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Competition and Inhibition in Lexical Retrieval: Are Common Mechanisms Used in Language and Memory Tasks?

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ABSTRACT

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The following series of experiments examined whether common mechanisms are involved in word retrieval within language and memory domains. Four patients with short-term memory (STM) deficits were examined; however, two of the patients showed a consistent impairment in inhibiting irrelevant verbal information as well. To the extent that repeatedly retrieving verbal items from the same category would require the capacity to suppress competing items to select the target, we investigated whether patients with a verbal inhibitory deficit, in addition to a reduced STM capacity, would be impaired in retrieving items in a semantic context relative to STM patients who do not display a similar verbal inhibition deficit and normal control subjects. Experiments 1- 4 consisted of language tasks which required the repeated naming or matching of items in a semantic or unrelated context. The findings revealed that verbal inhibition patients showed the greatest degree of difficulty during picture naming relative to the matching tasks in a semantic context, suggesting that they are susceptible to interference from semantic competitors to a greater extent at a lexical level. Experiments 5 – 7 consisted of recall and recognition memory tasks with items in a semantically related or unrelated context. Experiments 5 and 6 showed that while STM patients and controls displayed a similar degree of interference for items in a semantic context, STM patients can recall and recognize items near or within the range of controls when demands on STM capacity are minimal during encoding. However, Experiment 7 showed that recall can decline for patients with STM deficits when items are processed more rapidly during encoding. The results from Experiments 5 – 7 suggest that interference among items from the same category can occur in memory tasks (at a conceptual level), but verbal inhibition patients are not affected to a greater degree than control subjects. The overall findings are interpreted within the framework of spreading activation models, and provide implications for potential differences in competition and selection demands at lexical and conceptual levels of representation.

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Model of short-term memory proposed by Martin, Lesch, & Bartha (1999).

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Performance for semantically related items (e.g., items from the same semantic category) relative to unrelated items has been widely studied in the areas of memory and language. Numerous studies report enhanced performance or semantic priming either in terms of accuracy or reaction time for semantically related items. For instance, word recognition, word reading, and lexical decision are facilitated (as demonstrated by faster reaction times and increased accuracy) when target items are preceded by the category name or exemplar prime, e.g., tool – hammer, doctor – nurse, relative to unrelated primes, e.g., hammer – nurse (Warren, 1970, 1977; Meyer & Schvanevelt, 1971; Neely, 1977; Freedman & Loftus, 1971; Loftus, 1973; Loftus & Loftus, 1974). Similar effects also have been observed in word reading within a sentential context and reading same category word pairs (Elrich & Rayner, 1981; Freedman, Martin, & Biegler, 2004). In the long-term memory domain, recall performance improves when items in a study list are from the same category, and is further enhanced when the category name is provided during recall (Tulving & Pearlstone, 1966; Tulving & Osler, 1968; Kintsch, 1970; Roediger, 1973; della Rochetta & Milner, 1993). However, under certain conditions, semantic relatedness impairs performance in both language and memory paradigms, e.g., in picture-word interference (Schriefers, Meyer & Levelt, 1990; Damian & Martin, 1999) and part-list cueing (Roediger, 1973; Watkins, 1975). The aim of the following series of experiments was to examine whether similar mechanisms are involved in the interference effects observed for semantically related items in both language and memory domains.

In both episodic and semantic memory tasks, retrieval inhibition can occur, which is the impaired ability to recall or generate a list of items from the same category (see Roediger & Neely, 1982 for a review). Although recall typically improves for studied list items from the same category (blocked or randomly presented) when only the category name is provided as a cue, (Watkins, 1975; Roediger, 1973; Tulving & Pearlstone, 1966; Tulving & Osler, 1968) the presentation of a subset of same category studied or non-studied items at test actually impairs recall for remaining items (Brown, 1968; Slamecka. 1968, 1969; Roediger, 1973; Rundus, 1973; Watkins, 1975; Mueller & Watkins, 1977; although see Hudson & Austin (1970) for facilitatory effects observed for part-list cues). Retrieval inhibition is also observed in semantic generation tasks (i.e., generating members of a category from semantic memory) as demonstrated by the inverse relationship between the successful generation of same category items and prior successive retrievals (Brown, 1979, 1981; Brown, Zoccoli, & Leahy, 2005).

Analogous effects are reported in language tasks, for example, on tasks involving picture naming, word to picture matching, or word to word matching, when the stimuli are blocked by semantic category. The semantic blocked naming task involves the repeated presentation of sets of pictures over a series of trials in which the items are either from the same category (semantically blocked) or from mixed categories (Belke, Meyer & Damian, 2005; Schnur, Schwartz, Brecher & Hodgson, 2006). Belke et al. (2005) and Schnur et al., (2006) found no reliable differences in onset latencies or error rates between same and mixed category sets during the first cycle. However, during subsequent cycles, control subjects and aphasic patients displayed longer onset latencies and increased error rates, respectively, for semantically blocked picture sets. Similarly, neuropsychological studies have reported that some globally dysphasic patients display a preserved ability to match a spoken word to a picture or written word on the first presentation, but show markedly impaired performance to match the correct spoken and visual stimuli during subsequent presentations when the material is blocked by category (Warrington & McCarthy, 1983, 1987; Crutch & Warrington, 2003, 2005; Ford & Humphreys, 1995, 1997).

Given the similar patterns of performance reported across a variety of tasks with shared elements, i.e., successive presentations of verbal stimuli from the same category, the question arises whether common cognitive mechanisms are utilized during the previously discussed memory and language paradigms. Explanations within the memory domain for inhibition in retrieval often emphasize encoding and retrieval contexts or strategies, or limitations in the number of retrievable items. Although many of these models can provide an account for retrieval inhibition effects, they rarely include or consider aspects of the lexical system apart from storage, encoding and retrieval processes. Moreover, memory models often assume that the processes involved in perceiving or encoding lexical input are mirrored in the verbal response or output modality. Bock (1996) has termed this oversight the "mind-in-the-mouth assumption," pointing out that numerous cognitive theories or models assume that "...What one says, how one says it, and how long it takes to say it are unsullied reflections of input processing and interpretation" (p. 396). However, evidence within psycholinguistic and neuropsychological research indicates that verbal output results from a series of complex stages, which do not necessarily match those on the input side, and that separate capacities hold some input and output lexical information (Schriefers et al., 1990; Dell, 1986; Martin, Lesch, & Bartha, 1999). Explanations for the inhibition effects for semantically related items in the language domain focus specifically on the processes involved in output, for example, in selecting a name to describe a picture. In fact, the interference effects in the language domain seem to be limited to production tasks, with facilitation being observed in comprehension tasks. These findings would suggest that psycholinguistic models of lexical retrieval and output could augment or contribute to current theories in the memory domain by providing insight into the lexicon's organization and the processes involved in lexical selection and retrieval.

Although theories within the memory and psycholinguistic literature do not often reference each other, they have appealed to analogous mechanisms, e.g., spread of activation or inhibition, particularly for explanations regarding verbal stimuli from the same category. Accordingly, it would be advantageous for both fields to investigate whether the same cognitive mechanism(s) and corresponding principles are applicable in both domains. One method of addressing this matter involves conducting detailed patient case studies. Moreover, patients exhibiting a consistent pattern of deficits and preserved abilities across several comparable memory and language tasks would reveal common capacities or processes involved. The following experiments examined these issues by testing aphasic patients who have a reduced short-term memory capacity and age and education matched controls. The patients' selection criteria were based on lesion location and/or their particular pattern of deficits in language and short term memory tasks in order to compare their performance in similar episodic recognition and recall tasks. The ensuing discussion will first present the findings and theoretical models from the language and memory literature regarding the decline in performance often resulting from the repeated presentation of same category items. Subsequently, data from aphasic patients and controls tested in our lab will be presented followed by a series of seven experiments. The following experiments and corresponding predictions were based on results reported by Martin and colleagues (e.g., Hamilton & Martin, 2005; Martin & Freedman, 2001; Martin, Lesch, & Bartha, 1999; Romani & Martin, 1999; Martin, Shelton, & Yaffee, 1994) and previously in the literature, with the goal of assessing whether any parallel findings in the forthcoming memory and language tasks stem, at least in part, from a common source.

Lexical Access and Selection

Lexical access theories generally agree that at least one intervening stage occurs between accessing the target concept and its corresponding articulatory properties. For simplification, theories providing a detailed model of accessing lexical items from the same category will be the focus of the present discussion. Many speech production models assume that lexical retrieval proceeds in four major stages, i.e., activation spreads from the target concept, through two intermediate lexical levels (lexical-semantic/syntactic and lexical-phonological), finally reaching the articulatory or output stage (Levelt, Roelofs, & Meyer, 1999; Dell, 1986; Dell and O'Seaghdha, 1991; Harley, 1993a; Stemberger, 1985). These models also assume that connections from semantic features at the conceptual level map directly onto representations at the lexical-semantic level in the lexicon. Of course, features would be shared across semantically related items. For example, 'fur' or 'has four legs' are both characteristics of cats and dogs and both features would map onto the lexical-semantic representations of *cat* and *dog* in the lexicon (as well as to all other animals sharing those properties). Information specified at the lexical-semantic level or other subsequent levels depends on the model (e.g., the 'lemma' level from WEAVER ++, which is the first specifically lexical level in that model, contains syntactic information including gender rules, count/mass specifications, and word class in addition to links to semantic information). The lexical-phonological and articulatory stages are assumed to follow the lexical-semantic selection stage and include phonological information, e.g., individual phoneme segments, syllable, stress, sound and motor programming information. Individual theories may differ in terms of the particular stage(s) during which phonological encoding and retrieval occurs; but notably, models generally concur that phonological processing follows lexical-semantic selection.

Competition During Lexical Selection and Retrieval

Several studies report slower onset latencies or increased error rates to name pictures in a variety of semantic (same category) contexts, e.g., naming pictures in the presence of a related distractor, naming several pictures from the same category, or naming blocked sets of pictures repeatedly sampled from the same category (Lupker, 1988; Starreveld & Le Heij, 1995; Schriefers et al., 1990; Damian & Martin, 1999; Brown, 1981; Howard, Howard, Nickels, Coltheart, & Cole-Virtue, 2006; Belke et al., 2005; Schnur et al., 2006). Spreading activation accounts attribute the observed naming difficulties to competition among same category competitors at initial lexical-semantic/syntactic levels. That is, activation from the target concept, e.g., "DOG," spreads to its corresponding lexical-semantic node *dog*, and also partially activates related competitors such as *cat* or *rabbit* since semantic features activated at the conceptual level, e.g., 'fur' or 'has four legs,' can overlap at the lexical-semantic level. In computational models, such as WEAVER ++, the selection of the target lexical representation (*dog*) is based on the ratio of its activation to the total activation of its competitors (Levelt, 2001). Evidence indicating that naming interference occurs at the lexical-semantic/syntactic level derives from variations of the picture-word interference task (for alternative interpretations, see Caramazza & Costa, 2001a & b; Finkbeiner & Caramazza, in press). During these experiments, subjects are instructed to name pictures paired with an auditory or visually presented distractor. When the distractor is from the same category as the picture, subjects show slower onset latencies relative to an unrelated distractor. The magnitude of the interference effect is greatest when the semantically related distractor is presented at early stimulus onset asynchronies (SOAs), either slightly before the onset of the picture (e.g., - 200 ms) or simultaneously. As the effect diminishes or disappears at later SOAs, it is assumed that the stage during which lexical-semantic information is selected occurs before accessing phonological information. In contrast, distractors phonologically related to the target picture, e.g., Dog—'dock', produce facilitation which is greatest at later SOAs following the onset of the target picture. It should also be mentioned that naming interference during this task does not appear to arise at the conceptual level. That is, when subjects are instructed to make recognition or category judgments (without any production requirements) regarding a picture paired with a related distractor word or when the picture to be named is paired with a distractor that is a semantically related picture instead of a word, interference effects are not observed (Schriefer et al., 1991; Damian, Bowers, & Katz, 1997). The different effects (interference v. facilitation) and different time courses arising from semantically related and phonologically related distractors provide evidence for separate lexical-semantic/syntactic and phonological levels, and that the former level, at least initially, precedes the latter[1].

Slower naming times also have been reported for semantically related pictures (with no distractors) after subjects previously have named several single pictures from the same category (Kroll & Curley, 1988; Kroll & Stewart, 1994; Brown, 1981). Moreover, this interference effect has been shown to increase linearly with serial position and is obtained even when unrelated pictures are interspersed among related targets (Howard et al, in press). A similar task known as the semantic blocking paradigm, has compared naming latencies to pictures presented among a set (usually consisting of 4 – 6 pictures) of members from the same category, e.g., "dog," "cat," "bear," "skunk" or a set of members from different categories, e.g., "dog," "boat," "hand," "radio" over a series of cycles. Belke et al. (2005) found no difference in onset latencies between same and mixed category sets during the first cycle in college-age subjects. During cycles 2 – 8, subjects displayed faster naming latencies in the semantically blocked and mixed conditions, which Belke et al. (2005) attributed to a repetition priming effect; however, the priming effect for the semantically blocked sets was significantly attenuated, showing longer naming times (that remained relatively constant across cycles) relative to mixed category sets. In addition, the semantic blocking effect extended to new items from the same category, i.e., subjects showed longer onset latencies to pictures from the same category in semantically blocked sets that were not previously presented.

The semantic blocking paradigm also has been used to test aphasic patients, demonstrating that non-fluent patients with left frontal lesions have particular difficulty naming pictures that are repeatedly sampled from the same category (McCarthy & Kartsounis, 2000; Wilshire & McCarthy, 2002; Wilshire & McCarthy, 2002; Schnur et al., 2006). For example, Schnur et al. (2006) tested two groups of aphasic patients and age and education matched controls with the semantic blocking paradigm using four rather than eight presentation cycles. The controls displayed results similar to the findings obtained by Belke and colleagues, showing no onset latency differences between the same and different category sets during the first cycle. Unlike the Belke et al. study, Schnur et al. observed faster naming latencies for both conditions during cycles 2 – 4; however, relative to the mixed condition, the decrease in naming latencies was significantly attenuated in the semantically blocked condition. That is, reliably longer naming latencies for same category sets were observed at a constant rate across cycles 2 – 4, while naming latencies for unrelated sets became progressively faster across cycles.

The patients tested by Schnur et al. (2006) were identified as either non-fluent or fluent aphasic patients with lesions encompassing left anterior or left posterior regions respectively. Because the number of correct data points was insufficient to analyze onset latencies, error rates were reported. Non-fluent patients with left anterior lesions showed a semantic blocking effect that linearly increased over cycles. In comparison to the decrease in naming latencies observed in both conditions for undergraduates and controls, non-fluent patients only showed a decrease in error rates for mixed sets. Importantly, a decreasing error rate was not observed for same category sets in this group; instead, error rates continually increased after the first cycle. Conversely, fluent aphasic patients did not show a linearly increasing semantic blocking effect in error rates. In fact, two fluent aphasic patients who obtained a sufficient level of accuracy displayed a semantic blocking effect in reaction times that was within the range of controls.

Several theoretical accounts have been provided to explain the semantic blocking effect observed in neurally intact subjects and the exaggerated effects reported for some aphasic patients. Spreading activation accounts resulting in competition among highly activated items from the same category have been offered at both conceptual and lexical levels. According to the WEAVER ++ model, after accessing a target concept, e.g., 'DOG,' activation spreads to both the corresponding lexical node and the category node 'ANIMAL'. In turn, other lexical nodes from the animal category receive some activation via activation from the 'ANIMAL' category node. As additional category exemplars are accessed and named, e.g., "horse," "cat," "goat," the 'ANIMAL' category node receives additional activation, consequently activating all corresponding lexical nodes connected to that category. As lexical items within a category increase in activation, competition for selection ensues, and it becomes increasingly difficult for a target lexical node to reach the requisite level of activation above other activated competitors. Thus, longer onset latencies to name pictures in semantically blocked sets result from the additional time needed to boost the target's activation to a level sufficiently above its competitors.

Variations of the spreading activation account assert that competition is restricted to the lexical level and does not spread from an overall category node to every exemplar. Currently, it is not clear at which level over-activation originates, resulting in competition. Belke et al. (2005) showed that the semantic blocking effect extended to same category items not previously presented, which is consistent with category level activation proposed in the WEAVER ++ model. However, Schnur et al. (2006) found that non-fluent aphasic patients who displayed the exaggerated blocking effect tended to produce semantic substitution errors only for items that were previously named rather than exemplars outside the set of test items. They claimed that activation from same category lexical nodes activated each other via lateral connections and created competition only among the sampled set. Despite these differences, a mechanism (susbserved by the left prefrontal cortex) to select a target among several highly activated competitors would be consistent with either spreading activation account, and has been used to account for the particular difficulty non-fluent aphasic patients with left frontal lesions exhibit during tasks requiring selection among several related competitors (Kan & Thompson-Schill, 2004; Thompson-Schill, D'Esposito, & Kan, 1999; Wilshire & McCarthy, 2002; Schnur et al., 2006).

Other accounts of the semantic blocking effect have appealed to inhibition of competitors following the repeated presentation of items from the same category. For instance, some connectionist lexical retrieval models propose that activating the lexical node corresponding to a target concept serves to suppress other category members at the lexical level through lateral inhibition (Dell & O'Seaghdha, 1994; Stemberger, 1985). Thus, the target lexical representation is selected by simultaneously increasing its activation and suppressing potential activation from any competitors, i.e., selecting (and subsequently naming) *'dog'* should inhibit *'cat'* even if *'cat'* has not been selected yet. Consequently, if *'cat'* is presented during a subsequent trial, it will be more difficult to name because its lexical representation has been suppressed by previously naming *'dog.'*

This model would predict that items not yet presented should be more difficult to name, since selecting a lexical representation requires both self-activation and inhibition of competitors. Accordingly, naming difficulties should occur during the first cycle of the semantic blocking paradigm, i.e., affecting items like *'cat'* or *'horse'* if *'dog'* has been named previously. However this effect has not been demonstrated in previous reports since no onset latency differences were found during the first cycle (Belke et al., 2005; Schnur et al., in press). In addition, for naming difficulties to occur, the model must assume that competitors are inhibited below baseline. Perhaps competitors in the semantic blocking paradigm are not inhibited below baseline until the second cycle, although this assumption is purely speculative and has yet to be modeled and tested empirically.

Inhibition also has been proposed to occur at later stages within lexical access models as, after production, items undergo self-inhibition or post-selection inhibition in order to prevent re-selection (MacKay, 1987; Dell, 1988). To account for the semantic blocking effect, if an item's post-selection inhibition is incomplete, e.g., due to its repeated selection and naming over several cycles, it could remain partially activated and compete with other items from the same category. That is, remaining activation from naming *'dog'* on a previous trial would interfere with naming *'cat'* on a later trial. A deficit in post-selection inhibition would be particularly problematic for tasks that require repeatedly naming items from the same category. If during the semantic blocking task, post-selection is incomplete and same category items remain partially active in neurally intact subjects, patients with this type of deficit would have even greater difficulty selecting a target among competitors with or without other lexical access or retrieval deficits. In contrast, explanations for some patients (e.g., FAS) having particular difficulty with this task have proposed that the exaggerated effect is due to excessive post-selection inhibition such that lexical representations become inaccessible or refractory for a short period of time (McCarthy & Kartsounis, 2000). It should be noted that this claim derives from patients reported to have semantic (not specifically lexical) access deficits, i.e., semantic representations become temporarily inaccessible after repeated presentations. Tasks ostensibly inducing refractory semantic access are similar to the semantic blocking task in that subjects are required to repeatedly match pictures to a spoken word over a series of cycles either from the same or different categories. Findings from various studies using this task are reported in the next section.

Refractory Effects During Semantic Access

Several patients have been reported as having a semantic access deficit for particular categories, which is distinguishable from a semantic representation or knowledge deficit (e.g., semantic dementia) (Warrington & McCarthy, 1983, 1987; Forde & Humphreys, 1995; Crutch & Warrington, 2003, 2005). Whereas semantic knowledge for particular categories and exemplars is severely degraded or absent in patients with semantic representation deficits, semantic access patients can show spared knowledge for particular categories, but show impairment for these categories under some conditions. First, semantic access patients show inconsistent performance for recognizing items from an impaired category. Warrington and McCarthy (1983) tested VER, a globally dysphasic patient, who displayed extreme impairments in propositional speech, reading and comprehension. They determined the extent of VER's intact or impaired semantic knowledge using various matching tasks with words and pictures. During initial assessments, VER would sometimes recognize items from categories presented in an array that were in general more difficult for her, but her performance was unreliable. In subsequent experiments when all items across the tested categories were presented 3 or 4 times, serial position analyses indicated that VER's performance for items in impaired categories declined significantly from the first presentation to the second. Warrington and McCarthy (1983) reasoned that reliably recognizing an item on the first but not second presentation could not be explained by a deficit to the semantic representation itself. In addition, VER's performance improved during the various matching tasks when the rate between her response and the next trial, response-stimulus interval (RSI), was extended. Warrington and McCarthy (1987) later replicated the repeated presentation and rate effects with YOT, a severely global dysphasic patient, also showing that YOT could perform better with items from impaired categories (e.g., body parts) when they were presented at a slower rate among items from different categories, including other impaired categories (e.g., clothes and furniture).

