = 3.82$, $p = .001$, 95% CI of 891~2,948 msec] and the low-selection condition ($M = 2,093$ msec) [$t_1(9) = 4.60$, $p < .01$, 95% CI of 834~2,450 msec; $t_2(28) = 4.30$, $p < .001$, 95% CI of 1,149~3,236 msec]. There was no significant difference between RTs for the high-selection, high-association condition and the low-selection condition [$t_1(9) = 1.31$, $p = .22$, 95% CI of -258~970 msec; $t_2(28) = 0.69$, $p = .49$, 95% CI of -535~1,081 msec].

For each condition, the first and second most frequent responses were produced by the following percentages of participants: for high-selection, low-association, 21% and 11%; for high-selection, high-association, 48% and 22%; for low-selection, 53% and 15%. As with the young participants, mean reaction times for the most frequently produced verb (shown in Table 2) replicated the pattern for all verb responses.

Errors. In addition to the three types of errors mentioned earlier, responses that were longer than 10 sec were also counted as errors. The older controls' error data had a pattern similar to that for their RTs. They performed worst in the high-selection, low-association condition, producing the most nonverb responses, null responses,

and responses longer than 10 sec (see Table 3). They made significantly more errors in this condition than in the low-selection condition [$t(9) = 2.51$, $SE = 0.636$, $p < .05$] and the high-selection, high-association condition [$t(9) = 2.13$, $SE = 0.703$, $p < .062$], as revealed by analyses on the total number of errors across the three categories, though the latter difference was only marginally significant. No significant difference was found between the numbers of errors in the high-selection, high-association condition and the low-selection condition [$t(9) = 0.29$, $SE = 0.348$, $p = .78$].

Patient M.L.

The categorization of patient M.L.'s responses was more complex, since he made more types of errors, including self-corrected responses and correct responses after being reminded of the task by the experimenter. We focused mainly on his error data, but we also computed RTs for those items that were correct on his first attempt or that were self-corrected following an initial incorrect response.

Reaction times. M.L.'s reaction times were highly skewed; thus, geometric means were calculated, and the analyses were carried out on log-transformed data. The main effect of condition was significant [$F(2,21) = 5.33$, $MS_e = 0.178$, $p = .013$], using items as the random variable. His RTs in the high-selection, low-association condition (geometric mean = 5,893 msec, $N = 6$) were significantly longer than those in the low-selection condition (geometric mean = 1,316 msec, $N = 8$) [$t(12) = 3.23$, $p = .007$, 95% CI of 0.21~1.09 (in log RT units)] and in the high-selection, high-association condition (geometric mean = 1,326 msec, $N = 10$) [$t(14) = 2.71$, $p = .017$, 95% CI of 0.136~1.15]. No significant difference was found between the high-selection, high-association condition and the low-selection condition [$t(16) = 0.017$, $p = .986$, 95% CI of -0.42~0.42].

Errors. As shown in Table 4, M.L.'s pattern of correct and incorrect responses was consistent with his RT pattern. His worst performance was in the high-selection, low-association condition. Most of the nonverb responses (26%) came from this condition; nonverb responses in the other two conditions were both 7%. The high-selection, low-association condition had the fewest first correct responses, 33%, in comparison with 60% for the high-selection, high-association condition and 56% for the low-selection condition. We also found the total correct for each condition, including first response correct, corrected with reminder, and self-correction; M.L. was 93% correct in both the low-selection and high-selection, high-

Table 3
Mean Number and Percentage of Error Responses for Older Controls

Condition	Nonverb Responses (adj, n, prep, etc.)	No Response	Response Time > 10 sec	Total Errors	Microphone Problems
High selection, low association	1.0 (7%)	0.5 (3%)	1.1 (7%)	2.6 (17%)	0.5 (3%)
High selection, high association	0.5 (3%)	0.2 (1%)	0.4 (3%)	1.1 (7%)	0.9 (7%)
Low selection	0.3 (2%)	0.0 (0%)	0.7 (5%)	1.0 (7%)	0.9 (7%)

Table 4
Classification of M.L.'s Responses: Number and Percentage in Each Category

Condition	First Response Correct	Correct With Reminder	Self-Correction	Nonverb Response
High selection, low association	5 (33%)	5 (33%)	1 (7%)	4 (27%)
High selection, high association	9 (60%)	4 (27%)	1 (7%)	1 (7%)
Low selection	8 (53%)	6 (40%)	0 (0%)	1 (7%)

association conditions, whereas he was only 73% correct in the high-selection, low-association condition.

DISCUSSION

The young participants, older controls, and patient M.L. all showed a consistent pattern in verb generation to target nouns: RTs were faster in the two conditions that had at least one verb with a high association strength and slower when no verb had a high association strength. There was no difference between the two conditions with high association strength and differing selection demands. Thus, our study found that the association strengths of the candidate verbs greatly influenced participants' verb generation performance, whereas selection from competitors had no significant effect. Furthermore, the findings demonstrated exaggerated difficulty in the high-selection, low-association condition for patient M.L., whose lesion includes the left IFG, and thus support the conclusion that this brain area is particularly involved when association strength is low.