Warrington and McCarthy and others have proposed that the variable pattern of performance depending on the first to subsequent presentations, rate in terms of response-stimulus interval (RSI), and presentation among same or different category members is consistent with a semantic access deficit. The semantic representations are essentially intact but become inaccessible or refractory after repeated access. However, the refractoriness appears to be temporary since after some period of time (e.g., 10 or 30 seconds) the tested items are again accessible. Furthermore, the refractoriness spreads to surrounding or similar representations as performance worsens for semantic access patients when items are repeatedly sampled from impaired categories compared to when the same items are presented among members from different categories. Warrington and McCarthy (1983) speculated that refractoriness could result from temporary inactivity in the brain regions subserving knowledge of particular categories, or an increased signal to noise ratio. More recently, Crutch and Warrington (2005) have appealed to neurophysiological explanations. Perhaps neuromodulatory systems controlling neural activation in semantic access patients are specifically impaired rather than the neural correlates subserving the representation of semantic knowledge per se (Gotts & Plaut, 2002). Damage to neuromodulatory systems may lead to "excessive neuronal depression and a refractory period during which subsequent neural firing is blocked or reduced" (Crutch & Warrington, 2005, p. 616).

Thus far, two similar experimental paradigms testing lexical and semantic access have been discussed. These tasks and resulting effects share several features in common including worse performance for items presented repeatedly among same category members. Interestingly, rate effects for the semantic blocking tasks appear to be more variable as some patients show declines in performance at faster rates while others show improvement (Wilshire & McCarthy, 2002; Crowther & Martin, 2006). Furthermore, controls have been reported to benefit from a faster presentation rate (Schnur et al., 2006, Crowther & Martin, 2006). The data reported in later sections were acquired at what is considered a fairly fast presentation rate or RSI, e.g., 2000 ms. Results from our lab for patient ML, a non-fluent aphasic patient who will be discussed in subsequent sections, were similar to those reported by Warrington and colleagues (Warrington & McCarthy, 1983; Crutch & Warrington, 2003) and Wilshire and McCarthy (2002), in that his performance improved in a semantic blocked picture-to-spoken word matching task at a longer RSI, 5000 ms, relative to the shorter, 2000 ms interval (Crowther & Martin, 2006).

Retrieval Inhibition in Episodic and Semantic Memory Tasks

Instances of retrieval inhibition are widely reported and occur in numerous memory tasks under various conditions. There are several paradigms testing memory for same category items that are similar to the semantic blocking and refractory access paradigms which reportedly induce retrieval inhibition, including part-list or "part-set" cueing, recall with or without practice, recognition, and cued semantic generation tasks (see Roediger & Neely, 1982 and Anderson, 2003 for review). Although there are reports of tests of aphasic or amnesic patients on these tasks, the majority of studies and ensuing theoretical proposals are based on the results obtained from neurally intact subjects. However, some cognitive models based on data from neurally intact subjects can also accommodate the findings from neuropsychological reports. The following discussion will present findings and corresponding theoretical models first from neurally intact subjects followed by reports from the neuropsychological literature.

Slamecka (1968, 1969) was the first to report the effects of part-list cueing, i.e., providing some study list items as cues during recall to investigate their influence on the remaining items to be recalled. The results were rather unexpected as cues usually aid recall, at least during paired associate learning tasks. However, Slamecka found that subjects recalled fewer remaining list items when list cues were present compared to recall conditions without list cues (free recall). Variations of this paradigm replicated these results and produced additional findings. For instance, Roediger (1973) examined the effect of retrieving category-blocked list items when only category names or both category names and list members were presented as cues during recall. In addition, the number of list cues presented during recall was varied for participants receiving both category names and list cues. The main findings demonstrated that participants receiving the category names and items as cues performed more poorly than participants who only received category cues. As the number of cues increased, the proportion of remaining items to be recalled systematically decreased, and this effect remained after controlling the relative retrieval difficulty for cued and critical items.

Roediger (1973) interpreted these results in the context of Rundus' (1973) model which assumes that memory representations are organized hierarchically (e.g., Mandler, 1967). That is, assuming that individual items are subsumed under a higher order category unit, Rundus (1973) proposed that the probability of retrieving any one item from a category depends on the ratio of the connection strength between that particular item and connection strengths of all other items to that category. Accordingly, as the number of items within a category increase, the probability of retrieving any one item decreases. The presentation of category list cues during the recall phase is synonymous with retrieval and serves to strengthen the connections between the particular category member cue (A) and the higher order unit (category). The strengthening of A and its category increase the likelihood of A being retrieved and consequently decreases the retrieval probability of all other category members. Thus, an increase in list cues during recall will decrease the likelihood that other category members will be retrieved.

Watkins (1975) replicated Roediger's (1973) part-list cueing results with same category part-list cues; however, Mueller and Watkins (1977) found that the recall of items within a particular category (e.g., trees) was not inhibited when study list items presented as part-list cues from different categories (e.g., vehicles or musical instruments) were presented during test, i.e., no significant difference in the number of retrieved critical items was obtained when comparing a recall condition in which part-list cues were from different categories and a control condition in which only category names were presented as cues[2]. Watkins and colleagues proposed the cue overload approach to account for these findings. Based on the inverse relationship between list length and the probability of retrieving any one item from a list, it is assumed that study items and part-list cues that are from the same category are integrated into a higher order category unit such that increasing the number of part-list cues at test increases the total number of recallable items within that category and consequently decreases the probability of recalling the remaining critical test items.

Other models and principles have been put forward to account for the same category part-list cueing effect. For instance, the Search of Associative Memory Model (Raaijmakers & Shiffrin, 1980, 1981) proposed that cues are used to begin a search within memory to find and retrieve the target(s) for a given task. At study, the general context occurring during encoding acts as a cue for later retrieval. When subjects engage in free recall, they are able to use general context cues to retrieve items that have the strongest context-item associations first, while subjects receiving part-list cues are disrupted in using the general context as a cue and are unable to retrieve strong context-associated items. Consequently, subjects receiving part-list cues are forced to retrieve weak context-associated (or less accessible) items, leading to an overall decrease in the number of target items retrieved relative to targets retrieved in a free recall condition (Raaijmakers & Shiffrin, 1981). As the model assumes that retrieval is largely based on inter-item associations, the finding that related extra-list cues, i.e., cues from the same category but not presented in the study list, are as detrimental to recall as related intra-list cues is somewhat problematic for this model. Some mechanism, in addition to context-item associations within a study list, would need to account for non-study items disrupting recall (Roediger & Neely, 1982). That is, the model would also need to include parameters for retrieving any item within a given category, and not only items presented in a study list.

Congruency also has been proposed to play a role in inhibition effects observed during part-list cueing. Sloman, Bower, and Rohrer (1991) found that changing the order in which items are presented at study and as part-list cues at test, i.e., incongruency in the serial order presentation of items between study and test conditions, led to increased retrieval inhibition relative to a recall condition in which the order of part-list cues matched the order presentation at study and a free recall condition with no cues. In a second experiment, Sloman et al. (1991) investigated the relative impact of incongruent part-list cues that differed in both serial position and overall meaning of the category at test. Thus, the incongruent condition consisted of a subset of items from a category that deviated from the overall sense of the category, based on the exemplars provided at study. Sloman and colleagues (1991) obtained results similar to Experiment 1 as subjects recalled significantly fewer items relative to free recall and congruent part-list cued recall conditions. Sloman et al.'s (1991) findings suggest that associations are formed to some extent among items during study and can influence the retrieval context and ensuing recall performance when part-list cues are presented during recall.

In addition to part-list cueing, Anderson and colleagues (e.g., Anderson, Bjork, & Bjork, 1994, 2000; Anderson & Spellman, 1995) have reported retrieval induced forgetting in what they have termed the "retrieval practice paradigm" (Anderson, 2003, p. 418). In this task, category and exemplar pairs were presented during a study phase, e.g., Fruit – orange, Fruit – apple, Drinks – scotch. During a practice retrieval phase, subjects were required to produce the item corresponding to a category – stem cue (Fruit - or_____). During practice, only a subset of the exemplars was presented, which is similar to the presentation of a subset of the category items in part-list cueing. Also, for each subject, some categories received no practice (e.g., Drinks – scotch) to provide a baseline comparison, and it should be mentioned that practiced and unpracticed categories were counterbalanced across subjects in order to compare the recall of each item in both unpracticed and practiced conditions. After a 20 minute delay, subjects were instructed to recall all items presented during the initial study phase.

For clarification, the following discussion will adopt the labels used by Anderson and colleagues to identify each type of condition (Anderson et al., 1994; Anderson & Spellman, 1995). Items from a category that received retrieval practice (e.g., Fruit – orange) will be labeled Rp^+, while items from the same category that were not practiced (e.g., Fruit – apple) will be labeled Rp-. The control condition, in which no items from a category received practiced, will be labeled Npr. The critical comparison is the difference between the conditions Npr and Rp-, as both items were not practiced, but Rp- items belong to the category that contained some items that are retrieved during practice while the other, Npr, does not. Anderson et al. (1994) found that Rp^+ items generated during practice (e.g., or___ = 'orange') were recalled better than unpracticed items either remaining from the fruit category, Rp-, or from an unpracticed category, Npr, (e.g., drinks). Furthermore, Rp- items (e.g., Fruit—apple) were recalled significantly worse compared to Npr items (e.g., Drinks—scotch). The authors suggest that the retrieval of Rp^+ items suppresses any related items, i.e., Rp- items, in order to circumvent interference from competitors. Interestingly, Anderson and Spellman (1995) found that retrieval inhibition occurs for related items placed in separate categories. For instance, if Red Things is a retrieval practice category with 'blood' being an Rp^+ item and 'tomato' being an Rp- item, and Food is a separate unpracticed category, Npr, with exemplars 'radish' and 'bread,' subjects who practice 'blood' and not 'tomato' show an inhibition effect for 'tomato' at recall. In addition, retrieval inhibition is observed for 'radish' relative to 'bread,' in a separate condition in which no items are practiced. The results suggest that, if 'tomato,' a Red Thing, is suppressed, then other related Red Things, e.g., 'radish,' are suppressed as well (even without a 'practice' condition). However, as 'bread' is not a Red Thing, it is not suppressed, and thus, shows no effects of retrieval inhibition.

Recent work has called into question whether the effects of retrieval induced forgetting, i.e., retrieval inhibition, reported by Anderson and colleagues, are due to a suppression mechanism rather than resulting from interference among competing items to be retrieved. Anderson and Bjork (1994) pointed out two possible variables, (i.e., category typicality and cue independence) which would motivate opposing predictions for suppression and interference accounts. According to the suppression account proposed by Anderson and colleagues (Anderson & Bjork, 1994; Anderson et al., 1994), during retrieval practice, category name cues activate highly typical or strongly related non-target exemplars (e.g., strong Rp-, apple) to a greater extent than weakly related non-target exemplars (e.g., weak Rp-, guava). Strong non-target exemplars compete with the target item during practice (e.g., Rp^+, orange) and are consequently suppressed in order to generate the correct cued exemplar. As a result, retrieval inhibition is observed for competing unpracticed strong exemplars to a greater extent than weak exemplars because they were suppressed during retrieval practice. Conversely, weakly related items should show more retrieval inhibition, according to an interference account, based on a ratio rule for retrieval (Anderson et al., 1994). According to a ratio rule, an exemplar's retrieval is based on the ratio of its connection strength to the corresponding category relative to the sum of the connection strengths of all other exemplars to that category. It should be noted that Anderson et al. (1994) made specific assumptions about this particular ratio rule model in that weakly related exemplars show a proportionally greater increase in activation when cued relative to strongly related exemplars. Thus, a greater disparity occurs between the ratios of practiced and unpracticed weakly related exemplars compared to the ratios of practiced and unpracticed strongly related exemplars. Accordingly, unpracticed weak exemplars should show more retrieval inhibition than strong exemplars.

Anderson and Spellman (1995) proposed a cue independence account to further support suppression as the underlying mechanism of retrieval induced forgetting. That is, if cued retrieval of an item during practice, Rp^+, serves to suppress any other related items, unpracticed competitors should show retrieval inhibition regardless of the category cue provided during study and retrieval practice as suppression should spread throughout all items with common features. Specifically, retrieving the Rp^+ item, 'blood,' should suppress both the Rp- item, 'tomato,' from the same category, 'Red Things, 'as well as a related Npr item, 'radish,' from a different category, 'Food'. Conversely, if retrieval inhibition for unpracticed exemplars is due to proactive interference from previously generated exemplars to a particular category cue during the practice phase (i.e., Rp^+, 'blood'), retrieval inhibition should be cue dependent, i.e., it should only occur for items cued by that particular category (i.e., Rp-, 'tomato') (as opposed to other possibly related items that were studied under a different category, e.g., Npr, 'radish').

Williams and Zacks (2001) reported results from three experiments that varied only slightly from the retrieval practice paradigm design used by Anderson and colleagues (Anderson et al., 1994; Anderson & Spellman, 1995). Experiments 1 and 2 were specifically designed to assess the relative differences in retrieval inhibition of unpracticed strong and weak exemplars. Retrieval inhibition effects were replicated for Rp- items relative to Npr items. However, differences in retrieval inhibition between strong and weak Rp- exemplars failed to reach significance, i.e., both exemplar types showed retrieval inhibition to the same degree. In Experiment 3, Williams and Zacks tested the extent of cue independence for Npr items related to Rp- items. That is, they investigated whether related Npr items studied under a different category (e.g., Food—'radish' from previous example) would show retrieval inhibition to the same degree as Rp- items. Although they replicated retrieval inhibition effects for Rp- items relative to unrelated Npr items, they found that Npr items related to Rp- items did not significantly differ from the retrieval rate of unrelated Npr items. That is, their findings failed to show significant retrieval inhibition for Npr items related to Rp- items, suggesting that items outside of the retrieval practice category were unaffected by the retrieval practice of Rp^+ items.

Williams and Zacks (2001) proposed that the consistent finding of retrieval inhibition for Rp- items for both strong and weak exemplars, but not for related Npr items, suggests that retrieval induced forgetting is likely due to interference during final recall rather than the suppression of potential competitors during the practice phase. That is, the results suggest that the retrieval practice of Rp^+ items per se does not impact Rp- items directly. Instead, the practice of Rp^+ increases the probability of their recall during the test phase. Consequently, as a higher proportion of Rp^+ items are recalled during the recall test phase, the probability of retrieval for unpracticed, or Rp- items decreases. Rundus (1973) and Roediger (1973) have put forth similar claims, as discussed in previous sections. Although Williams and Zacks (2001) did not specify the state of activation for Rp^+ and Rp- items, it is conceivable to assume that Rp^+ are activated to a greater extent than Rp- items, increasing their probability of selection. The contrasting models accounting for retrieval inhibition, i.e., interference due to prior retrievals (proactive interference) or suppression of strong competitors, are of considerable theoretical relevance to both language and memory models discussed throughout the results and discussion sections, and will be considered again in the General Discussion.

Inhibition effects have been reported in recognition tasks for targets following several primes from the same category as well. In a forced choice recognition task, Todres and Watkins (1981) presented subjects with intra-list and extra-list primes related to the target as well as unrelated primes. In contrast to findings from the part-list cueing paradigm, Todres and Watkins only obtained inhibition effects to targets following extra-list related primes. However, when they presented the lists items randomly rather than blocked by category, they found inhibition for related intra-list cues as well. The authors hypothesized that the procedure used in the first experiment maintained the global study context, thereby precluding any inhibitory effects resulting from related intra-list primes. Presenting intra-list cues randomly during recognition prevented any benefit obtained from reintroducing a familiar study context. Neely, Schmidt and Roediger (1983) manipulated the number of related and unrelated primes preceding a critical item in a yes/no recognition task. They found significantly slower reaction times for targets and increased error rates for lures when preceded by six related primes relative to two. In addition, the inhibiting effects were more reliable when the primes were lures instead of targets, which is consistent with Todres and Watkins' (1981) findings that extra-list (or lures in this case) produce more robust inhibition in recognition tasks of this nature (Roediger & Neely, 1982). Neely et al. (1983) attributed their findings to a spread in lateral inhibition within a semantic network, which is similar to explanations discussed within the lexical access and retrieval sections. Although there appears to be a positive relationship between the amount of inhibition and the number of cues or primes during the testing phase of recognition and recall tasks, the conditions in which inhibition is obtained are not identical. That is, intra-list items introduced at test are not as detrimental to recognition as they are in recall. Conceivably, reinstating the global context during recognition is more beneficial than during recall.

The majority of work on retrieval inhibition has focused on episodic tasks in which memory is assessed for material studied prior to testing. Studies by Brown and colleagues, Brown, 1979, 1981; Brown et al., 2005) have investigated inhibition effects in semantic memory tasks, which require subjects to draw on their own semantic knowledge to generate responses that are appropriate to a given cue. In a series of experiments manipulating the relationship between the cue and the target response, Brown and colleagues consistently found that as the number of generated exemplars from a category increased, the proportion of remaining items to be generated decreased. For instance, Brown (1981) and Brown et al. (2005) investigated responses generated from cues of a given category, e.g., animals: d__, c__, as they developed across successive retrievals and found an inverse relationship between the number of previously generated items and the successful retrieval of subsequent items. Brown and colleagues (2005) proposed that the retrieval inhibition observed when generating category members either was due to an automatic suppression of competitors that have not yet been retrieved or the interference of previously generated exemplars. They reasoned that an interference account would assume that the number of prior successful retrievals would remain in the conscious awareness of the subject, and that as the number of prior successful retrievals increase the number of successful subsequent retrievals would decrease. Conversely, if the observed retrieval inhibition was due to an automatic suppression of not yet retrieved competitors, previous retrievals would not remain in consciousness and, therefore, have no impact on later retrievals. To test these hypotheses, Brown et al. (2005) divided their subject pool into high and low performers based on a median split of total correct retrievals across categories and exemplar cues. That is, high performers obtained a greater number of successful retrievals at earlier serial positions. They found no significant difference in retrieval inhibition across serial positions between high and low performers, i.e., both groups showed a linear decline in performance at the same rate.

Brown et al. (2005) concluded that since the number of correctly produced category exemplars at early serial positions was unrelated to the number of generated exemplars at later positions, the decline in performance across successive retrievals was due to an automatic suppression of non-produced exemplars[3].

However, Brown et al.'s (2005) failure to find a difference between high and low performers should not rule out the possibility of proactive interference from previously retrieved items. That is, the absence of a difference in retrieval inhibition between high and low performers could be due to the ability of high performers to inhibit previously retrieved (activated) items, preventing residual activation from impeding future retrievals at least to the same extent as low performers (see Rosen & Engle (1998) and Brewin & Beaton (2002) for other related studies involving the relationship between high performance in working memory and inhibitory control). It should be noted that other memory models (e.g., Cowan, 1988) have proposed that verbal information can remain activated (potentially causing proactive interference), though outside of awareness. Although this model does not directly address the findings obtained by Brown et al. (2005), it is relevant to theoretical proposals assuming that retrieval inhibition arises either from suppression or interference during memory retrieval.

Neuropsychological Reports of Inhibition in Episodic Retrieval

Few studies have investigated retrieval inhibition specifically using the part-list cueing paradigm in patients with memory deficits. As one might expect, the available data suggest that patient performance varies depending on the locus of functional impairment, which is in turn related to lesion localization. As language processing is predominantly left lateralized, patients with damage to the left hemisphere are typically more impaired in processing and remembering verbal material relative to patients with right lateralized damage. Memory for verbal material in patients with left medial temporal lesions, including the hippocampus, is consistently reported to be severely impaired and is attributed, at least in part, to the rapid forgetting of recently processed verbal information (Milner, 1975; Milner, 1978; Frisk & Milner, 1990). While patients with frontal lobe lesions also display significant impairment in the recall of verbal material, their difficulties appear to stem from a deficit in controlled processing at encoding and retrieval stages rather than rapid forgetting (Moscovitch, 1992; Shimamura, 1995, 2000a). Moscovitch (1989, 1992) has distinguished between automatic or "cue dependent" and strategic or more effortful retrieval processes. According to this view, automatic retrieval processes are primarily subserved by the hippocampus, while more effortful or internally generated search strategies require additional input from the prefrontal cortex. Evidence to further support this hypothesis was observed in neuroimaging findings obtained through PET with neurally intact subjects. Schacter, Reiman, Uecker, Polster, Yun, & Cooper (1995) and Schacter, Alpert, Savage, Rauch, & Alpert (1996a) found increased hippocampal activation during high frequency/deep encoding conditions, leading to easier retrieval, while increased prefrontal activation was observed during low frequency/shallow encoding conditions, i.e., conditions requiring more effortful retrieval processes.

Considering the different sources of impairment for left frontal or left medial temporal patients, della Rochetta & Milner (1993) investigated recall performance in patients who had sustained surgical excisions in either left temporal, right temporal, left frontal or right frontal lobes. All patients' temporal excisions included portions of the hippocampus and were further subdivided into groups with large (LTH) and small (LTh) hippocampal excisions. In Experiment 1, patients and controls received study lists and subsequent recall tasks in the following four conditions (study: recall): 1) mixed category: free recall, 2) mixed category: recall with category labels, 3) category blocked: free recall, 4) category blocked: recall with category labels. The four conditions were designed with the prediction that the proportion of items recalled in the mixed presentation conditions would be less than recall for lists blocked by category and that the presentation of category labels would improve performance at test relative to free recall (Tulving & Pearlstone, 1966; Roediger, 1973). It was hypothesized that patients with left hemisphere excisions involving a large portion of the hippocampus (LTH) would be severely impaired in all four conditions, given their inability to retain verbal information. Due to a rapid loss of verbal information, these patients should not benefit from encoding or retrieval manipulations that otherwise aid neurally intact subjects or patients whose impairment is not attributed to rapid forgetting. Alternatively, patients with left frontal excisions only should be susceptible to conditions in which items are not grouped in a meaningful manner during encoding or during recall conditions which require self-initiated search processes without the benefit of cues.

When collapsing across all four conditions, the left frontal and LTH patients showed significantly impaired recall relative to controls, while the right hemisphere patients (frontal and temporal) and LTh patients did not perform significantly different from controls. Controls and all patient groups performed better in category blocked presentation conditions relative to the mixed presentation conditions and recalled the most items in the category blocked: recall with category labels condition. Although both left frontal and LTH patients recalled significantly fewer items overall, left frontal patients showed a larger benefit during recall in the category blocked: category labels condition. That is, left frontal patients' recall performance was unimpaired relative to controls when both organized encoding and cued retrieval conditions were provided, which is consistent with a deficit in effortful/internally generated retrieval strategies, and contrasts with LTH patients who displayed impaired performance even when encoding and retrieval conditions were maximized.

Several studies have demonstrated that left frontal patients are also extremely susceptible to proactive interference (Gershberg & Shimamura, 1995; Shimamura, Jurica, Mangels, 1995; della Rocchetta & Milner, 1993; Moscovitch, 1992; Petrides & Milner, 1982; Hamilton & Martin, 2005, in press; Martin & Lesch, 1996). For instance, patients with frontal lobe lesions have been reported to disproportionately intrude previously encoded items during recall in both short-term memory (Martin & Lesch, 1996; Hamilton & Martin, 2005, in press) and long-term episodic memory tasks (Gershberg & Shimamura, 1995; Shimamura et al., 1995). As executive function processes are ostensibly subserved by the frontal lobes, exaggerated proactive interference effects observed in frontal lobe lesion patients have been attributed to deficits in the manipulation (e.g., organization) of relevant and/or the inhibition of irrelevant information during recall (Baldo & Shimamura, 2002; Hamilton & Martin, 2005, in press). Given the design of the part-list cueing paradigm, it is conceivable that part-list cues (especially same category items) act as highly salient yet distracting stimuli that must be inhibited in order to search for the remaining items to be recalled. In fact, some memory models propose that part-list cues are overactive during retrieval, preventing access to the remaining items to be recalled (Rundus, 1973; Shiffrin, Murnane, Gronlund, & Roth, 1989). Even if suppression of the part-list items is not required, several memory models (e.g., SAM) propose that normal search strategies are disrupted during recall by the part-list cues. Accordingly, left frontal lobe lesion patients should have particular difficulty when part-list cues are presented during recall. However, if the information is still available, only inaccessible, left frontal patients should significantly improve when cues are provided that aid rather than disrupt recall (e.g., category labels without part-list cues). In comparison, LTH patients (i.e., patients with large hippocampal excisions) should not benefit from retrieval aids if impaired recall is due to rapid forgetting (della Rocchetta & Milner, 1993).

In a second experiment, della Rocchetta & Milner (1993) tested the same patient groups (i.e., left temporal, right temporal, left frontal or right frontal) in a modified version of the part-list cueing paradigm. Patients and controls studied lists of items from various categories and subsequently received recall conditions in which only category labels or category labels plus part-list cues were presented. In addition, recall tests were conducted at immediate and delayed intervals (90 minutes), such that all subjects received each of the following four conditions: category labels (list A)/immediate, category labels plus part-list cues (list B)/immediate, category labels (list A)/delayed, category labels with no part-list cues (list B)/delayed. It should be mentioned that only category labels (without any part-list cues) were presented during recall after the delay in order to ensure that additional retrieval blocks did not compound any recall impairment after a delay. In addition, separate lists (A and B) were constructed in order to compare performance for recall after a delay to conditions in which either the previous list during immediate retrieval contained category labels only or category labels plus part-list cues.

In the immediate recall interval, all subjects showed significant benefit during recall when only category labels were present in comparison to category labels and part-list cues. Left frontal patients displayed the most difficulty in the category labels and part-list cues/immediate condition, recalling significantly fewer items relative to right temporal patients and controls, while LTH patients' performance was not significantly different from any other group. As predicted, however, left frontal patients showed substantial improvement in recall when only category labels were present at test, showing no significant difference from controls. Conversely, LTH patients showed relatively little benefit when only category labels were presented, recalling significantly fewer items relative to controls during immediate recall.

Although only category labels were presented at the delay, controls recalled significantly more items from list A than list B (list B contained category labels plus part-list cues presented during *immediate* recall); however, none of the patient groups showed this difference. Both left frontal and LTH patients recalled significantly fewer items from list B relative to controls and right temporal patients. In addition, LTH patients recalled significantly fewer items for list A, while, importantly, the number of items left frontal patients recalled in list A (which contained no part-list cues) did not reliably differ from controls. The results obtained in the immediate and delayed conditions during recall when only category labels or category labels plus part-list cues were presented are consistent with the hypotheses developed from performance patterns often observed in patients with left frontal or left medial temporal lesions. LTH patients were not as susceptible to the effects of part-list cues and did not benefit from the absence of part-list cues to the same extent as left frontal patients. Furthermore, LTH patients displayed a substantial decline in recall from the immediate to delayed conditions, indicating that their impaired recall performance is more affected by the progression of time rather than interference during retrieval. Conversely, left frontal patients were particularly vulnerable to conditions requiring effortful retrieval (overcoming the effects of part-list cues). However, when only category cues were present, this patient group improved substantially, showing no significant difference in recall from controls even after the delay. The pattern of performance observed for left frontal patients suggests that their recall impairment was not merely attributable to a rapid decay of the material, but more to its inaccessibility.

Neuropsychological Reports of Inhibition in Semantic Retrieval

The left prefrontal cortex has been shown to be critically involved in semantic retrieval, especially when the task demands are high (Poldrack, Wagner, Pruli, Desmond, Glover, & Gabrieli, 1999; Thompson-Schill, D'Esposito, Aguirre, & Farah, 1997). Consistent with the distinction between automatic and controlled or effortful retrieval processes and the proposed involvement of left frontal regions during more demanding retrieval tasks (Moscovitch, 1989, 1992), patients with damage to left frontal regions have also shown deficits in a semantic retrieval tasks, i.e., generating a verb to a noun cue, under conditions in which retrieval is difficult (Thompson-Schill, Swick, Farah, D'Esposito, Kan, & Knight, 1998; Martin & Cheng, 2005).

In contrast to the hypothesized role in difficult semantic retrieval, Thompson-Schill et al. (1997, 1998) have proposed that the role of the left prefrontal cortex, specifically the left inferior frontal gyrus (LIFG) is to select an appropriate response (related verb) among several competing alternatives. Thompson-Schill and colleagues (1998) found that patients with focal lesions involving the LIFG showed severe difficulty generating appropriate verb responses to nouns in a high-selection condition with two appropriate verb alternatives compared to low-selection conditions with one dominant verb response. However, Martin and Cheng (2005) noted a possible confound in association strength between the high and low conditions. That is, the possible verb responses in the high selection condition had low association strengths with the noun as well. Martin and Cheng (2005) partially replicated the methods used by Thompson-Schill and colleagues (1997, 1998), adding a third condition to manipulate association strength. Thus, the three conditions evaluated were a high selection/low association, high selection/high association, low selection/(high association) (see Martin and Cheng, 2005, for details). The investigators reasoned that if selection was critical to the verb generation task, both high selection conditions, regardless of association values, should be more difficult than the low selection condition. However, if association strength is the crucial factor influencing the ease or difficulty with which verbs are retrieved, then the high selection/low association condition should be more difficult than the other two conditions.

Martin and Cheng (2005) tested neurally intact Rice undergraduates, elderly controls and ML, an aphasic patient with a left frontal lesion including the LIFG. ML's performance was of particular interest in order to compare his data to that obtained by Thompson-Schill et al. (1998) and investigate more thoroughly the involvement of the left IFG on selection demands and association strength. Undergraduates and elderly controls performed similarly across all three conditions, displaying significantly longer reaction times for the high selection/low association condition relative to either the high selection/high association and low selection conditions, showing no significant difference between the latter two. The performance pattern observed in elderly controls' reaction times was reflected in their error rates as well, showing significantly more errors in the high selection/low association condition than either of the other two conditions[4]. Error rates in the high selection/high association and low selection conditions did not significantly differ. ML showed a similar pattern as the undergraduates and control subjects but with exaggerated difficulty for the high selection/low association condition relative to the high selection/ high association and low selection conditions. Reaction times in these latter two conditions did not significantly differ and were below the means for elderly controls. ML showed the same pattern with error rates as he was 93% accurate in both the high selection/high association and low selection conditions but only 73% accurate in the high selection/low association condition. ML's performance in the low compared to high association conditions is consistent with the hypothesis that retrieval in the verb generation task is critically influenced by the strength of the relationship between the cue and appropriate response, rather than the number of competing responses. When the relationship between the cue and response is subtle or ambiguous, strategic or effortful retrieval processes are required, placing increased demands on left frontal regions, and consequently, creating more difficulty for patients with left frontal lesions.

Patients with damage to left frontal regions also have been reported to have deficits in other semantic retrieval tasks including category or letter fluency (Benton, 1968; Bornstein, 1986; Milner, 1964; Jankowski, Shimamura, Kritchevsky, & Squire, 1989; Baldo, Shimamura, Delis, Kramer & Kaplan, 2001, Baldo & Shimamura, 1998). Fluency tasks of this nature entail verbally generating as many different exemplars as possible (e.g., category: animals or letter: F) within a limited time frame (e.g., one minute). The task involves the generation of unique items within a specific domain, requiring the ability to retrieve several exemplars within a short period of time while monitoring the items already generated to prevent their reselection. Deficits in fluency tasks for left frontal patients potentially arise from a susceptibility to proactive interference (previously generated items interfere with subsequently retrieved items) or impaired strategic retrieval in semantic memory (Baldo & Shimamura, 1998). In addition, patients with left frontal lesions have shown an inability to endogenously switch between subcategories of exemplars, which is a strategy that has been demonstrated in neurally intact subjects, which might be attributed to the general disruption of executive function in patients with frontal damage. For instance, Troyer, Moscovitch, Winocur, Alexander, and Stuss (1998) found that control subjects strategically switched among subcategories of animals, e.g., pets or farm animals, while left frontal patients continued generating exemplars from the same subcategory. However, Baldo et al. (2001) found that when left frontal patients were specifically instructed to switch between categories (rather than subcategories), the switch cost was not disproportionately greater than right frontal lesion patients or controls. Their finding is consistent with the hypothesis that patients with left frontal lesions are specifically impaired in internally generated search strategies, but benefit significantly when items are presented in a meaningful manner at encoding (e.g., blocked by category) or when cues (e.g., category names) are provided during retrieval.

Short-term memory and encoding and retrieval in long-term memory

Thus far, the discussion regarding episodic and semantic retrieval inhibition in patients with memory deficits has focused on patients who have difficulty encoding and retaining new episodic memories due to a rapid loss of information or patients who have difficulty recalling information requiring internally generated retrieval processes and/or tasks that induce proactive interference. Given the relationship observed between short-term and long-term memory (e.g., Hanley, Young & Pearson, 1991; Martin, 1993; Romani & Martin, 1999), performance for memory tasks reported to induce retrieval inhibition effects is also worthy of investigation in patients with short-term memory deficits. Neuropsychological evidence suggests that deficits in short-term memory can adversely affect long-term learning and that distinct capacities maintain lexical-semantic and phonological information in short-term memory (Hanley, Young & Pearson, 1991; Martin, 1993; Martin, Shelton, & Yaffee, 1994; Romani & Martin, 1999). Although patients displaying impaired short-term memory can demonstrate preserved long-term retention, the extent of this retention depends on the type of short-term memory deficit and task (Shallice & Warrington, 1970; Warrington & Shallice, 1969; Baddeley et al., 1988; Martin, 1987; Martin, Shelton, & Yaffee, 1994; Romani & Martin, 1999). Patients showing deficits in retaining lexical-semantic information in short-term memory also have been reported to have damage to regions within the left prefrontal cortex. Moreover, factors underlying deficits in episodic and semantic retrieval tasks, namely, a susceptibility to proactive interference and an inability to inhibit irrelevant information, have been proposed to play a role in semantic short-term memory deficits as well (Hamilton & Martin, 2005, in press). This issue will be revisited in subsequent sections.

Martin and colleagues (Martin et al., 1994; Martin & Lesch, 1996; Romani & Martin, 1999; Martin & Freedman, 2001; Freedman & Martin, 2001; Freedman, Martin & Biegler, 2004; Martin & He, 2004; Hamilton & Martin, 2005, in press) have reported extensive case studies for patients AB and ML, who have been identified as having a semantic short-term memory deficit. Both AB and ML sustained CVAs which resulted in left frontal lesions and also included damage to adjacent parietal areas. Martin and colleagues (Martin et al., 1994; Martin & He, 2004; Martin & Lesch, 1996) demonstrated that both AB and ML have reduced semantic short-term memory capacities that are not solely attributable to semantic knowledge or semantic or phonological processing deficits. AB's and ML's single picture naming abilities on the Boston Naming Test were well within the range of controls and both patients scored 100% correct on questions judging the attributes of single items (e.g., "Is sandpaper soft?"). AB and ML also showed good single word processing as they scored 98% and 96% correct on single word repetition respectively. Although AB displayed slightly impaired performance on auditory lexical decision: 96% correct for words and 87.5% correct for nonwords, and auditory discrimination tasks: 90%, ML performed very well, obtaining 97% correct for auditory discrimination and 99% correct for auditory lexical decision tasks.

Despite preserved semantic knowledge and single word production and processing abilities, Martin et al. (1994) and Martin and Lesch (1996) reported that AB and ML displayed very reduced word spans and impaired retention for lexical semantic information in short-term memory. AB and ML performed very similarly, showing phonological similarity effects and better performance for auditorily presented lists. Regarding serial recall for word and nonword lists presented auditorily, AB scored 73% and 77% respectively and his recall dropped considerably for 3 item lists, obtaining 27% for words and 13% for nonwords. ML had similar difficulties with word and nonword lists, obtaining 70% and 60% correct for 2 item word and nonword lists respectively. His performance further declined for 3 item lists, obtaining only 10% correct for both words and nonwords. The observed phonological similarity and auditory presentation effects indicate that both patients' phonological processing capacities were operating in a manner similar to control subjects. However, neither patient showed a significant benefit from recalling word lists compared to nonword lists suggesting that their recall capabilities relied on phonological rather than lexical codes. In addition to recall, AB and ML showed extreme difficulty maintaining lexical-semantic information when no output was required. One task assessing this ability includes the category probe task in which items are presented followed by a probe. The subject must determine whether the probe is from the same category as any of the previously presented list items. A similarly designed rhyme probe task also has been used to assess the ability to maintain phonological information in short-term memory. Control subjects typically perform substantially better in the rhyme probe relative to the category probe task, obtaining mean spans of 7.02 and 5.38 respectively (Martin et al., 1994). Comparatively, AB and ML scored well below the range of control subjects on the category probe task, obtaining spans of 2.2 and 1.8 respectively (Martin et al., 1994; Martin & He, 2004). However, as demonstrated with controls, AB and ML showed better performance in the rhyme probe task with spans of 4.6 and 3 respectively, displaying an advantage for retaining phonological compared to lexical-semantic information. In addition, both patients showed an impaired ability to make attribute judgments when matching the correct attribute to one of two items, e.g., "Which is rough, cotton or sandpaper?". AB only obtained 50% (chance performance) while ML obtained 65% correct. In contrast, both patients were able to make 100% correct judgments for the same attribute questions presented visually for an unlimited amount of time, i.e., requiring no memory load (Martin et al., 1994; Martin & He, 2004). They also performed substantially better for shorter auditory items containing only one noun and one attribute (e.g., "Is cotton rough?"), with AB scoring 100% correct and ML scoring 88% correct.

In contrast to ML's and AB's better performance for phonological relative to lexical-semantic retention, Martin et al. (1994) reported data for patient EA who showed the opposite pattern. EA sustained a left lateral CVA which resulted in lesions within the left primary auditory cortex, superior temporal gyrus, and the superior and inferior parietal lobes. EA also has a reduced short-term memory capacity, although she shows a better ability to retain lexical-semantic information relative to maintaining phonological information. During serial list recall, EA did not show a significant advantage for auditorily presented lists. During word and nonword serial list recall, EA showed an advantage for recalling words (whereas AB and ML did not) indicating that lexical-semantic information aided her list recall. Interestingly, AB and ML displayed better performance for lists correct compared to EA. For two item word lists, EA obtained 67% correct and 30% correct for nonword lists. Her recall declined substantially for 3 item lists, obtaining 17% correct for words and no lists correct (0%) for nonwords. Regarding non-recall tasks that require short-term retention, EA performed similarly for the rhyme and category probe tasks, showing a span of 2.65 and 2.82 respectively. However, both AB and ML had greater rhyme probe spans but significantly lower spans for the category probe task. In addition, EA scored 100% correct on the two-item attribute judgment questions (with no repeated words across questions) when presented auditorily.

Although EA shows a better ability to maintain lexical-semantic relative to phonological information in short-term memory, she is severely impaired in repeating sentences verbatim, consistently making semantic substitutions and paraphrases during sentence recall. AB made several semantic substitutions and other errors as well, but his overall verbatim repetition was substantially better than EA's. For example, for syntactically complex sentences, AB recalled 50% of the sentences verbatim whereas EA recalled only 3% verbatim (Martin et al., 1994). It is notable that while EA's verbatim repetition was very poor, she often preserved the meaning of the sentences in her repetition, suggesting that phonological short-term memory retention is necessary for verbatim sentence repetition but not for preserving the propositional meaning of a sentence.

Given the observed double dissociation in capacities for maintaining phonological and lexical-semantic information in short-term memory, and resulting performance in retaining individual words or sentences over a short time period, what is the relationship between short-term and long-term memory? Tasks involving long-term retention vary widely in both the materials presented and processes used to perform the task. However, previous evidence indicates that short-term memory influences performance on long-term memory tasks, suggesting that patients would show different patterns of performance based on whether they have a semantic or phonological short-term memory deficit.

Romani and Martin (1999) tested patient AB's long-term retention abilities in a variety of tasks including standard recognition and recall tasks, in addition to sentence and story recall. AB displayed exceptionally good visual recall performance on the Wechsler Memory Scale (Wechsler, 1987), which involved the recall of abstract geometric shapes, scoring 99% on immediate recall and 98% on delayed recall. During a separate recognition test with meaningful pictures, AB obtained 98% correct and scored within the range of controls even when semantic and phonological distractors were added. Conversely, AB showed substantially impaired performance for the recall of word lists (e.g., free recall) and paired associates. In contrast to amnesic patients, AB did show improved performance during a repeated list learning task, though his level of performance remained far below that of controls. AB's performance pattern for the long-term retention of individual words parallels his inability to maintain words in short-term memory, suggesting that short-term memory is involved in the transfer of lexical-semantic information to long-term memory. AB also showed impaired performance in a recognition task with spoken words, scoring 71% with no distraction task and 74% with an intervening counting task. However, his recognition improved substantially, scoring 95% for concrete words and 88% for abstract words when items were presented visually for two seconds. Although the recognition task did not require output, AB continued to show an impaired ability to retain lexical information when it was not presented for an extended period of time. His performance improved, however, during visual presentation with extended time, suggesting that additional time during encoding potentially influences the transfer, organization, and subsequent retention of lexical information as well. That is, since left frontal patients have been shown to be susceptible to disruptions in encoding context (e.g., part-list cueing), while benefiting from studying list items in an organized manner (della Rochetta & Milner, 1993, Baldo & Shimamura, 2002), better performance may arise from additional encoding time as it could provide additional opportunity to encode the study context or individual items in a meaningful manner.

Romani and Martin (1999) also investigated whether the same capacity is used to retain individual word meaning and propositional meanings (as represented in a story). If AB demonstrated an impaired ability to retain individual word meanings, especially at short presentation intervals, then he should show the same degree of impairment for story comprehension if the same capacity is involved. AB performed very well for the story comprehension questions, scoring within the range of controls on all story types. However, his comprehension declined to a level outside of the range of controls when answering questions for individual unrelated sentences that could not be further integrated into higher order propositional meanings. Romani and Martin (1999) reasoned that the discrepancy in AB's long-term retention of individual words and story-related information suggests that separate capacities maintain unintegrated lexical-semantic information and integrated propositional meanings.