Our results could be interpreted as consistent with Badre and Wagner's (2002) proposal regarding the role of left IFG in controlled semantic retrieval. As mentioned in the introduction, it is possible that when association strength between nouns and verbs is strong, a verb could automatically come to mind through a spreading activation process following activation of the noun's meaning. When there is no highly associated noun, a controlled search for a verb response would instead be carried out. Controlled search is often thought of as involving the strategic use of retrieval cues to access information (Rosen & Engle, 1997). Thus, in some sense, controlled search might be argued to involve "selection," though not necessarily selection from competitors. Of course, if the term *selection* is interpreted in this fashion, the distinction between controlled search and selection disappears.⁶

Whereas Badre and Wagner's (2002) approach involved a dichotomy between automatic and controlled semantic retrieval, the degree of involvement of the left IFG may depend directly on association strength. In the information processing model of brain activation presented by Anderson et al. (2003), neural activation is related to the duration of an information processing event. The retrieval buffer in their model, which they argue is localized in the left prefrontal cortex, is assumed to be involved in initiating a memory search and holding the results of the search. In applying this model to verb generation, the noun would be the cue that is used by left prefrontal cortex to initiate a search of declarative memory (localized elsewhere)

to obtain an associated verb. Speed of retrieval is then predicted to be related to the rate of spread of activation, which would depend in part on the strength of the connection between the noun and various verbs (in other words, association strength). Hence, in this model the time for retrieval (and the associated brain response) would be related in a continuous fashion to association strength.

It is interesting that competition appeared to play no role in the verb generation task, given that models of word production typically assume a role for competition from semantically related representations (e.g., Dell & O'Seaghdha, 1992; Levelt, Roelofs, & Meyer, 1999). The explanation for this apparent contradiction may be that the hypothesized competitors as determined from verb generation norms (e.g., "eat" and "toss" for *salad*) are simultaneously activated at a conceptual rather than a lexical level. Once a concept is chosen (e.g., "eat"), semantically related lexical items (e.g., *devour* or *consume*) might compete for selection. These lexical competitors would not necessarily be those in the verb generation norms, since these terms are often semantically unrelated (as are "eat" and "toss"). Hence, the high- and low-selection conditions assess competition at a conceptual level. Previous studies, however, have shown that the interfering effects of semantic competitors in word production occur at a lexical rather than a conceptual level (Damian & Bowers, 2003; Schriefers, Meyer, & Levelt, 1990). Thus, the present results might be considered consistent with these findings.

We understand that neuroanatomical conclusions about the role of the left IFG in semantic retrieval must remain tentative on the basis of the findings from patient M.L., since his brain damage is not located in the left IFG exclusively.⁷ There is some suggestion in the neuroimaging literature that different left IFG regions may be involved in controlled semantic retrieval and selection from competitors (see Badre & Wagner, 2002, for discussion), thus providing a means to accommodate both the retrieval and selection hypotheses.⁸ However, there as yet appear to be no studies that have directly manipulated factors related to both hypotheses in the same participants, in order to provide a stronger test of a separation in localization. Therefore, further patient data and further evidence from neuroimaging studies will be needed in order to associate left IFG (or any specific cortical structure) with semantic retrieval based on association strength and to determine whether a distinct region may be involved in selection. The present results indicate, however, that the verb generation task does not appear to be an appropriate task to use to test for the effects of selection demands, since it appears to be sensitive only to association strength.

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NOTES

1. We obtained these stimuli from Sharon Thompson-Schill after having completed our norming study. Thus, our norms only included a subset of the Thompson-Schill et al. (1997) stimuli (i.e., 28 of their 47 stimuli in the high-selection condition and 19 of 47 in the low-selection condition). Their frequency data for verb production were no longer available.
2. Other data have been reported by Thompson-Schill and colleagues supporting the selection account (see, e.g., Thompson-Schill, D'Esposito, & Kan, 1999); however, the interpretation of these findings has also been challenged by Badre and Wagner (2002).
3. Barch et al. (2000) reported an interaction between selection condition and prepotency in the anterior cingulate cortex such that in the low-selection condition there was substantially less activation for prepotent than for nonprepotent responses, whereas in the high-selection condition there was a much smaller difference in activation for the two response types. They attributed this pattern to the need to overcome the conflict from the strong prepotent response in the low-selection condition and the relatively weaker competition from the prepotent response in the high-selection condition. However, these findings could purely reflect association strength of the responses produced. That is, the difference in association strength between prepotent and nonprepotent responses is necessarily larger in the low- than in the high-selection condition because the ratio of first to second verb frequency is, by definition, larger in the low- than in the high-selection condition.
4. We used both visual and auditory presentation because of our intention to use this paradigm in the future with aphasic patients, many of whom may have reading problems.
5. Voice key latencies are affected by initial phoneme characteristics and onset cluster complexity (see, e.g., Kessler, Treiman, & Mullennix, 2002), which were uncontrolled in the verb responses. However, variations due to such factors are small and could not account for the large RT differences between the high-selection, low-association condition and the other two conditions. Nonetheless, we cannot rule out the possibility that we failed to detect a small difference between the high-selection, high-association condition and the low-selection condition because of such phonetic confounds.
6. One reviewer suggested that the effects of selection demands might be evident only when all responses are weakly associated. A correlational approach could also be used to address this issue by examining the independent contribution of the strength of the second strongest verb association in predicting reaction time after factoring out the contribution of the strength of the strongest verb. A positive semipartial correlation would indicate longer reaction times for verbs with stronger competitors. There was no sign of such a relation in the undergraduate data for the high-selection, low-association condition, since that semipartial correlation was $-.37$; however, a much larger sample of stimuli would be needed to provide more definitive evidence.
7. M.L.'s lesion might encompass both regions, thereby accounting for the findings showing an exaggerated effect of association strength in the verb generation task, which is not affected by competition, and an exaggerated effect in tasks like the Stroop task that involve inhibition of strongly competing responses (Hamilton & Martin, 2005).
8. Neuropsychological and neuroimaging studies have implicated left IFG in the processing of verbs (see, e.g., Caramazza & Hillis, 1991; Perani et al., 1999; but see Warburton et al., 1996). Thus, further evidence regarding the retrieval of other kinds of semantic information than verbs is clearly required to strengthen the conclusion that the left IFG is involved generally in semantic retrieval.