EA was not tested on the same long-term memory tasks as AB, and could potentially do as poorly on long-term individual word retention tasks, given her particularly reduced word span. However, other patients with phonological STM deficits have been reported to perform within the normal range in long-term memory tasks, e.g., paired associates and repeated list learning. Warrington and Shallice (1969) tested patient KF on a variety of repetition, perception, matching, identification, and long-term recall tasks. KF displayed a severe impairment for word repetition scoring only 33% lists correct for two items and 7% correct for three items. KF showed unimpaired articulatory and auditory perception abilities, indicating that his impaired repetition was not due to speech motor or perception deficits. In contrast to his short-term retention performance, KF performed fairly well in a paired associate learning task, scoring just outside the range of controls. On lists of incomplete words and pictures, in which the items were somewhat degraded, and on a repeated list learning task in which items were presented auditorily, KF performed within the range of controls.

A similar pattern of performance has been reported for patient PV (Baddeley et al., 1988). PV displayed very reduced digit and item spans and a pattern consistent with a phonological STM deficit, yet performed well on a paired associate learning task for words in her primary language. However, PV was severely impaired when given a paired associate learning task with words from another language. Martin (1993) tested EA on a task learning words from a foreign language (Spanish) and found similarly impaired performance. PV's and EA's performance suggest that phonological retention is needed to learn new phonological codes associated with learning new words, i.e., from another language, but is not necessary in retaining familiar individual words in long-term memory (Romani & Martin, 1999). Based on evidence presented previously for KF and PV, patients with short-term memory deficits for mainly phonological information should show better performance during episodic and semantic retrieval tasks than semantic short-term memory patients, possibly performing within the range of controls (Freedman & Martin, 2001).

Patient Backgrounds

The previous discussion regarding episodic and semantic retrieval and the relationship between short-term and long-term memory based on neuropsychological reports was presented in order to formulate hypotheses for the following patients' performance in subsequently proposed experiments. As stated in the introduction, the goal of the proposed experiments is to assess whether similar effects, i.e., interference in language tasks and inhibition in memory tasks, derive from a common source. Namely, are lexical representations accessed in a similar manner during word recall or recognition memory tasks and picture naming, picture-word matching, or word-word matching tasks such that repeated sampling from the same category leads to similar effects across comparable language and memory tasks? Non-fluent aphasic patients with left anterior lesions have displayed exaggerated interference effects in a semantic blocked naming task that have been attributed to an excess of inhibition among several related lexical representations or an inability to select the correct item among several active related lexical representations (McCarthy & Kartsounis, 2000; Schnur et al., in press). Schnur and colleagues (in press) have proposed that an "executive selection mechanism," outside of the lexicon, selects a target lexical representation among several competitors. The "executive selection mechanism" is impaired in left frontal patients leading to an increased difficulty during lexical selection when repeatedly naming the same items in a related context. The processes underlying this mechanism have not yet been specified. For example, it is not clear whether the executive selection mechanism is separate from other executive processes that have been proposed, e.g., inhibition or switching (Miyake et al., 2000). However, this conceptualization is consistent with other findings proposing that executive processes that are external to the lexical system act on lexical representations in order to distinguish between relevant and irrelevant information and subsequently inhibit irrelevant verbal representations (Hamilton & Martin, 2005, in press). Conceivably, a deficit in inhibiting irrelevant, active lexical representations, in order to select the correct item, may also play a role in deficits observed in left frontal lesion patients during episodic and semantic retrieval tasks with semantically related items. That is, patients with damage to left frontal areas may be highly susceptible to proactive interference because they have a deficit in an executive processing mechanism used to distinguish between previously presented or retrieved related items during subsequent recall or generation.

Given the relationship Romani and Martin (1999) observed between the retention of individual lexical items in short-term and long-term memory tasks, it follows that patients who display proactive interference in short-term memory should show a similar pattern in long-term memory tasks. Notably, proactive interference has been shown to be a contributing factor in ML's impaired performance for tasks involving short-term memory (Hamilton & Martin, 2005, in press). Moreover, Romani and Martin (1999) assert that, based on AB's performance, patients with code-specific short-term memory deficits should always show impaired long-term retention for information containing the same type of code, e.g., lexical-semantic. Accordingly, patients who do not show excessive proactive interference effects in short-term memory tasks should not show exaggerated interference effects in long-term memory tasks. In summary, if proactive interference is related to overly active or inhibited lexical items, patients should show exaggerated interference effects in language and memory tasks with repeatedly sampled related items; however, patients not susceptible to proactive interference should show interference effects that are near or within the normal range.

The following series of studies will test patients ML, AR, JJ, and LW. Each patient's background will be presented subsequently.

Patient ML.

ML is a right-handed male who is approximately 63 years of age. He sustained a left hemisphere lesion from a cerebral vascular accident in 1990. A recent structural MRI scan obtained from our lab revealed a lesion encompassing the left inferior and middle frontal gyri and large areas of the left parietal lobe. However, the temporal lobe appears to be relatively intact. ML is a non-fluent aphasic who is characterized as having a very reduced speech rate, hesitations, and word finding difficulties, although his speech would not be classified as agrammatic. He does not appear to be apraxic and shows good single word repetition with few errors (96%). ML demonstrates normal picture naming and single word comprehension abilities as he scored 98% on the Philadelphia Naming Task (Roach, Schwartz, Martin, Grewal, & Brecher, 1996) and scored above the mean (88%) on the Peabody Picture Vocabulary Task (Dunn & Dunn, 1981) in which subjects are instructed to choose the object that most closely matches one of two other objects (Martin & Lesch, 1996; Martin & He, 2004). He also shows good single word reading abilities. On the Psycholinguistic Assessment of Language Processing in Aphasia (PALPA) (Kay, Lesser, & Coltheart, 1992), ML received 95% correct overall for single words varied on frequency and imageability. He only showed slight frequency and imageability effects scoring 93% correct for low frequency or low imageability words and 98% correct for high imageability and high frequency words. ML also displayed good performance for reading words from various grammatical classes, e.g., verbs, nouns, adjectives and function words. Although some aphasic patients with left frontal lesions have shown difficulty reading verbs and/or function words (e.g., Berndt et al., 1997), ML was 100% correct for reading verbs, nouns and adjectives, but showed a slight decline in performance for function words, scoring 85% correct. However, on another assessment controlling for the imageability of function words, ML scored 100% correct. ML shows difficulty reading nonwords (Lesch & Martin, 1998), scoring only 55% correct overall on a list of nonwords varied on syllable length. ML was also tested on nonwords from the PALPA battery (Kay et al., 1992) and showed word length effects scoring 67% correct for three letter nonwords, 33% correct for four and five letter nonwords and 17% correct for 6 letter nonwords.

As discussed in earlier sections, ML has a reduced short-term memory capacity, with a span of 2 that primarily involves a deficit in retaining lexical-semantic information[5]. Although his span is also reduced for phonological information relative to controls, it is impaired to a much lesser extent. Freedman and Martin (2001) calculated composite Z scores for AB, ML and EA across several tasks tapping phonological or semantic short-term memory. ML's phonological score was (-.23), while his semantic score was (-2.59). His pattern of scores paralleled AB's, (-.06) for phonological retention and (-3.30) for semantic retention, but contrasted EA's, (-4.14) for phonological capacity and (3.86) for semantic capacity. ML's short-term memory deficit has been partly attributed to excessive proactive interference and an inability to inhibit irrelevant verbal information (Martin & Lesch, 1996; Hamilton & Martin, 2005, in press). On list repetition for three items, Martin and Lesch (1996) reported that out of 14 of ML's errors, 12 included intrusions of items from previous lists. AB displayed somewhat of a similar pattern, showing intrusions in 11 out of 28 error responses. In contrast, EA only displayed one intrusion error (unpublished data). ML's error patterns indicated that his errors were not due to a rapid loss of information, but to previously retained items interfering with current list items. Hamilton and Martin (2005, in press) further tested this observation using a version of the recent negatives task (Monsell, 1978). The recent negatives task involves identifying whether a probe appearing at the end of a list of items appeared in the current list. The critical manipulation is to include a probe in the present list that was not actually in the current list but present within the *previous list*. The correct response is to reject the probe since it was not in the *present* list. Control subjects have been reported to show significantly longer reaction times to reject a recent negative probe relative to a non-recent probe appearing several lists back from the previous list. ML showed excessive difficulty rejecting recent negative probes relative to non-recent probes, which indicated that irrelevant information from the previous list remained in short-term memory, and that ML was unable to suppress it to provide the correct response.

Hamilton and Martin (in press) also investigated the relative influence of probes that were semantic and phonologically related to list items that were either in the current list or previous list. In particular, they were interested in whether ML would display exaggerated interference effects for both types of probes, suggesting that semantic and phonological codes remain active, and are therefore both important components of short-term memory. Age-matched controls showed significant interference effects in reaction time to reject semantic and phonologically related probes in the same list but not from previous lists. In contrast, ML showed excessive interference effects in reaction times to reject semantic and phonologically related probes both in the same and previous lists. ML's interference effects were more than 2 standard deviations above the control's mean for phonologically related probes and more than 4 standard deviations above the control's mean for semantically related probes. In addition, the magnitude of interference effects in standard deviations above the control means were greater for both phonological and semantically related probes in the previous lists compared to the same lists. ML's performance suggests that both types of codes remained active in short-term memory and is consistent with the view that ML is unable to suppress persisting irrelevant information in short-term memory.

Hamilton and Martin (2005) have also reported that ML displayed an exaggerated interference effect in an incongruent condition within the standard Stroop color word task (Stroop, 1935). To the extent that the stroop task requires the ability to inhibit a prepotent response (e.g., reading a written word), Hamilton and Martin (2005) proposed that ML's impaired performance was due to a damaged executive inhibitory mechanism, conceptually similar to the inhibitory mechanism reported by Miyake et al. (2000). However, ML performed within the range of controls in tasks requiring an inhibitory response with non-verbal stimuli, e.g., the anti-saccade task or spatial stroop task. Based on ML's pattern of performance in verbal and non-verbal inhibitory tasks, Hamilton and Martin (2005) attributed ML's deficit to an impaired inhibitory mechanism that is outside of the lexicon, yet specific to verbal material, which acts to suppress irrelevant lexical representations that are active in both language and memory tasks. It should be mentioned that ML showed a similar exaggerated interference effect in a picture-word interference task which required naming a picture and ignoring a simultaneously presented written distractor word that was semantically related or unrelated to the target picture. ML showed an interference effect in naming latencies (229 ms) for the semantically related condition that was almost six times larger than the mean for controls (40 ms). His performance in the picture-word interference task is consistent with Hamilton and Martin's proposal that ML has great difficulty suppressing irrelevant verbal information.

Patient AR.

AR is a right-handed male who is approximately 70 years of age. He sustained a left hemisphere lesion from a cerebral vascular accident in 1999. A structural MRI scan revealed a substantial lesion including the left frontal, parietal, and temporal regions. AR is non-fluent, showing a severely reduced speech rate marked by hesitations, word finding difficulties, and agrammatic speech as indexed by Quantitative Production Analysis measures (Saffran, Berndt, & Schwartz, 1989). AR shows fairly preserved picture naming and word repetition abilities as he scored 93% on the Philadelphia Naming Task (Roach et al., 1996) and 95% correct for single word repetition. In addition, AR displays fairly preserved semantic knowledge and processing as he received a standard score of 99 on the Peabody Picture Vocabulary test with spoken words. However, he only scored 76% correct within a single item attribute judgment test (e.g., "Is sandpaper soft?"). Upon further investigation, 8/20 errors were specific to color judgments, e.g., "Is a lemon orange?" AR has demonstrated difficulty in previous tasks processing color and producing color names. As AR shows good performance in picture naming and picture-word matching tasks (e.g., PPVT), it is possible that AR's inability to correctly answer questions regarding the color of fruits or vegetables is restricted to color processing difficulties rather than a loss of knowledge for fruits and vegetables. If these particular errors are not included, AR scored 86% correct on the single item attribute judgment task. AR also shows somewhat preserved auditory phonological processing as he was 93% correct in discriminating words from nonwords and 91% correct discriminating among one syllable nonwords. However, his performance dropped to 78% when discriminating between two syllable nonwords. With regard to his reading ability, as assessed by the PALPA, (Kay, Lesser, & Coltheart, 1992), AR has shown characteristics of deep dyslexia. Although he shows no effects of frequency, AR shows a significant imageability effect, obtaining 83% correct for high imageability words and only 38% correct for low imageability words. When comparing his single word reading ability for nouns, verbs, adjectives and function words, AR shows the best performance for nouns (65% correct) (which is consistent with his imageability effects), 40% correct for verbs and adjectives, and only 5% correct for function words. When imageability was matched for function words and nouns, AR obtained 15% and 30% correct respectively. AR shows very little ability to convert graphemes to phonemes as he has extreme difficulty sounding out individual letters, cannot read nonwords aloud or matching spoken to written nonwords. Thus, his word reading ability likely occurs through accessing lexical or semantic representations from print and using those representations to access phonological representations.

AR displays a restricted short-term memory capacity, with a short-term memory span of 2. However, he does not show a clear dissociation between semantic and phonological short-term memory. He displayed word length effects within two-item span tasks as he obtained 90% lists correct for one syllable words and 60% lists correct for three syllable words. His performance demonstrated the use of phonological information during list recall, which is a characteristic finding in patients with semantic short-term memory deficits. However, AR has difficulty in repeating single nonwords, scoring 70% correct for one syllable nonwords and 50% for two-syllable nonwords. Although AR showed phonological effects in word list recall, his nonword repetition suggests a deficit in phonological retention, especially when no lexical information is available and output is required. However, on two order probe tasks which do not require output, but instead require subjects to judge whether the order of the probe items matches the order of preceding list items, AR performed either just outside or within the range of controls as he scored 69% correct for words and 73% correct for nonwords.

AR also displayed considerable effects of imageability and frequency at all serial positions during word repetition, particularly during positions two and three for three item lists, and no effects of recency. It should be noted that large imageability effects and an absence of recency effects are incompatible with previous reports of semantic short-term memory deficits since, presumably, phonological rather than semantic information should primarily influence recall. Interestingly, AR showed the opposite pattern in a serial position probe task in which the subject is asked to identify which position in the list a probe occurred. AR no longer displayed imageability or frequency effects and showed a considerable recency effect. On the category probe task, AR scored 85% for one item, 75% for two items, 83% for three items, and 75% for four items. On two and four item category probe lists, AR also showed recency effects as he tended to make slightly more errors when probes from the same category occurred in earlier serial positions indicating that he performed better when there were no intervening items between the final list item and the probe; however, he did not show this pattern for three item lists. On the rhyme probe task, AR scored 95% for one item, 75% for two items, and 79% for three items; however, his performance dropped substantially (46%) for four items. Similar to the pattern observed in the category probe task, on three and four item rhyme probe lists, AR made no errors when the probe rhymed with the final list item, but made errors, i.e., saying the probe did not rhyme with any list items, in earlier serial positions. In addition, AR made several false positive responses in the four item list. That is, out of twelve possible responses in which the probe did not rhyme with any list item, AR made a "yes" response on 9 trials, i.e., he responded that the probe did rhyme with a previous list item. While, the short-term retention observed for ML, AB and EA appears relatively constant for tasks requiring input and output, AR shows somewhat of an advantage for retaining information in short-term memory when no output is required. His performance is consistent with a separation in input and output phonological buffers (Martin, Lesch, & Bartha, 1999), suggesting that phonological information degrades rapidly in the output buffer, as indicated by his impaired nonword repetition performance and the lack of a recency effect in the repetition tasks but not in the probe tasks.

Hamilton (2004) tested AR on two versions of the recent negatives task. In the initial version, the probe either matched one of the items one list back (recent negative) or a list item several lists back (non-recent negative) (see methods in Hamilton & Martin, 2005). The second version contained probes that were semantically or phonologically related to list items in the current or previous lists (see methods in Hamilton & Martin, in press). In the initial version of the recent negatives task, AR showed a non-significant

(99 ms) interference effect in reaction times to reject a recent negative probe that was within the range of controls. However, he was significantly less accurate in the recent negatives condition, obtaining only 56% trials correct compared to 85% trials correct in the non-recent negatives condition – an effect that was far outside the range of controls. In a second version containing phonologically or semantically related probes, AR showed no significant phonological relatedness effects in reaction times for probes either in the same or previous lists. AR did show a significant interference effect in reaction time for semantically related probes in the same list but not in the previous list. However, he failed to show any significant phonological or semantic relatedness effects in accuracy in either the same or previous lists, and his accuracy was slightly higher overall in the semantic relative to the phonological condition. AR's performance on the recent negatives tasks is consistent with other measures of his semantic and phonological short-term retention as he is not as impaired as ML in short-term memory tasks (particularly with semantic information) and does not display extensive interference effects.

At this time, we have not tested AR on the various inhibition tasks reported for ML previously, e.g., the Stroop color word task (Stroop, 1935), because AR has difficulties processing and producing color words. Alternatively, we plan to test him on a picture-word interference task since he shows a preserved ability to name pictures. However, we will need to pretest the written word distractors to be sure he can read them. Although inhibitory factors have not been directly associated with the picture-word interference task as have been found for the Stroop task (e.g., Miyake et al., 2000), we propose that, similar to the stroop task, the picture-word interference task requires the ability to ignore or suppress a response to reading the distractor word in order to name the picture. As discussed earlier, ML has been tested on this task and shows an exaggerated interference effect when a semantically related picture and distractor word are presented simultaneously. It will be interesting to investigate the nature of AR's inhibitory abilities and whether he performs within the range of controls or similarly to ML. His results could further elucidate the relationship between the ability to inhibit irrelevant verbal information and proactive interference in short-term memory.

Patient JJ.

JJ is an 84 year old right handed male who sustained a left lateralized lesion resulting from a cerebral vascular accident in 1994. Results from a structural MRI scan obtained in October 2002 revealed a lesion encompassing left superior temporal and supramarginal gyri, in addition to "symmetrical microvascular ischemic/ involutional (i.e., degeneration or decline in normal physiological function due to aging) deep white matter changes in bilateral frontal and parietal lobes, especially peritrigonal regions". Recently, JJ reported experiencing additional language difficulties that were not present previously. We have speculated that JJ may have sustained additional Transient Ischemic Attacks (TIAs or "mini strokes"), or has suffered from further degeneration or decline in frontal and parietal regions, although we have no neurological evidence to support this conjecture. However, we plan to obtain structural MRI or CT scans of JJ for the lab in the near future, if his medical condition will allow it.

JJ is fluent and shows a fairly normal speech rate, although he reports having some word finding difficulties. He demonstrates good picture naming and word repetition abilities, as he is 95% correct on the Philadelphia Naming Task (Roach et al., 1996) and scored 93% correct in a single word repetition task. He also showed preserved semantic knowledge as he scored 98% correct on the Pyramids and Palm Trees Test, which requires the subject to choose one of two pictures that best corresponds to the target picture. In addition, JJ scored 96% correct on the single-item attribute judgment test. JJ demonstrates somewhat preserved phonological processing abilities as he was 87% correct on an auditory lexical decision task and 81% correct on a nonword discrimination task containing items with one or two syllables; however, he showed no effect of syllable length on either of these tasks. JJ displays very good single word reading abilities as assessed by the PALPA (Kay et al., 1992). He scored 95% correct reading single words varied on imageability and frequency, but showed slight effects of imageability and frequency. He obtained 98% for high imageability words and 93% correct for low imageability words, and scored 100% correct for high frequency words and 90% correct for low frequency words. JJ will be tested on words varied by grammatical class. JJ displays difficulty reading nonwords, showing some length effects. He scored 83% correct reading nonwords with three letters, 66% correct with four and five letters, and 50% correct with six letters. On a second set of nonwords with one syllable, JJ scored 60% correct (24/40). He tended to lexicalize nonwords, providing sounds of real words (e.g., pook → "poke") for 11/16 errors.

JJ has a span of 2.5. Comparing one- and three-item auditory word span tasks, JJ failed to show a word length effect, scoring 88% correct for one-item, 100% lists correct for two-item lists, and 30% lists correct for three-item lists for both one and three syllable word lists. JJ tended to intrude previous list items for one syllable three item lists as 5/8 errors were items from previous trials. JJ also displayed intrusions for three-syllable three-item lists, but tended to repeat the same few words. That is, the 11 intrusions from this list consisted of four words recalled repeatedly. JJ obtained 84% lists correct for the two item repetition task, but his score dropped substantially for the three item repetition task as he obtained only 19% lists correct. With regard to items correct, JJ shows an advantage for maintaining items in the first serial position and shows more difficulty retaining items in the second and third serial positions, failing to show recency effects. JJ also shows effects of imageability and frequency to a lesser extent. He is better able to recall lists of words relative to nonwords scoring only 81% correct for one item nonword lists (compared to 93% correct for one item word lists) and 20% lists correct for two item nonword lists. In short-term retention tasks not requiring output, JJ shows a pattern of performance which contrasts with controls as he shows a slight advantage for maintaining semantic relative to phonological information as he obtained 85%, 70%, and 63% of trials correct in the category probe task for one item, two items and three items respectively compared to obtaining 70%, 70%, and 58% of trials correct in the rhyme probe task for one item, two items and three items respectively. JJ also appears to be somewhat impaired in retaining semantic information as he scored 83% correct in an attribute judgment task for two items, e.g., "Which is rough, cotton or sandpaper?" while scoring 96% correct for single item attribute judgments using the same items. JJ's pattern of performance is consistent with a phonological short-term memory deficit, though he also has some degree of semantic STM deficit. Although his ability to retain lexical-semantic information in short-term memory is below the range of controls, he shows an advantage for words compared to nonwords in list recall and items in the first serial position, as well as better performance in the category probe task. However, he does not show recency effects and displays a considerable inability to recall nonwords, suggesting a deficit in retaining phonological information in short-term memory.

Hamilton (2004) tested JJ on the same version of the recent negatives task as ML and AR, in which a probe item appeared in either the previous list or several lists back. JJ showed non-significant interference effects in reaction times (420 ms) and accuracy (70% for recent negatives and 89% for non-recent negatives). Hamilton (2004) also tested JJ on the recent negatives task with semantic and phonologically related probes in the same list or previous list. JJ displayed a non-significant facilitation effect (73 ms) for phonologically related probes from the same list, yet showed a significant interference effect (365 ms) that was 2.49 standard deviations above the control mean for phonologically related probes from the previous list. In addition, JJ displayed semantic interference effects for probes in the same list (107 ms) and in the previous list (89 ms), although the effects were not significant.

The effects in reaction times JJ displayed for phonological and semantically related probes were interpreted with caution as his accuracy for all conditions was very low, with his d' scores being close to zero. JJ scored 60% correct for phonologically related probe trials in the same list and 57% correct in the previous list. For semantically related probe trials, JJ scored 60% correct for probes in the same list and 50% correct in the previous list. None of the effects of phonological and semantic relatedness with regard to accuracy were significant. Given his poor accuracy and low d' scores, JJ (and ML) were tested on two, rather than three item lists[6]. JJ's accuracy increased substantially for all conditions. Although the phonological effects for accuracy were not significant, JJ was 91% correct on phonologically related trials for the same list and 97%

correct on previous lists. In addition, JJ was 100% correct for semantically related same list trials and 94% correct for previous lists. None of the effects of semantic relatedness were significant. With regard to reaction times for two item lists, JJ showed a significant interference effect (306 ms) for semantically related probes in the same list, with no other effects being significant. Hamilton (2004) concluded that given his improved accuracy and the absence of an interference effect for phonologically related probes, JJ's interference effect for phonologically related probes in three item lists was likely a Type 1 error. JJ's interference effect for semantically related probes but not for phonologically related probes suggests that he was relying on a semantic code to retain items. However, the mechanism (e.g., executive selection or suppression mechanism) needed to distinguish among similar representations and inhibit the incorrect response is impaired. We have tested JJ on the picture-word interference task and the verbal stroop task. On the picture-word interference task JJ displayed a 487 ms interference effect that was twice as large as ML's in both non-transformed and natural log transformed scores. It should be noted that JJ's reaction time scores were obtained with a voice key rather than through digitized media. He had quite a few voice key errors during the task, although they were distributed fairly evenly in the semantically related and neutral conditions. We had planned to re-test him by recording his responses and obtaining onset latencies digitally but he was unavailable due to medical conditions. On the verbal stroop task, JJ showed even greater difficulty, obtaining a 2733 ms interference effect and 63% errors in the incongruent condition. However, he also obtained 49% errors in the neutral condition indicating that he has some general trouble naming colors. JJ's performance on the picture-word interference and verbal stroop tasks suggests that he has a deficit in inhibiting irrelevant verbal information, in some cases, to a greater extent than ML. However, he is also the most elderly patient we have tested and it is unclear to what extent his performance is attributable to advanced age or an inhibition deficit. Nevertheless, based on his pattern of performance in the recent negatives task, picture-word interference and verbal stroop task, he should perform similarly to ML in the following language and memory experiments.

Patient LW.

LW is a right-handed male who suffered from an extracranial cerebral vascular incident due to arterial blockage in 2003. We do not have neurological reports or structural scans providing the lesion location at this time as he is medically ineligible to obtain an MRI scan, but we will obtain medical records from when his CVA was diagnosed. LW displays excellent picture naming and semantic processing abilities as he scored 96% correct on the Philadelphia Naming Test and 96% correct on the Pyramid and Palm Trees task. In addition, LW scored 98% correct on the two item attribute judgment task (e.g., "Which is rough, sandpaper or cotton?"), performing considerably better than ML, AR or JJ. LW also demonstrates fairly preserved phonological processing (although below the range of controls) obtaining 84% correct in an auditory lexical decision task, 88% correct on a word-nonword discrimination task and 85% correct on a nonword discrimination task. On the Boston Diagnostic, LW scored very well, obtaining 100% correct on single word reading and spelling assessments. LW scored 98% correct when reading single words varying in imageability and frequency, scoring equally well in all conditions. He also showed no effects of syllable and word length (PALPA, Kay et al., 1992). LW scored 100% correct for words varying in grammatical class, also scoring equally well for nouns, function words, adjectives and verbs (Kay et al., 1992), and scored 98% on a visual lexical decision task which required distinguishing between words and nonwords. He scored 83% in reading 3, 4 or 5 letter nonwords but only scored 33% when reading 6 letter nonwords. Although LW displayed very poor performance (approximately 10% correct) when sounding out individual letters, his performance for 3, 4 and 5 letter nonwords suggests that he has some preserved ability to use a sublexical reading route, i.e., converting orthography to phonology, and is not solely reading via a semantic or lexical route.

LW has a span of 4. He scored 97% correct on single item word repetition, 90% lists correct on two item repetition and 75% lists correct on three item repetition. He showed a slight imageability effect on the three item list, but no effects of frequency. In addition, LW showed a slight tendency to make errors in the first and third serial positions in the three item list, which upon further inspection tended to be low on imageability. On one vs. three syllable word span tasks, LW scored 100% on one syllable one and two item lists, 70% lists correct for three items, 30% lists correct for four items, and no lists correct for five items. For three syllable word lists, LW scored 100% correct on one and two item lists, 80% correct for three items, 10% correct for four items, and no lists correct for five items. LW does not appear to show a considerable word length effect for one compared to three syllable lists, although he does tend to show a recency effect in three and four item lists for both syllable lengths. This finding may seem contrary to an absence of a recency effect for the word repetition results just reported. However, the words in the one v. three syllable lists are matched on frequency and imageability, which may make them easier to retain relative to low imageability words. He shows difficulty repeating single nonwords, as he scored 70% correct on repeating one syllable nonwords. For nonword lists, he scored only 20% correct on two-item one-syllable nonword lists and was unable to recall any lists correctly on a three-item one-syllable nonword list. On the category probe task, LW obtained 90% correct for one and two item lists, 75% for three items, 71% for four items and 65% for five items. However, LW showed an advantage for the rhyme probe task as he scored 100% correct for one item, 85% correct for two items, 90% correct for three items, 79% correct for four items, and 80% correct for five items. LW shows an advantage for retaining words relative to nonwords, yet no word length effects as observed in the one v. three syllable word list recall tasks. LW's ability to maintain semantic information as indexed by the category probe task is at or above the level of AR and JJ, while his phonological retention is superior to the other patients' level of performance. However, given his relatively better performance for list repetition and retention, and the relationship established previously by AB between short-term retention and long-term memory, LW would be predicted to show better performance in the proposed episodic and semantic retrieval tasks relative to ML.

LW has completed the recent negatives task in which the probe either appeared in the same list or previous list and did not show an exaggerated susceptibility to proactive interference as he obtained a 285 ms interference effect which was within the range of controls (-74 ms – 337ms) (Hamilton & Martin, 2005). He has also been tested on the semantic and phonological version of the recent negatives task and showed facilitation, rather than interference effects for semantic and phonological same and previous list probes (phon same list: -96 ms, phon previous list: -43 ms, sem same list: -30 ms, sem previous list: -81 ms). Taken together, the results from the two recent negatives tasks suggest that LW does not display proactive interference effects in short-term memory beyond the range of controls. LW has also completed the Stroop color-word (Stroop, 1935) and picture-word interference tasks. In comparison to the results obtained by Hamilton and Martin (2005), LW showed an interference effect in the Stroop color-word (438 ms) that was more than twice as large as the control mean interference effect and greater than 1.5 times the largest interference effect among controls. Although his interference effect was not exaggerated to the same extent as ML's (969 ms), LW's interference effect in terms of natural log transformed data (.15) was still larger than the mean interference effect for controls (.086) and was in fact comparable to the interference effect for ML (.17). Conversely, LW showed no interference effect (0 ms) during the picture-word interference task for the semantically related condition when pictures and distractors were presented simultaneously[7]. The discrepancy in performance between the Stroop and picture-word interference paradigms is puzzling, especially since he obtained very few errors in both tasks (3/70 for Stroop and 4/60 for picture-word interference). However, recent unpublished verbal Stroop data obtained in the lab has also shown large interference effects in reaction times for patients who are more similar to LW than ML with regard to speech fluency, short-term memory, and language processing in a semantic context (Crowther, 2006). Conceivably, the verbal Stroop task could be especially difficult for a wide range of aphasic patients, and not restricted to patients with large left frontal lesions. As we have been unable to obtain a structural MRI for LW due to a medical condition, the locus of his lesion is unknown. Nevertheless, he does not display excessive proactive interference in the previously discussed short-term memory tasks or exaggerated inhibition difficulties in the picture-word interference task. Thus, in contrast to ML, LW is predicted to perform close to or within the range of controls in the following language and memory experiments.

The following experiments were designed to assess whether patients who have difficulty inhibiting irrelevant information in order to select the correct item among competing representations in language tasks (e.g., the Stroop task or picture/word interference) and short-term memory tasks (e.g., the recent negatives task) would show similar patterns of performance in language and long-term episodic memory tasks that require the selection of a correct item among several similar items from the same category that are repeatedly sampled, i.e., repeatedly presented or retrieved. Experiments 1 – 4 are language tasks testing the repeated naming or matching of pictures and words from the same category, while Experiments 5 – 7 are proposed long-term memory tasks with designs that are very similar to Experiments 1 – 4 in order to closely compare each patients' performance across all experiments.

Experiment 1: Semantic Blocked Naming

Method

Subjects.

Seven control subjects with no history of neurological injury and patients ML, AR, JJ, and LW participated in the semantic blocked naming task. Both the control subjects and patients received $10 per hour of participation. The control subjects were recruited from the Brain and Language Lab subject pool and were education and age-matched with the patients, with ages ranging from 55 – 75 years and an education level of at least a high school degree, with most having had some college education. English was the first language of all subjects.

Materials and Design.

The stimuli used in Experiment 1 were the same materials used by Schnur et al. (in press). The materials consisted of 72 Snodgrass and Vanderwart (1980) pictures or other similar line drawings selected from 12 different categories. Each category contained six exemplars and were presented in both semantically blocked, e.g., ear, arm, toe, nose, chin, thumb, and mixed sets, e.g., ear, table, goat, fan, mountain, dress. The materials were matched on frequency, phonological onset, and rhyme similarity for both semantically blocked and mixed sets (see Schnur et al., in press, for more detailed methods). The semantically blocked and mixed sets each contained six pictures. Both set types were presented across four cycles with the pictures appearing in random order during each cycle. Following the sixth picture, the next cycle began repeating the previous set of pictures (in a different order). One block consisted of four cycles with six pictures per cycle, adding to 24 pictures presented in each block. There were 24 blocks total, 12 same category blocks and 12 mixed blocks. The same category and mixed blocks were presented in a different random order for each subject.

Procedure.

All pictures were presented using Psyscope 1.2.5 (Cohen, MacWhinney, Flatt, & Provost, 1993). Before the experiment began, the controls, ML, AR, JJ, and LW participated in a practice session in which they were familiarized with each of the 72 pictures presented during the experiment. A single picture appeared on the screen followed by the word describing it 1000 ms after picture onset. Subjects were instructed to name the picture using the word printed on the screen and proceed to the next picture at their own pace by pressing the space bar.

The experimental procedure used for all subjects was similar to the fast presentation rate condition used by Schnur et al. (in press), with some minor changes. Each trial began with the simultaneous presentation of a beep and a single picture that remained on the screen for 2000 ms. Two small dots at the bottom of the screen indicated when the voice key was triggered. Following the subjects' response, the experimenter pressed the keys 1, 2 or 3 indicating whether the response was correct, an equipment error occurred (e.g., the voice key was did not function correctly) or a subject error occurred (e.g., the incorrect name was produced) and proceeded to the next trial.

Data Analysis.

The following analysis methods apply to Experiments 1 – 5. Reaction times were removed if they were classified as an error response or were three SDs above or below each subjects' mean (2.5 SD for controls in Experiment 1). Errors were categorized into two types: equipment errors in which the voice key was incorrectly triggered (only in Experiment 1) or subject errors in which the incorrect name was produced for a picture. As reaction times for patients were highly skewed, we conducted all reaction time analyses for patients and control subjects using a natural log transformation in order to compare the patients' performance to the controls'. All patients' data were analyzed individually using items as a random factor, while the data for control subjects were averaged and the ranges reported. In addition, all t-tests reported throughout Experiments 1 – 7 for control subjects and patients are two-tailed.

Results

Control Subjects.

Only 0.3% equipment and 1.0% subject errors were found for controls. Excluded reaction times that fell above or below 2.5 standard deviations of the mean constituted 1.4% of the data.

Reaction times were analyzed using a 2 (semantic blocking) x 4 (presentation cycle) within subjects ANOVA. Significant effects of cycle, $F(1, 6) = 26.84$, $MSe = 3.103E^{-03}$, $p < .001$, and the semantic blocking x cycle interaction, $F(3, 18) = 11.44$, $MSe = 7.043E^{-03}$, $p = .004$, were observed, while the main effect of semantic blocking approached significance, $F(1, 6) = 5.537$, $MSe = 1.962E^{-03}$, $p = .057$. In addition, linear contrast effects were significant for the semantically blocked x cycle interaction, $F(1, 6) = 14.172$, $MSe = 1.073E^{-02}$, $p = .009$ indicating that the difference between the semantically blocked and mixed conditions increased across cycles. As displayed in Table 1, the controls showed a 27 ms facilitation effect during cycle 1, just reaching significance ($p = .049$), which switched to interference that progressively increased during cycles 2 – 4 (mean differences: cycle 2 = 8 ms, cycle 3 = 15 ms, and cycle 4 = 28 ms). The interference effects were significant at cycles 3 and 4 (both ps < .02). The effects for controls replicate the results reported by Schnur et al. (2006). Relative to cycle 1, reaction times continually decreased across cycles 2-4 in both conditions; however, the amount of decrease was greater in the mixed condition.

Patient ML.

ML made few errors with only 1.2% subject errors (producing the incorrect name for a picture) and 3.8% equipment errors. Due to his low error rate, ML's errors were not analyzed further. In addition, data points that were three standard deviations above or below the mean for each condition were not included in analyses, totaling to 2.4% of the data.

We analyzed all patients' data individually examining the effects of semantic blocking and presentation cycle using the natural log transformed scores for each item as a random factor. For ML, a main effect of semantic blocking, $F(1, 65) = 15.28$, $MSe = 2.82$, $p < .001$, and a semantic blocking x cycle interaction, $F(3, 195) = 2.97$, $MSe = .444$, $p = .036$, were obtained with the natural log transformed data. However, the main effect of cycle was not significant, $F(3, 195) = 1.82$, $MSe = .267$, $p = .149$. In addition, the linear contrast of the semantic blocking x cycle interaction was significant, $F(1, 65) = 6.25$, $MSe = 1.109$, $p = .015$, indicating that the difference between the semantically blocked and mixed conditions increased over cycles. In contrast to the performance for control subjects, ML showed a 60 ms interference effect (which was non-significant) rather than facilitation for cycle 1, and exhibited interference effects during cycles 2 – 4 that were up to ten times greater than the largest difference for controls (see Table 1). As shown in Table 1, the increasing blocking effect was largely due to increasing reaction times in the semantically blocked condition. When comparing natural log transformed scores, ML displayed a semantic blocking effect for cycles 2 – 4 that was over three times greater than the largest difference for controls.

Patient AR.

AR made few errors with only 6.8% subject errors (producing the incorrect name for a picture) and 2.9% equipment errors. Due to his low error rate, AR's errors were not analyzed further. Data points that were three standard deviations above or below the mean for each condition, which constituted 2.4% of the data, were not included in the analyses.

AR obtained significant main effects for semantic blocking, $F(1, 59) = 97.5$, $MSe = 1.226$, $p < .001$, and cycle, $F(3, 177) = 24.30$, $MSe = 1.071$, $p < .001$, as well as a significant interaction, $F(3, 177) = 49.05$, $MSe = 4.016$, $p < .001$. Significant semantic blocking x cycle linear $F(1, 59) = 60.87$, $MSe = 5.019$, $p < .001$ and semantic blocking x cycle quadratic $F(1, 59) = 9.05$, $MSe = 8.943E^{-02}$, $p = .004$ contrast effects were obtained as well, indicating that, while AR showed a non-significant facilitation 515 ms effect during the first cycle, the semantic blocking effect significantly increased during cycles 2 – 4. The source of the quadratic effect is likely due to a smaller difference between the semantically blocked and mixed conditions in the fourth cycle relative to the third. However, the pattern of increasing reaction times in the semantically blocked condition and decreasing reaction times in the mixed condition remained consistent across cycles. It should be mentioned that although AR showed a large facilitation effect during the first cycle, it was within the range of controls when comparing natural log transformed scores. The difference between the semantic and mixed conditions grew substantially for AR from cycles 2 – 4, showing a difference that was almost 30 times greater than the largest difference for controls. As shown in Table 1, the increasing blocking effect was largely due to increasing reaction times in the semantic blocked condition. When comparing semantic blocking effects in terms of natural log transformed scores, AR displayed a difference that was more than four times greater than the largest difference for controls.

Patient JJ.

JJ obtained 3.9% subject errors and 5.3% equipment related errors. As JJ produced few errors, they were not analyzed further. Data points that were three standard deviations above or below the mean constituted 1.9% of the data and were excluded from the analysis.

Main effects of semantic blocking $F(1, 54) = 53.11$, $MSe = .138$, $p < .001$ and cycle $F(3, 162) = 19.15$, $MSe = 5.383E^{-02}$, $p < .001$ were obtained, in addition to a significant semantic blocking x cycle interaction, $F(3, 162) = 23.86$, $MSe = .296$, $p < .001$. Linear contrast effects for the semantic blocking x cycle interaction were also obtained, $F(1, 54) = 37.414$, $MSe = .449$, $p < .001$, indicating that the semantic blocking effect significantly increased across cycles. JJ showed a non-significant 205 ms facilitation effect during the first cycle and displayed a semantic blocking effect that was up to four times greater than the largest effect for controls. When comparing natural log transformed scores, JJ's facilitation effect for cycle 1 was just outside the range of controls and was within the range of controls for cycles 2 and 3, but showed a blocking effect for cycle 4 that was 1.6 times greater than the largest effect for controls. As shown in Table 1, JJ's semantic blocking effect can be attributed to reaction times slightly increasing in the semantic blocked condition, while becoming progressively faster in the mixed condition.

Patient LW.

LW obtained 3.1% subject errors and 2.1% equipment related errors. Since LW obtained so few errors, they were not analyzed further. Reaction times that were more than three standard deviations above or below the mean for each condition constituted 3.1% of the data and were not included in the analysis.

Significant main effects of semantic blocking, $F(1, 63) = 274.37$, $MSe = .361$, $p < .001$ and cycle, $F(3, 189) = 450.12$, $MSe = 1.226$, $p < .001$ as well as a significant semantic blocking x cycle interaction $F(3, 189) = 46.27$, $MSe = 3.654E^{-02}$, $p < .001$ were observed. Linear contrast effects for the semantic blocking x cycle interaction were also significant, $F(1, 63) = 52.65$, $MSe = 1.487E^{-02}$, $p < .001$, indicating that the semantic blocking effect increased over cycles. LW displayed effects across all four cycles that were either within or just outside of the range of controls. He displayed interference effects at cycles 1, 2, 3, and 4 that were 39 ms, 13 ms, 70 ms, and 50 ms respectively that were significant at cycles 3 and 4 (both ps < .001). As shown in Table 1, the semantic blocking effect was not due to continually increasing reaction times in the semantic blocked condition, but instead was attributable to progressively faster reaction times in the mixed condition across cycles.

Discussion

The results for control subjects from Experiment 1 replicated the effects obtained by Schnur et al. (2006), showing that reaction times became faster after cycle 1 in both conditions; however, the decrease in reaction times was significantly reduced in the semantically blocked condition. While reaction times continued to decline across cycles in the mixed condition, reaction times remained relatively stable through cycles 2 – 4 in the semantic blocked condition. Interestingly, control subjects displayed a significant facilitation effect for cycle 1, which has not yet been reported for the semantic blocked naming task. A facilitation effect during the first cycle would not be predicted by a lateral inhibition account since naming a particular item within a category should serve to inhibit related competitors in the lexicon, which would presumably create more difficulty, e.g., longer reaction times, when naming subsequent items from the same category. On the other hand, it is conceivable that when initially naming a few related items, spreading activation from one lexical representation (A) to another related representation (B) could lead to facilitation during early stages of the semantic blocked naming task. That is, spreading activation from naming A would somewhat raise B's activation level, making the time for B's activation to reach threshold shorter than if it had started from baseline. However, this scenario assumes that an excess of activation among related lexical representations has not yet occurred as would happen when repeatedly naming the same items from the same category. It should be mentioned, however, that a switch from facilitation to interference could suggest that separate processes are influenced by semantic relatedness during picture naming (Martin & Biegler, in press). This issue will be revisited in the General Discussion.

The semantic blocking effects observed in reaction times differences for ML, AR, and to some extent, JJ, were analogous to the results previously reported by Schnur et al. (2006) for semantic blocking effects (reported in error rates) for Broca's aphasic patients with left anterior lesions. While ML, AR, and JJ displayed an exaggerated semantic blocking effect, LW performed more similarly to controls. That is, LW displayed increasingly faster reaction times after cycle 1 in both conditions; however, the reduction was less for the semantically blocked condition. Furthermore, his interference effects observed across cycles were close or within the range of controls. In contrast, reaction times for ML, AR, and JJ in the semantically blocked condition continually increased across cycles, whereas their reaction times decreased in the mixed condition across cycles. As discussed earlier, longer reaction times for semantically blocked relative to mixed conditions have been attributed to a lateral inhibition of competing related lexical representations below baseline that is sustained over cycles. Accordingly, an exaggerated semantic blocking effect would arise from overly suppressed lexical representations. However, this view is not consistent with deficits in inhibiting irrelevant verbal information and would not predict the facilitation effects observed for AR and JJ during the first cycle. Alternatively, a deficit in lateral inhibition could entail a *reduced* ability to suppress related lexical representations that have been recently accessed. Presumably, lateral inhibition for these patients works in the same manner as controls, but only slowly, such that more time is needed until a critical difference between the target and its competitors is achieved. The carryover effect of previously sampled items from the same category would depend on the state of the target and its competitors once the selection criterion for the target is reached. If patients used the same criterion, then no difference from controls would be expected in terms of the carryover across cycles. However, one could expect a larger main effect of longer time for semantically blocked than mixed items.

We propose instead that the pattern of performance observed for both control subjects and patients is consistent with an over-activation account, and that a more parsimonious explanation for the exaggerated semantic blocking effects observed for patients ML, AR, and JJ would presume a deficit in a post-selection inhibition mechanism outside of the lexicon (Martin & Biegler, in press). As the semantic blocking task repeatedly samples the same items from the same category, any decrease in reaction times for the semantically blocked condition in controls would be reduced because the post-selection inhibition mechanism is unable to completely suppress previously selected targets to baseline levels. Presumably, lexical knowledge and the lexical system are preserved in patients ML, AR and JJ since they show normal single picture naming and picture-word matching abilities according to standardized tests. However, lexical selection could become exceedingly difficult if previously selected representations remain active during subsequent lexical selection. That is, a post-selection inhibition deficit, i.e., an inability to suppress related lexical representations after their selection, would result in an accumulation of overly active lexical competitors across cycles. The semantic blocking effect would be predicted to increase as activation accrues with repeated sampling from the same category.

Schnur and colleagues (2006) found that fluency was significantly correlated with the semantic blocking effect such that the less fluent the patient, the greater the blocking effect. Other patient characteristics including lexical access abilities, conceptual processing or semantic comprehension, did not correlate significantly with the semantic blocking effect. Furthermore, the analysis of non-Broca's patients' reaction times revealed a semantic blocking effect that was within the range of controls. The performance observed for ML, AR and LW is consistent with their findings as the non-fluent patients, ML and AR, showed an excessive semantic blocking effect, while the effect for LW, a fluent patient, was near the range of controls. JJ's pattern of performance is less clear since he is also a fluent patient, yet shows a larger semantic blocking effect than controls. As discussed previously, JJ has recently reported word finding and other language related difficulties which could have contributed to the observed effects. Of course other factors have been shown to contribute to the semantic blocking effect including lesions involving the left inferior frontal gyrus (Schnur, Lee, Coslett, Schwartz, & Thompson-Schill, 2005) and it is unknown at this time whether JJ has experienced additional neurological injury, although his medical records indicate some bilateral ischemic white matter changes in frontal and parietal regions.

Several previous studies suggest that semantic interference is restricted to the lexical-semantic retrieval stage during speech production in neurally intact subjects (Damian & Bowers, 2003; Damian et al., 2001; Schriefers et al., 1990). That is, semantic interference only has been found during the picture/word interference task with semantically related pictures and distractor words (Schriefers et al., 1990; Damian & Bowers, 2003) and semantically blocked picture naming (Belke et al., 2005; Damian et al., 2001; Schnur et al., in press; Martin & Biegler, in press). However, semantic interference has *not* been observed in normal subjects during a recognition memory task in which pictures are embedded with semantically related distractor words (Schriefers et al., 1990), a picture/word interference naming task in which the distractors in one condition were themselves pictures from the same category (Damian & Bowers, 2003), a phonologically blocked picture naming task, i.e., pictures share the first initial phoneme (Hodgson, Schwartz, Schnur and Brecher, 2005), and a semantic blocked naming task using written words instead of pictures (Damian et al., 2001). Schriefers et al. (1990) and Damian and Bowers (2003) have proposed that semantic interference did not occur in their respective experiments because neither task imposes a conflict at the lexical-semantic retrieval stage. Presumably, only visual conceptual information is needed to perform the recognition task designed by Schriefer et al. (1990) without accessing lexical information. Similarly, Damian and Bowers (2003) proposed that paired target and distractor pictures from the same category only overlapped at a conceptual level, precluding any conflict at a lexical-semantic level. Accordingly, even when naming pictures, semantic interference should only occur when a conflict arises during the retrieval of lexical-semantic information.

In addition, Hodgson et al. (2005) found facilitation in control subjects when naming sets of phonologically blocked pictures, while Damian et al. (2001) found facilitation in a semantically blocked written word naming task. In a phonologically blocked picture naming task, it could be argued that overlap at a lexical-phonological level could lead to facilitation rather than interference since lexical-semantic retrieval has already started (or occurred), preventing any conflict at the lexical-phonological level. Lexical-phonological representations from previously named items may remain activated above baseline, facilitating the retrieval of lexical-phonological representations for subsequent items[8]. Damian et al. (2001) proposed that the facilitation during word naming could be attributable to an interaction between the orthographic or phonological input and semantics. In either case, the results suggest that word naming can bypass lexical-semantic retrieval, preventing any conflict. Although prior evidence suggests that the locus of semantic interference in neurally intact subjects is at the lexical-semantic level, it is plausible that patients who have difficulty inhibiting irrelevant verbal information (e.g., distractors from the same category) would have difficulty suppressing competing verbal representations in order to select a target, even when lexical-semantic retrieval, as conceptualized in production, is not required. Alternatively, semantic interference effects in non-production tasks could reflect a semantic access deficit in some patients as well.

Experiment 2: Semantic Blocked Single Picture – Spoken Word Matching

Given the semantic blocking effects obtained in Experiment 1, Experiment 2 was conducted to investigate whether a semantic blocking effect would be observed in a task in which lexical representations were accessed but production was not required. We initially tested patients ML, AR, and LW on a paradigm that was similar to previously reported experiments testing patients with refractory access deficits (Warrington & McCarthy, 1983, 1987; Forde & Humphreys, 1995; Crutch & Warrington, 2003, 2005). However, we were unable to obtain data that accurately reflected the patients' lexical access abilities due to the constraints of the design, i.e., measuring reaction times rather than errors to select a picture within an array using a mouse with the non-dominant hand. Accordingly, we changed the design to be similar to Experiment 1, displaying a single picture, rather than an array, and requiring subjects to decide whether the picture matched a simultaneously spoken word by making a yes/no judgment. As discussed in the Introduction, deficits in the semantic blocking paradigm have been attributed to refractory, or temporarily inaccessible lexical representations (McCarthy & Kartsounis, 2000), drawing from analogous explanations for semantic access deficits put forth by Warrington and colleagues (Warrington & McCarthy, 1983, 1987; Forde & Humphreys, 1995; Crutch & Warrington, 2003, 2005). If it is the case that lexical representations become temporarily refractory when the same semantically related items are repeatedly accessed, it would be predicted that similar semantic blocking effects should arise any time they are accessed, with or without production.

Alternatively, a semantic blocking effect could plausibly occur during non-production tasks according to a spreading activation account if several related lexical representations are active while matching a spoken and visual target; however, spreading activation accounts, e.g., WEAVER ++ have assumed that semantic interference only occurs during lexical selection in production (see also Schriefers et al., 1990; Damian et al., 2001; Damian and Bowers, 2003). As discussed previously, Schnur et al. (in press) have proposed that accruing activation among related lexical representations builds up over cycles and that interference is resolved in order to select a target through an executive selection mechanism outside of the lexicon. Although this type of mechanism is conceivably involved in order to select a target among several related competitors, their explanation of the effect does not include a post-selection inhibition mechanism. If semantic blocking effects of similar form and magnitude are not found in non-production tasks, i.e., showing continually increasing interference across cycles, perhaps accounts including a post-selection inhibition component in the semantic blocked naming task would provide a more complete explanation.

Method

Subjects.

Fourteen control subjects from the Brain and Language Lab subject pool ML, AR, JJ, and LW participated in the semantic blocked single picture matching task. Both the control subjects and patients received $10 per hour of participation.

Materials and Design.

The materials and design used in Experiment 2 were identical to those used in Experiment 1.

Procedure.

All pictures were presented using Psyscope 1.2.5 (Cohen, MacWhinney, Flatt, & Provost, 1993). As in Experiment 1, the controls, ML, AR, JJ, and LW participated in a practice session before the experiment in which they were familiarized with each of the 72 pictures presented during the experiment. The practice session procedure was the same as in Experiment 1.

The experimental procedure was as follows. Each trial began with a 500 ms inter-stimulus interval (ISI), followed by the simultaneous presentation of a picture and a spoken word. The spoken word matched the picture on 50% of the trials within each cycle. Spoken words that did not match the picture presented were drawn from the set of stimuli featured in each block. For example, in a block featuring the category, body parts, all answer choices would only include one of the six exemplars, e.g., ear, arm, toe, nose, chin, thumb. Similarly, mismatched spoken words within a mixed block would only include one of six exemplars from that particular block, e.g., ear, table, goat, fan, mountain, dress. Following the stimuli presentation, subjects pressed one of two keys on a Psyscope button box labeled "yes" or "no" with their non-dominant hand, and had an unlimited amount of time to make their response. After subjects made a response, the experimenter pushed a key from the keyboard to proceed to the next trial.

Results

Control Subjects.

Only 1.4% subject errors and 1.4% outlying scores were found for controls.

Reaction times were analyzed using a 2 (semantic blocking) x 4 (presentation cycle) within subjects ANOVA. Control subjects obtained significant main effects of semantic blocking, $F (1, 13) = 25.18$, $MSe = 3.338E^{-02}$, $p < .001$ and cycle, $F (3, 39) = 25.18$, $MSe = 3.868E^{-02}$, $p < .001$, but no significant interaction, $F (3, 39) = 1.39$, $MSe = 1.553E^{-03}$, $p = .266$. In addition, no significant linear or quadratic contrast effects were observed for the semantic blocking x cycle interaction. As displayed in Table 2, control subjects displayed a small, yet significant disadvantage for semantically blocked sets as indicated by difference scores, which remained fairly constant across cycles.

Patient ML.

ML made few errors only totaling to 1.0%. Due to his low error rate, ML's errors were not analyzed further. In addition, data points that were three standard deviations above or below the mean for each condition were not included in analyses, totaling to 3.0% of the data.

Significant effects of semantic blocking, $F(1, 66) = 51.06$, $MSe = 1.961$, $p < .001$, cycle, $F(3, 198) = 126.49$, $MSe = 1.118$, $p < .001$, and a semantic blocking x cycle interaction, $F(3, 198) = 47.43$, $MSe = .123$, $p < .001$, were obtained for ML. Significant linear, $F(1, 66) = 99.19$, $MSe = 1.019$, $p < .001$ and quadratic, $F(1, 66) = 15.61$, $MSe = .163$, $p < .001$, contrast effects of the semantic blocking x cycle interaction were obtained as well, pointing to an initial increasing semantic blocking effect from cycles 1 to 3 followed by a decrease from cycle 3 to 4. ML's semantic blocking effect, as indicated by difference scores, was within the range of controls, except for cycle 3, which was only 1.4 times (79 ms) greater than the largest difference for controls. When examining log transformed scores, ML displayed a similar comparison, showing a blocking effect that was 1.66 times greater than the largest difference for controls.

Patient AR:

AR obtained 5.2% subject errors. Due to his low error rate, AR's errors were not analyzed further. Data points that were three standard deviations above or below the mean for each condition, which constituted 3.0% of the data, were not included in the analyses.

AR obtained significant main effects for semantic blocking, $F(1, 61) = 31.11$, $MSe = 1.45$, $p < .001$, and cycle, $F(3, 183) = 17.09$, $MSe = .208$, $p < .001$, as well as a significant interaction, $F(3, 183) = 50.05$, $MSe = .541$, $p < .001$. Significant linear $F(1, 61) = 82.13$, $MSe = .358$ $p < .001$ and quadratic $F(1, 61) = 67.44$, $MSe = .208$, $p < .001$, contrast effects were obtained as well. Similar to ML, AR displayed a semantic blocking effect that increased from cycle 1 to 3, and then decreased from cycle 3 to 4. The semantic blocking effect observed for AR was slightly larger than ML's (see Figure 4), with the exception of cycle 3, which was 3.1 times greater than the largest difference for controls, and 1.99 times greater than the largest control difference when considering natural log transformed scores.

Patient JJ.

JJ obtained 3.5% subject errors which were not analyzed further and excluded from the analysis. Data points that were three standard deviations above or below the mean constituted 2.1% of the data and were excluded from the analysis.

Significant effects of semantic blocking $F(1, 61) = 35.39$, $MSe = .292p < .001$ and cycle $F(3, 183) = 123.74$, $MSe = .575$, $p < .001$ were obtained, in addition to a significant semantic blocking x cycle interaction, $F(3, 183) = 353.27$, $MSe = .448$, $p < .001$. Significant linear $F(1, 61) = 264.06$, $MSe = .200$, $p < .001$ and quadratic $F(1, 61) = 743.40$, $MSe = .169$, $p < .001$, contrast effects for the semantic blocking x cycle interaction were also obtained. JJ displayed a non-significant 45 ms facilitation effect during the first cycle, subsequently showing a semantic blocking effect that fluctuated across cycles 2 – 4 (see Table 2). JJ's semantic blocking effect, as observed in difference scores, was within the range of controls, with the exception of cycle 2, which was only 35 ms greater than the largest difference for controls. When considering log transformed scores, JJ was also within the range of controls with the exception of cycle 2.

Patient LW.

LW obtained 2.1% subject errors, which were not analyzed further and excluded from the analysis. Reaction times that were more than three standard deviations above or below the mean for each condition constituted 1.7% of the data and were not included in the analysis.

Significant main effects of semantic blocking, $F(1, 66) = 306.95$, $MSe = .677$ $p < .001$ and cycle, $F(3, 198) = 350.50$, $MSe = .344$, $p < .001$ as well as a significant semantic blocking x cycle interaction $F(3, 198) = 160.94$, $MSe = .128$, $p < .001$ were observed. Linear, $F(1, 66) = 62.10$, $MSe = 4.216E^{-02}$, $p < .001$, and quadratic $F(1, 66) = 13.56$, $MSe = 1.159E^{-02}$, $p < .001$, contrast effects were significant as well. Although he displayed a non-significant 7 ms facilitation effect during cycle 2, LW's semantic blocking effect fluctuated somewhat, but not to a great degree, and was within the range of controls for both non-transformed and log transformed data (see Table 2).

Discussion

The findings observed for control subjects in the semantic blocked single picture-word matching task showed a somewhat different pattern of results relative to the semantic blocked naming task in Experiment 1, as a significant semantic blocking x cycle interaction was not obtained. Reaction times in the semantically blocked condition were consistently slower than those observed in the mixed condition, and a speeding of reaction times after cycle 1 was observed in both conditions. The absence of a significant semantic blocking x cycle interaction was possibly due to the semantically blocked and mixed conditions declining at relatively the same rate. This pattern contrasts the effects observed in Experiment 1 in which reaction times in the mixed condition continually declined from cycles 1 – 4, while reaction times in the semantically blocked condition showed an initial decrease from cycle 1 to 2 but remained stable from cycle 2 to 4, suggesting that any further facilitatory effect was counteracted by interference from the activation of related words.

LW showed significant semantic blocking x cycle interaction as well as linear and quadratic effects. His performance is somewhat unstable as his semantic blocking effect fluctuates between 159 and –7 ms. However, LW's results are within the range of controls and demonstrate a similar pattern as his reaction times in both the semantic blocked and mixed conditions show a relative decline from cycle 1 to cycle 4. While JJ and ML obtained significant semantic blocking x cycle interaction and linear and quadratic contrast effects, they did not show an exaggerated semantic blocking effect to the same extent as in Experiment 1. In fact, the semantic blocking effects for JJ and ML were within the range of controls with the exception of one cycle. In addition, AR displayed a semantic blocking effect in Experiment 4 that was much less exaggerated in comparison to Experiment 1, as the largest interference effect for the matching task was 592 ms compared to 1531 ms in the semantic blocked naming task.

As evidence from several studies with neurally intact subjects suggests that semantic interference is restricted to the lexical-semantic retrieval stage during speech production (e.g., Belke et al., 2005; Damian, 2003; Damian et al., 2001; Damian &

Bowers, 2003), it remains uncertain how subjects are performing the semantic blocked single picture-word matching task, and at which level, lexical or conceptual, the semantic interference occurs. Although no subjects produced any words during the experiment, it is possible that merely observing a picture could tacitly elicit the name and that subjects use the name to perform the matching task. For instance, Crowther (2006) found a significant positive relationship between picture-name agreement and reaction time in a picture-word matching task similar to Experiment 2, suggesting that factors influencing the production of pictures are also involved in picture comprehension. If so, the buildup of semantic interference across cycles might be occurring at the lexical level, i.e., from competition during lexical selection in implicit naming. If this is the case, then the semantic blocking effect observed in the matching task is no different from the blocking effects observed during naming. However, if it is the same effect, it's unclear why patients did not show an exaggerated semantic blocking effect to the same extent as in Experiment 1[9].

An alternative explanation, however, is that a semantic blocking effect can occur without picture naming, under certain conditions. While picture naming requires the selection of the correct lexical representation at the lexical level without the benefit of phonological input, picture word matching may not require lexical *selection* in the same fashion. That is, the auditory input constrains the lexical representation that is activated from the input and the competitors during recognition would be phonologically related words rather than semantically related words. Once a lexical representation of the spoken word is identified, the semantic information for that word would be retrieved. This semantic information would then be compared to the semantic information in the picture.

If that is the case, then the findings from Experiment 4 could have resulted from selecting among several semantically related representations at a conceptual level that are highly activated after repeated sampling. This possibility is important to explore as it could impact interpretations for semantic and episodic memory tasks, since evidence suggests that memory retrieval primarily occurs at a conceptual level (Neath, 1998; Roediger, Weldon, & Challis, 1989). The increasing semantic blocking effects observed at least for ML (and possibly AR) may derive from a deficit in inhibiting highly active semantic competitors in order to judge whether the spoken word matches the picture. On the other hand, given the extent and location of his lesion, AR's pattern of performance may be the result of a refractory semantic access deficit in which semantic representations become temporarily inaccessible following repeated sampling of items in a related context. Thus, Experiments 3 (a written word-spoken word matching task) and 4 (a picture and associated spoken word matching task) were conducted to further pinpoint the nature of ML's and AR's deficits. That is, Experiments 3 and 4 were different from Experiments 1 and 2 in that different types of information were required to be accessed to perform the task. If AR's performance is due to a refractory access deficit, he should show a growing semantic blocking effect when conceptual, lexical, and phonological representations, must be accessed in a related context, similar to the pattern observed in Experiments 1 and 2. In addition, Experiment 3 was designed to explore whether patients whose word reading ability partially or primarily occurs through accessing lexical or semantic representations, e.g., ML, would display a semantic blocking effect in a single word to word matching task analogous to Experiment 2. Experiment 4 was designed to assess whether a semantic blocking effect is restricted only to picture naming, or if it is observable when subjects are required to access the object's meaning rather than its name in order to match the picture to a spoken word (Forde & Humphreys, 1997). Moreover, the spoken words selected for Experiment 4 were associated with the picture, e.g., DOG—"kennel," such that accessing the name of the picture is irrelevant to performing the task. An increasing semantic blocking effect obtained in Experiment 4 would suggest that interference can occur without naming and that the source of the semantic blocking effect in Experiment 2 occurred at least partly at a conceptual level rather than being constrained to a lexical level due to implicit name retrieval.

Experiment 3: Semantic Blocked Single Written Word – Spoken Word Matching

Method

Subjects.

Ten control subjects from the Brain and Language Lab subject pool ML, AR, JJ, and LW participated. Both the control subjects and patients received $10 per hour of participation.

Materials and Design.

The materials and design used in Experiments 1 and 2 were identical to those used in Experiment 3, except that written words replaced the pictures used previously.

Procedure.

Both written and spoken words were presented using Psyscope 1.2.5 (Cohen et al., 1993). The experimental procedure was identical to Experiment 2.

Results

Control Subjects.

Controls subjects obtained 1.8% subject errors (choosing the incorrect word), which were not included in the analysis. Reaction times that were three standard deviations above or below the mean for each condition, constituting 1% of the data, were also excluded from the analysis.

No significant effects of semantic blocking, $F(1, 9) = .805$, $MSe = 1.032E^{-03}$, $p = .393$ or the semantic blocking x cycle interaction, $F(3, 27) = .845$, $MSe = 5.86E^{-04}$, $p = .477$ were obtained. However, the main effect of cycle was significant, $F(3, 27) = 9.67$, $MSe = 8.282E^{-03}$, $p = .002$. Linear and quadratic contrast effects were not significant as well. As shown in Table 3, the difference scores were small and fluctuated during cycles 1 – 4, as both semantically blocked and mixed conditions continually decreased across cycles.

Patient ML.

ML obtained 0.8% errors which were not further analyzed and not included in the analysis. Reaction times that were three standard deviations above or below the mean for each condition, constituting 2% of the data, were excluded from the analysis.

Significant effects of semantic blocking, $F(1, 68) = 17.62$, $MSe = 3.04$, $p < .001$ and cycle, $F(3, 204) = 4.43$, $MSe = .480$, $p = .006$ were obtained; however, the semantic blocking x cycle interaction, was not significant $F(3, 204) = 1.17$, $MSe = .153$, $p = .315$. While linear contrast effects were not significant, quadratic contrast effects approached significance, $F(1, 68) = 3.49$, $MSe = .337$, $p = .066$. As shown in Table 3, ML's reaction times were longer in the semantically blocked condition across all four cycles, although they fluctuated somewhat. Conversely, reaction times in the mixed condition continually declined across cycles 1 – 4. The semantic blocking effect was considerably outside the range of controls in every cycle except cycle 2, displaying a difference almost 5 times greater in non-transformed scores and 3 times greater in natural log transformed scores than the largest difference for controls.

Patient AR.

Reaction times that were three standard deviations above or below the mean for each condition, constituting 1.4% of the data, were excluded from the analysis. AR obtained 18% subject errors in the semantically blocked condition and 5% errors in the mixed condition, a difference that was significant χ^2 (1) = 24.8, P < .001. As shown in Table 3, error rates decreased from cycle 1 – 4 in the semantically blocked condition but increased slightly in the mixed condition.

A significant effect of semantic blocking, F (1, 53) = 4.91, MSe = .776, p = .031, was observed for reaction times; however, neither the main effect of cycle, F (3, 159) = 2.04, MSe = .158, p = .119 nor the semantic blocking x cycle interaction, F (3, 159) = .959, MSe = .204, p = .409 were significant. No linear or quadratic contrast effects were observed as well. Although AR showed a 59 ms facilitation effect during the first cycle, it was not significant (t < 1). Numerically, the semantic blocking effect, as observed in difference scores, increased from cycle 1 – 4; however, the semantically blocked and mixed conditions both decreased across cycles. AR displayed a semantic blocking effect that was well outside the range of controls in cycles 2 – 4, showing a difference that was almost four times greater than the largest difference for controls. When comparing semantic blocking effects in terms of natural log transformed scores, AR displayed a difference that was more than 1.5 times greater than the largest difference for controls.

Patient JJ.

JJ obtained 1% subject errors which were not included in the analysis. Reaction times that were three standard deviations above or below the mean for each condition, constituting 2% of the data, were excluded from the analysis as well.

The effect of semantic blocking was marginally significant, $F(1, 67) = 3.21$, $MSe = .111$, $p = .078$, although the effect of cycle, $F(3, 201) = 1.42$, $MSe = 5.12E^{-02}$, $p = .242$, and the semantic blocking x cycle interaction, $F(3, 201) = 2.22$, $MSe = 6.89E^{-02}$, $p = .09$ were not. Linear and quadratic contrast effects were not significant as well. JJ's difference scores fluctuated across cycles, but all were within the range of controls. Although JJ's difference scores were within the range of controls, the marginally significant blocking effect suggests that he experienced some interference (with the exception of cycle 2) in the semantically blocked condition. A potential interpretation of this effect is addressed in the Discussion.

Patient LW.

LW obtained 1% subject errors which were not included in the analysis. Reaction times that were three standard deviations above or below the mean for each condition, constituting 1.7% of the data, were excluded from the analysis as well.

Neither the effect of semantic blocking nor the semantic blocking x cycle interaction were significant ($Fs < 1$); however the effect of cycle was marginally significant, $F(3, 204) = 2.45$, $MSe = .117$, $p = .074$. Linear and quadratic contrast effects for the semantic blocking x cycle interaction were not significant as well. As shown in Table 3, LW performed well within the range of controls showing mainly small but fairly consistent effects of facilitation for semantically blocked sets in every cycle except cycle

2. Reaction times for both semantically blocked and mixed sets tended to decrease across cycles with the exception of cycle 4 in the mixed condition.

Discussion

As written word reading presumably accesses conceptual or lexical-semantic representations to a lesser extent than matching or naming pictures, we did not expect to observe a significant main effect of semantic blocking or a semantic blocking x cycle interaction. The significant effect of cycle was the result of reaction times in both conditions continually decreasing across cycles (with the exception of cycle 4 in the semantically blocked condition). The significant effect of cycle and the absence of a significant semantic interference effect suggest that the task primarily required matching phonological to orthographic information, which improved with experience performing the task.

As discussed in the Patient Description section, AR has shown characteristics of deep dyslexia during single word reading. Although he showed no effects of frequency, AR showed a substantial imageability effect obtaining 83% correct for words with high imageability and only 38% correct for words with low imageability. Since AR shows an advantage for reading concrete words, e.g., nouns, in addition to showing extreme difficulty sounding out individual letters, matching spoken to written nonwords, and an inability to read nonwords aloud (Kay et al., 1992), his word reading ability likely occurs through accessing lexical or semantic representations. If that is the case, matching spoken to written words from the same category would be difficult if the meaning of the written word displayed was very similar to the simultaneously presented spoken word. When observing AR perform the task, he would often accept two semantically related items, e.g., the written word 'dog' and spoken word 'cat,' as a match, especially when a mismatched paired appeared before a matched pair, e.g., both written and spoken presentations of 'dog.' Upon observing a matching spoken and written word pair during later trials, AR, in some cases, appeared to realize his previous error, and accepted the correct matched pair but rejected a subsequent mismatched pair, e.g., the written word 'dog' and spoken word 'goat,' which would account for the decrease in errors across cycles in the semantically related condition. Accordingly, AR may have obtained fewer errors overall in the mixed condition because the mismatched pairs were more dissimilar in meaning, e.g., the written word 'dog' and spoken word 'cloud,' thus allowing AR to discriminate between matched and mismatched pairs to a greater extent.

Although AR obtained a main effect of semantic blocking in Experiment 3, neither his errors nor reaction times increased continually from cycle 1 to cycle 4 as observed in the picture naming task in Experiment 1 and the picture-word matching task in Experiment 2. As discussed in previous sections, patients who have been reported to display a refractory access deficit show an increasing decline in performance across cycles for both pictures and words in a semantically related context (Warrington & McCarthy, 1983, 1987; Crutch & Warrington, 2003, 2005; Forde & Humphreys, 1995; but see Forde & Humphreys, 1997). In contrast, AR does not show this pattern of declining performance across cycles when matching written and spoken words. While the difference in his errors and reaction times in the semantically blocked and mixed conditions suggests that he accessed semantic representations in order to perform the word-to-picture matching task, his pattern of performance is not consistent with a refractory access deficit at a conceptual-semantic level, as indexed by error rates and reaction times, after repeated presentations. Instead, his errors in the semantically blocked condition decreased over cycles, while reaction times in cycles 3 and 4 did not grow beyond the first cycle. In addition, the entire task was carried out at a fast presentation rate with 1 to 1.5 second inter-trial intervals, indicating that the lack of refractory-type performance was not due to an extended amount of time between trials. However, his performance in Experiment 3 does not rule out the possibility that AR's pattern of performance in the previous picture naming and matching experiments was the result of a refractory access deficit at the lemma or lexical-semantic level (e.g., McCarthy & Kartsounis, 2000). This issue will be revisited in the General Discussion.

Although ML, JJ and LW obtained very few errors, ML and JJ showed evidence of semantic interference in reaction times, while LW performed within the range of controls. That is, LW showed facilitation in all but one cycle, an effect also observed for three controls. As discussed in the patient descriptions, LW displays good single word reading and shows evidence of a somewhat preserved sublexical route, as he scored 83% correct when reading nonwords up to five letters in length. Assuming he can read many words via a sublexical route, he may be able to perform this task similarly to controls, i.e., matching orthographic and phonological representations. In contrast, ML and JJ show great difficulty reading nonwords, suggesting that they are mainly performing the task by using a lexical or semantic route. While previous evidence suggests that ML can read via a lexical route that does not required access to meaning (Wu, Martin & Damian, 2002; Freedman et al., 2004), perhaps repeated exposure to items from the same category activated competing conceptual representations, accounting for longer reaction times to judge whether spoken and written word pairs matched in the semantically related condition. ML may rely almost entirely on a lexical route to read words, which for him, have degraded semantic representations, e.g., certain body parts (see Wu et al., 2002 for a more in depth discussion). Conceivably, however, he may also access semantic representations when reading words for which the semantic representations are intact. That is, ML appeared to have intact semantic representations for the stimuli used in Experiment 3 as was evident in his accuracy in the previous picture naming and matching experiments.

While observing the performance of ML and JJ (as well as AR) across cycles, it is interesting to note that they all show a substantial decrease in reaction times from cycle 1 to cycle 2 which then increases in cycles 3 and 4, especially for ML. It is unclear how to interpret this pattern unless the patients experienced some type of practice effect during cycle 2, which turned to interference as the conceptual representations remain active during the task in subsequent cycles. Furthermore, the semantic blocking effect observed for ML was larger in reaction times than that for AR, which contrasts with the results reported for Experiments 1 and 2 in which AR showed the largest blocking effect. However, AR also obtained significantly more errors in the semantically blocked condition, an effect he did not display in picture naming and picture-word matching. Although ML, AR and JJ did not show a growing pattern of difficulty (as indexed by error rates or reaction times) across cycles in the semantically blocked condition, the results suggest that some patients are particularly susceptible to resolving or distinguishing among competing representations (either through selection or inhibition as we have proposed), at both conceptual and lexical levels. In order to further explore this hypothesis, we conducted Experiment 4. As discussed in previous sections, the picture-word associative matching task was designed to require access to semantic representations without naming, in an attempt to bypass lexical-semantic or phonological information when performing the task. Patients showing a semantic blocking effect in Experiments 3 and 4 would provide further evidence that semantic interference can occur at a conceptual level.

Experiment 4: Semantic Blocked Single Picture – Associative Word Matching

Method

Subjects.

Fourteen control subjects from the Brain and Language Lab subject pool, ML, AR, JJ, and LW participated. Both the control subjects and patients received $10 per hour of participation. The same control subjects participated in Experiment 4, as well as all subsequent experiments investigating short-term and long-term episodic memory. As patients ML, AR, JJ, and LW participated in all of the proposed memory experiments and several of the same items were featured in many of the tasks, potential practice effects may have occurred. Although this possible outcome is not optimal, the same control subjects were tested on all of the same tasks as well to make a uniform comparison in performance across experiments.

Materials and Design.

The materials and design were similar to Experiment 2, except that six additional categories were added to the original 12 (see Appendix B). Experiment 4 included many of the same pictures displayed in semantically blocked and mixed contexts in order to directly compare the effects obtained in Experiment 2. The spoken word stimuli consisted of words that were associatively matched to each of the pictures. All associated spoken words were simultaneously presented with their related picture in semantically blocked and mixed conditions to assess whether repeatedly accessing related concepts would also induce an interference blocking effect. Similar to Experiment 2, subjects made 'yes' or 'no' responses to judge whether the spoken word is commonly associated to a particular picture.

The associative items were selected intuitively or from the Nelson Association Norms (Nelson, McEvoy & Schreiber, 1998) and included nouns, adjectives, or verbs that were specifically related to each picture but not from the same category, e.g., 'dog' → 'kennel', as opposed to 'dog' → 'cat'. Every effort was made to select items for 'yes' responses that had an obvious association while meeting the criteria listed previously. In addition, we attempted to select items that were not also related to items in other categories; however, this was not always possible given the total number of categories and the primary aim of selecting strongly associated items. It should be noted that some of the category exemplars from the categories used in Experiments 1, 2 and 3, e.g., circle, do not have suitable associates outside of their own category, e.g., shapes. For this reason, two categories used previously were not included in Experiment 4, and were replaced by eight new categories in order to obtain additional data points for the single subject analyses conducted with patients (see Appendix B). As some of the 'no' trials were sometimes ambiguous, i.e., a picture and word shared an unintentional, distant relationship for some subjects, only 'yes' trials were considered in the analyses, assuming that subjects will score correctly on the majority of picture/word associated pairs with an obvious association. That is, we wanted to ensure we only considered trials in which subjects had accessed the correct concept corresponding to a particular item.

Procedure.

All subjects participated in a practice session of five trials that were identical to the experimental procedure, but were not included in any of the testing items. They were instructed to indicate, by pressing the 'yes' or 'no' button, whether the picture and auditorily presented word were *commonly* associated, not merely distantly or possibly related. The experimental procedure in Experiment 4 was similar to Experiment 2 and proceeded as follows. Each trial began with a 500 ms inter-stimulus interval (ISI), followed by the simultaneous presentation of a picture and a spoken word. The spoken word was the associate of the picture on 50% of the trials within each cycle. Spoken words that did not match the picture presented were drawn from the set of stimuli featured in each block. For example, in a block featuring the category, animals, all answer choices would only include one of the six associates, e.g., 'dog'—'kennel', 'cat'—'yarn', 'skunk'—'odor', 'bear'—'honey, 'lion'—'jungle', 'horse'—'saddle'. Thus, 50% of the trials included a spoken word that was only used in that set but was not associated, or was a mismatched associate, with the picture, 'dog'—'saddle'. Similarly, all mismatched associates within a mixed block only included associates featured within that particular block. That is, if 'vacuum' is paired with the associate 'carpet' but was in the same mixed set as 'dog,' its mismatched associate may be 'kennel'. Following the stimulus presentation, subjects had an unlimited amount of time to press one of two keys on a Psyscope button box labeled "yes" or "no" with their non-dominant hand to indicate whether the picture was associated with the spoken word. After subjects made a response, the experimenter pushed a key from the keyboard to proceed to the next trial.

Results

Control Subjects.

Errors. The error rates were larger for control subjects in the associative matching task relative to Experiments 1, 2 and 3, as they obtained 9.4% errors (making 'no' responses to 'yes' trials) overall, which were not included in the reaction time analysis (see Table 4a). When considering the semantically blocked and mixed sets separately, controls obtained 9% and 10% errors respectively. As shown in Table 4a, controls showed fairly consistent error rates across cycles.

Reaction times. Reaction times that were three standard deviations above or below the mean for each condition, constituting 2% of the data, were also excluded from the analysis. Control subjects obtained significant effects of semantic blocking, $F(1, 13) = 5.11$, $MSe = 1.420E^{-02}$, $p = .042$ and cycle, $F(3, 39) = 52.46$, $MSe = 2.114$, $p < .001$, although the semantic blocking x cycle interaction was not significant, $F(3, 39) = 1.42$, $3.541E^{-03}$, $p = .258$. However, a significant semantic blocking x cycle linear trend was obtained, $F(1, 13) = 4.87$, $MSe = 6.606E^{-03}$, $p = .046$. As shown in Table 4b, reaction times in both the semantically blocked and mixed cycles decreased from cycle 1 – 4, yet, the mean semantic blocking effect continually increased across cycles.

Patient ML.

Errors. ML obtained 12% total errors which were excluded from the reaction time analysis. When considering the semantically blocked and mixed sets separately, ML obtained 14% and 11% errors respectively, although the difference between conditions when collapsing across cycles was not significant $\chi^2(1) = 1.05$, $P = .304$. As shown in Table 4a, error rates in the semantically blocked condition increased slightly from cycle 1 to 3, but then decreased in cycle 4, while error rates in the mixed condition were relatively constant with the exception of cycle 3, showing an error rate of 20%.

Reaction times. Reaction times that were three standard deviations above or below the mean for each condition, constituting 2.3% of the data, were excluded from the analysis. The main effect of semantic blocking was marginally significant F (1, 39) = 2.93, MSe = .896, p = .095; however, the main effect of cycle F (3, 117) = 1.10, MSe = 1.102, p = .346, and the semantic blocking x cycle interaction F (3, 117) = 1.00, MSe = 1.001, p = .394 were not. No significant semantic blocking x cycle linear or quadratic contrast effects were obtained as well. Reaction times in the semantically blocked condition increased from cycle 1 – 3, but decreased in cycle 4, while reaction times in the mixed condition decreased from cycle 1 – 3 but slightly increased the fourth cycle. As shown in Table 4b, ML obtained a 23 ms non-significant facilitation effect (t < 1) in cycle 1, which switched to an increasing semantic blocking effect for cycles 2 and 3, but decreased considerably in cycle 4.

Given the anomalous decrease in cycle 4 relative to cycle 3, we conducted a second reaction time analysis to investigate whether ML would show a semantic blocking effect when only considering the first three cycles. The main effect of semantic blocking was marginally significance F (1, 39) = 3.09, MSe = .502, p = .087; however, the effect of cycle F (2, 78) = 1.03, p = .360 and the semantic blocking x cycle interaction F (2, 78) = 1.48, p = .235 were not significant. The linear contrast for the semantic blocking x cycle interaction was marginally significant F (1, 39) = 2.89, MSe = .979, p = .097. As shown in Table 4b, ML displayed semantic blocking effects that were within or near the range of the largest difference for controls in cycles 1, 2 and 4. ML displayed blocking effects in non-transformed and natural log transformed scores that were 1.8 and 1.2 times larger, respectively, than the largest effect for controls.

Patient AR.

Errors. AR obtained 21% errors total which were excluded from the reaction time analysis. When considering the semantically blocked and mixed sets separately, AR obtained 20% and 22% errors respectively, and the difference between conditions when collapsing across cycles was not significant χ^2 (1) = .225, P = .636. As shown in Table 4a, error rates in the semantically blocked condition decreased slightly from cycle 1 to 3, but then increased slightly in cycle 4, while error rates in the mixed condition remained stable across cycles with the exception of cycle 3, showing an error rate of 26%.

Reaction times. Reaction times that were three standard deviations above or below the mean for each condition, totaling to 2%, were excluded from the analysis. No significant effects of semantic blocking, cycle (Fs < 1), or a semantic blocking x cycle interaction F (3, 105) = 1.12, MSe = .252, p = .344 were obtained. No significant semantic blocking x cycle linear or quadratic contrast effects were obtained as well. Reaction times in the semantically blocked condition fluctuated slightly from cycles 1 – 3, increasing in cycle 4. In comparison, reaction times varied considerably in the mixed condition across cycles. As shown in Table 4b, AR obtained an semantic interference effect in cycle 1 that was within the range of controls, which switched to a non-significant facilitation effect in cycle 2 (t < 1). Although AR displayed a semantic blocking effect that was outside of the range of controls in non-transformed scores in cycles 3 and 4, the effects were within the control range when comparing natural log transformed scores.

Patient JJ

Errors. JJ obtained 16% errors total which were excluded from the reaction time analysis. When considering the semantically blocked and mixed sets separately, JJ obtained 19% and 14% errors respectively. JJ's error rates were relatively stable across cycles in the semantically blocked condition with the exception of the decrease in cycle 2. Conversely, error rates in the mixed condition increased from cycles 1 – 3, and then decreased in cycle 4 to a rate lower than the error rate in cycle 1 (see Table 4a). When comparing error rates for both conditions after collapsing across cycles, the difference was not significant χ^2 (1) = 1.70, P = .192.

Reaction times. Reaction times that were three standard deviations above or below the mean for each condition, totaling to 2%, were excluded from the analysis. JJ obtained significant effects of semantic blocking F (1, 39) = 8.37, MSe = 1.057, p = .006 and cycle F (3, 117) = 3.33, MSe = .438, p = .024, although the semantic blocking x cycle interaction was only marginally significant F (3, 117) = 2.27, MSe = .290, p = .09. The semantic blocking x cycle linear contrast effect just missed significance F (1, 39) = 3.88, MSe = .378, p = .056. As shown in Table 4b, reaction times in the semantically blocked condition were longest at cycle 1, decreasing considerably during cycle 2, then increasing during cycles 3 and 4. Conversely, reaction times in the mixed condition showed a relative decrease from cycle 1 – 4. Although a non-significant 134 ms facilitation effect (t < 1) was observed in cycle 2, the semantic blocking effect showed an increasing effect from cycle 1 – 4. The semantic blocking effects in cycles 3 and 4 were both outside of the range of controls, showing effects in non-transformed scores up to 1.8 times larger than the largest effect for controls. When considering natural log transformed scores, the semantic blocking effect for JJ was 1.2 times larger than the largest effect for controls.

Patient LW.

Errors. LW obtained 30% errors total which were excluded from the reaction time analysis. In comparison to the other patients, LW obtained the most errors overall. When considering the semantically blocked and mixed sets separately, LW obtained 35% and 26% errors respectively. When comparing the total error rates for each condition the difference is significant, χ^2 (1) = 3.96, P < .05. As shown in Table 4a, error rates increased in cycles 2 – 4 relative to cycle 1 in the semantically blocked condition. Although errors fluctuated across cycles in the mixed condition, rates increased from cycle 1 – 4 as well.

Reaction times. Reaction times that were three standard deviations above or below the mean for each condition, totaling to 1.4%, were excluded from the analysis. LW obtained a main effect of cycle F (3, 93) = 3.28, MSe = .307, p = .032, but the effect of semantic blocking (F < 1) and the semantic blocking x cycle interaction F (3, 93) = 1.03, MSe = 7.741E^{-02}, p = .378 were not significant. Linear and quadratic contrast effects for the semantic blocking x cycle interaction were not significant as well. As shown in Table 4b, reaction times in the semantically blocked condition decreased from cycle 1 – 3, but then increased in cycle 4 to a level comparable to cycle 1. Although reaction times in the mixed condition fluctuated somewhat, they showed a relative decline across cycles. With the exception of the non-significant 66 ms facilitation effect in cycle 2 (t < 1) the semantic blocking increased across cycles, but was within the range of controls for every cycle except the non-transformed difference score in cycle 4.

Discussion

Although control subjects did not show an effect of semantic blocking in error rates, they did show the effect in reaction times which increased across cycles at a magnitude comparable to the effects observed in Experiment 1. Moreover, the pattern in both the semantically blocked and mixed conditions is similar to the semantically blocked naming task as both conditions showed decreasing reaction times after the first cycle, but the facilitatory effect was attenuated for semantically blocked sets. As discussed previously, Experiment 4 was designed to address the question of whether any increasing effect of semantic relatedness that was obtained in Experiment 2 for word-picture matching might be due to patients' performing the task on the basis of naming the picture and matching the name to the word. As naming the picture for the associative matching task would not provide a means of answering the question of whether the word was related in meaning to the picture, it was reasoned that subjects would perform the task on the basis of accessing the meaning of the word and comparing that to the semantic representation of the picture object to determine if they are related. Similar to the lexical networks described in previous sections, e.g., WEAVER ++, several models of semantic knowledge assume that semantic representations are grouped together according to the degree of shared features, e.g., animals: four legs, eat, move, have tails (Caramazza, Hillis, Rapp & Romani, 1990; Caramazza, Hillis, Leek, & Miozzo, 1994; McRae, de Sa, & Seidenberg, 1997; Devlin, Gonnerman, Andersen, & Seidenberg, 1998; Mayall & Humphreys, 1996). Furthermore, these models assume that when a particular representation is accessed, activation spreads to its neighbors to some extent. Thus, it is possible that increasing activation of related representations would occur at a conceptual level, leading to an increasing effect of semantic relatedness due to difficulty in choosing the correct conceptual representation.

The data for control subjects suggest that, after the first cycle, subjects became relatively faster at judging whether the spoken word was associated with the picture in both conditions. Presumably, the faster reaction times after cycle 1 arose from having made the particular associative judgment previously, e.g., 'dog' → 'kennel,' since there was only one correct associate per item, i.e., 'dog' was not also paired with the potential associate 'leash.' The smaller decrease in reaction times in the semantically blocked condition, however, suggests that competition or interference had occurred among same category items. That is, if several members from a category are repeatedly accessed over a series of cycles, their relative activation states may remain above threshold, making it difficult to suppress or distinguish among competitors in order to make a correct judgment about a particular item. Given that control subjects did not show an interaction of semantic relatedness with cycle in Experiment 2 that involved picture-word matching, it is surprising that an increasing semantic blocking effect across cycles was obtained here with associative matching. That is, it could be argued that both picture-name matching and picture-associative word matching would require fine-grained distinctions to either select the name of a particular item or identify a property that is specific to an item. We speculate that the controls did not show increasing difficulty in Experiment 2, based on the absence of the interaction with semantic blocking and cycle, because it was less difficult to discriminate among category members to decide whether the picture and the spoken word in Experiment 2 did not match relative to judging whether the picture and spoken word were or were not associated in the present experiment. For example, the majority of paired pictures and mismatched names for the 'no' trials for the category "Nature" in Experiment 2 (e.g., 'sun' and 'volcano') were fairly dissimilar. In contrast, judgments of what is most often associated in the present experiment (e.g., 'sun' and 'beach' v. 'cloud' and 'beach') were potentially more difficult, since although clouds can appear in the sky at the beach (or it could start raining), trips to the beach are most frequent when it is sunny. Perhaps increasing the degree of similarity between all items from a particular category, creating 'no' trials such as 'sun' and 'moon,' would result in an effect in a picture to name matching task that is similar to the interaction obtained in Experiment 4, i.e., an increasing difficulty in accessing detailed semantic information as items are continually sampled from the same category.

It is interesting that, while semantic or associative priming for related relative to neutral primes and targets has been widely reported, (Warren, 1970, 1977; Meyer & Schvanevelt, 1971; Neely, 1977; Freedman & Loftus, 1971; Loftus, 1973; Loftus & Loftus, 1974), the results from Experiments 1 - 4 show significant interference, for items repeatedly presented in the same category relative to items presented in an unrelated or mixed context. Conceivably, the apparent opposing effects, e.g., interference v. facilitation, could be attributed to differences in experimental design. That is, most semantic priming experiments use a single presentation of two category members, e.g., 'nurse' → 'doctor' and then switch to another category. The results from the present experiment at least initially suggest that, in contrast to facilitation effects observed for a single presentation of a prime and target, the repeated sampling of same category items can have an interfering effect when subjects are required to make distinctions among category members at conceptual and lexical levels, as in the case of making judgments on the basis of detailed semantic information and selecting the name of a particular item.

ML, AR, JJ and LW did not show a consistent growing pattern of reaction times or error rates across cycles. In fact, in the semantically blocked condition, ML and JJ obtained reaction times that were faster at cycle 4 relative to cycle 1, while LW and AR showed a difference at cycle 4 of only 20 ms and 88 ms respectively. With the exception of LW, the other patients obtained lower error rates during cycle 4 relative to cycle 1 in the semantically blocked condition as well. Nevertheless, all four patients showed longer reaction times and three patients showed higher error rates overall in the semantically blocked relative to the mixed condition. The associative matching task was likely more difficult for the patients in comparison to Experiment 2, as the present experiment required access to detailed semantic information that was not apparent from the name of the picture or from visual information in the picture and involved a greater degree of discrimination among same-category items that was not required in the picture-word matching task. It is also likely that ML, JJ, LW, and, particularly AR, had difficulty performing the task even in the mixed condition in which items were not from the same category. Surprisingly, LW obtained higher error rates in both conditions than we had anticipated, as he had performed within the range of controls in Experiments 1 – 3. It is possible that LW had adopted a very conservative criterion in that he was more likely to respond 'no' when judging whether the picture and spoken word were associated. Perhaps the overall level of task difficulty created more variability in both conditions, possibly accounting for the large fluctuations in effects across cycles and the absence of significant semantic blocking effects in reaction times for ML, AR and LW.

As discussed previously, for some patients, increased difficulty or a decline in performance for naming or matching pictures or written words in a semantic context has been attributed to a refractory access deficit, i.e., excessive inhibition of semantic representations. We had hypothesized that out of the four patients tested, AR's performance would most likely be attributable to a refractory access deficit, given his extensive lesion that includes left frontal, parietal, and temporal regions. However, in the current experiment, he performed very similarly to JJ and ML with regard to reaction times and showed higher error rates overall in the mixed relative to the semantically blocked condition. In comparison, all of the patients previously reported to have a refractory semantic access deficit consistently showed a growing decline in performance across cycles in a semantic context *whenever* lexical or semantic representations of patients' impaired categories were accessed (e.g., Warrington & McCarthy, 1983, 1987; Forde & Humphreys, 1995, 1997). Thus, the results obtained in this experiment initially suggest that AR's performance is inconsistent with a refractory semantic access deficit, according to the criteria put forth by Warrington and Shallice (1979). However, these results do not rule out excessive inhibition or a deficit in lateral inhibition at a lexical level. This issue will be further addressed in the General Discussion in light of the Discussion in Experiment 1.

As controls obtained a significant semantic blocking effect that increased across cycles in the present experiment, it seems unlikely, or at least un-parsimonious to assume that the interference effects observed for controls and patients were due to different processes or mechanisms, i.e., overactivation v. excess inhibition. We propose that, for patients, the spread of activation among similar concepts in the semantic system occurred in a manner similar to controls; however, ML, AR, JJ and LW had somewhat more difficulty distinguishing among or suppressing competing representations in the semantically blocked condition. Unlike the previous experiments, the patients tested in the associative matching task did not show distinctively different levels of performance in this task. That is, in Experiments 1 – 3, AR and ML tended to show the most difficulty with JJ and LW showing intermediate or normal performance. As mentioned previously, the associative matching task proved to be more difficult and had more variability for both controls and patients relative to Experiments 1 – 3, which was evident in the wide range in reaction times and error rates and the fluctuations in performance across cycles. Previous versions of the associative matching task (Forde & Humphreys, 1997) presented an array of items rather than one item at a time. We had used a single presentation in order to keep the design consistent across experiments; however, within an array, subjects could answer on the basis of which item is the best fit for the associate, rather than making a forced choice judgment of 'yes' or 'no'. Future experiments in the lab will conduct this experiment with an array of items instead of using a single presentation design, providing additional data points per subjects (we excluded all 'no' answers in the analysis) and perhaps eliminating some of the variability. In the associative matching task with a single picture, there was no clear cutoff for making a "yes" or "no" decision. That is, the subjects had to set some criterion for judging whether an attribute was sufficiently related to make a "yes" decision. For some trials on which a "no" decision was anticipated, subjects might come up with some way that the picture and word were related (e.g., in the "beach" – "cloud" example), though they might take a long time to come to this decision. In an array design, subjects will be performing the same task on every trial, i.e., selecting the most appropriate exemplar. With this design, there should be a clear correct answer on each trials in terms of which pictured item is most related to the word. In addition, using the array design will allow direct comparison to the results to similar previous studies (e.g., Forde & Humphreys, 1997).

The results obtained from Experiments 1 – 4 suggest that interference can occur during naming and matching tasks when items are repeatedly sampled from the same category. As discussed in previous sections, the next set of experiments was designed to investigate whether a similar degree of interference or decline in performance would occur in memory tasks in which subjects were required to discriminate among or retrieve sets of items from the same category relative to sets of unrelated items, i.e., items from several different categories. We hypothesize that a pattern of performance in the following episodic memory tasks that is analogous to the performance observed in the previous language processing tasks would suggest that competition can arise among similar representations during recognition and recall, and that perhaps the same mechanism(s), e.g., selection and/or inhibition, are used to resolve interference resulting from competing category members in order to select the correct items. If the same mechanisms are involved, we further hypothesize that patients showing exaggerated interference effects relative to control subjects would show a similar level of difficulty with semantically blocked sets during the memory tasks in Experiments 5 – 7. Alternatively, perhaps episodic memory, as indexed by the following experiments, operates in a different manner such that recognition and recall are either enhanced or at least show a lesser degree of interference for items from the same category relative to mixed sets of items. Accordingly, if the mechanisms involved in selecting the correct item in the subsequent episodic memory tasks and the previous naming and matching tasks are in fact different, conceivably, patients showing marked difficulty in the previous language experiments may show a different pattern of performance in the following recognition and recall tasks.

Experiment 5: Recognition of Semantically Blocked and Mixed Word Sets

Experiment 5 was modeled after standard recognition tests comparing the ability to discriminate between targets and lures within semantically blocked and mixed sets of items. Furthermore, the present experiment was specifically designed to assess whether the four patients of interest, particularly ML, would perform similarly to AB in a recognition task (Romani & Martin, 1999). As Romani and Martin (1999) initially reported that AB performed well in a recognition task with unrelated items, the purpose of Experiment 5 was to attempt to replicate their findings with ML and other patients with short-term memory deficits, i.e., investigating whether patients with short-term memory deficits can perform within the range of controls in a recognition task when items are unrelated. Furthermore, we investigated whether performance for control subjects would decline when test items, both targets and lures, are all members from the same category and whether patients with difficulties inhibiting irrelevant verbal information, i.e., similar non-target items, would show a markedly greater disadvantage when having to select a target among several related lures relative to controls.

Method

The following experiments were designed according to a single case study model such that in most cases, all participating subjects received the same categories and items across conditions in order to make direct comparisons among individual patients and between patients and control subjects. However, categories, items, and conditions were pre-ordered pseudo-randomly or in other ways to control for strategic effects or other possible confounds as much as possible.

Subjects.

Patients ML, AR, and LW, participated in the present experiment in addition to 13 of the 14 control subjects that participated in Experiment 4. JJ was unable to participate due to medical complications. In addition, AR was unavailable during most of the testing period for Experiments 4 – 7. Consequently, AR was tested on half of the total number of items in the present experiment. However, we counterbalanced the items to ensure that each item appeared in both a blocked and mixed context, but did not appear in the same session.

Materials and Design.

Experiment 5 contained 48 word lists (24 blocked and 24 mixed) drawn from 24 categories (each containing 24 items). Several of the categories in the present experiment were also included in the previous language experiments (see Appendix C). Each experimental block/set (same category or mixed) contained 24 items, in which 12 items were presented during the study phase and a total of 24 items (12 new items or lures in addition to the 12 study items) were presented during the test phase. We designed this study in order to ensure that each item was presented in both a blocked and mixed context, without appearing twice in one session, in order to control for common lexical effects, e.g., frequency, word length, and imageability. Thus, one session included 12 semantically blocked sets composed of 24 items each and 12 mixed sets composed of 24 items from each of the remaining 12 categories. Accordingly, the second session contained the reverse ordering, i.e., all items in the mixed sets were presented in a blocked context and all previously blocked sets were presented in a mixed or unrelated context. At least two days elapsed between sessions.

Each mixed set contained two items from each category and were constructed so that only one item from each category appeared in the study list. The presentation of all study and test items within mixed sets was pre-randomized such that at least two items from different categories were presented between any two items from the same category. Items within semantically blocked sets were pre-randomized as well so that patients and controls received the same item order during the study and test phases. In addition, the order in which semantically blocked and mixed sets occurred in each session was pre-randomized to prevent potential confounds or strategic effects that could arise if all semantic and mixed sets were presented together rather than being intermixed.

Procedure.

All items in both study and test phases were presented on a computer screen through Psyscope (Cohen et al., 1993) in 70 point Arial font. During the study phase, each item was presented for five seconds for patients and two seconds for control subjects, with a one second inter-trial interval (ITI). During the test phase, all items remained on the screen (indefinitely) until subjects made a response to indicate whether the item was presented at study (old) or was new. Before the experiment began, all subjects were told that they would be viewing lists of words that they will be asked to remember during a subsequent memory test. They were then given instructions for the subsequent memory test explaining that they would receive both old (studied) and new words and that they were to indicate, using labeled buttons on the button box, whether the item was old or new.

One experimental session contained 12 semantically blocked sets (or study/test blocks) and 12 mixed sets (study/test blocks). At the start of the study phase in each block, the computer screen displayed the word "STUDY." After the experimenter pressed the space bar, each of the 12 study items were presented one at a time. Following the study phase, the prompt "Count to 30!" appeared, instructing all subjects to count to 30 aloud before receiving the test phase. The intervening counting task was used in order to prevent the rehearsal of study items in short-term memory. When subjects finished counting to 30, the experimenter pressed a space bar at which time the screen displayed the word "TEST." After subjects indicated that they were ready to start the test, the experimenter pressed the space bar to initiate the test phase. During the test phase, each target and lure item was presented individually and subjects were instructed to indicate, by pressing one of two buttons on the button box whether an item is old (a study list item) or new (not studied). After subjects completed each study/test block they had the option to continue on to the next study/test block or receive a break of up to five minutes.

Results

Control Subjects.

Accuracy. Control subjects obtained mean hit rates of 90% in the semantically blocked condition and 88% in the mixed condition, a difference that was not significant $t(12) = 1.75$, $p = .106$ (see Table 5a). However, controls obtained a significantly higher false alarm rate of 14% in the semantically blocked condition relative to 8% in the mixed condition, $t(12) = 3.55$, $p = .004$. Some patient populations have been reported to have differences in response bias, relative to control subjects, that are not detected in recognition models in which discrimination and response bias are not independent (Snodgrass & Corwin, 1988). Thus, Snodgrass and Corwin (1988) have suggested using both signal detection (d' as the discrimination measure and C as the response criterion measure) and the two-high threshold model (Pr as the discrimination measure and Br as the response criterion measure) with patient populations as both measures have been shown to detect subtle changes in discrimination and response bias. Measures from signal detection and two-high threshold models were computed for both controls subjects and patients and are displayed in Table 5a.[10] In contrast to d', which assumes that discrimination ability for old and new items lies along a continuum, the two high threshold model assumes distinct thresholds for both old and new items (Snodgrass & Corwin, 1988). According to the two-high threshold model, recognition for a particular item falls under three discrete classifications: old, new, or uncertain, with response bias being the probability of responding that an item is old when it falls under the uncertainty classification. Controls obtained significantly higher d' scores in the mixed condition (mean = 3.42) relative to the semantically blocked condition (mean = 2.75), t (12) = 3.09, p = .009, indicating that controls were better able to discriminate between old (study) and new items in the mixed condition. The discrimination measures of the two-high threshold model (Pr) for semantically blocked (.76) and mixed sets (.80) showed a similar pattern, although the difference was not significant, t (12) = 1.75, p = .106. C values less than zero and Br values greater than .5 indicate a liberal response bias (Neath, 1998). The response bias measures in the signal detection and two-high threshold models, were significantly different in the semantically blocked and mixed conditions condition, C, t

(12) = 6.36, p < .001, Br, t (12) = 4.67, p = .001, indicating that control subjects adopted a more liberal response bias, i.e., were more likely to report that an item was old, in the semantically blocked condition (C = -.080, Br = .51) relative to the mixed condition (C = .234, Br = .29) (Neath, 1998).

Reaction times. In the reaction time analyses for control subjects and patients, misses and false alarms were removed. Reaction times that were three standard deviations above or below the subject mean (1.1% for controls) were excluded as well. In addition, reaction times for hits and correct rejections were converted to natural log scores (for the same reasons listed previously for Experiments 1 – 4). For control subjects, reaction time data were analyzed using a 2 (semantically blocked v. mixed) x 2 (hits v. correct rejections) within subjects ANOVA. Controls obtained a significant main effect of semantic blocking, F (1, 12) = 13.88, MSe = 3513.744, p = .003, a significant main effect of response type (hits v. correct rejections), F (1, 12) = 6.51, MSe = 156,188.724, p = .025, and a significant semantic blocking x response type interaction, F (1, 12) = 37.46, MSe = 5,204.827, p < .001. Simple tests revealed that control subjects were significantly faster (-45 ms) to make a hit response in the semantically blocked condition relative to the mixed condition, t (12) = 3.64, p = .003. Conversely, controls were significantly slower (147 ms) to make a correct rejection in the semantically blocked condition in comparison to the mixed condition (3 ms), t (12) = 6.17, p < .001. In addition, control subjects were significantly faster (-339 ms) to make hits compared to correct rejections in the semantically blocked condition, t (12) = 3.27, p < .007; however, this difference (-147 ms) did not reach significance in the mixed condition, t (12) = 1.67, p = .121 (see Table 5b).

Patient ML.

Accuracy. ML obtained hit rates of 92% in the semantically blocked condition and 93% in the mixed condition. In addition, ML obtained a slightly higher false alarm rate in the semantically blocked condition (7%) relative to the mixed condition (2%) (see Table 5a). ML's hit rates and false alarm rates in the semantically blocked and mixed conditions were within the range of controls. ML obtained a d' score of 2.88 (Pr = .87) in the semantically blocked condition and 3.53 (Pr = .91) in the mixed condition, indicating that he was better able to discriminate between old and new items in the mixed condition relative to the semantically blocked condition. When considering the difference in d' prime scores between semantically blocked and mixed conditions, ML obtained a difference of -.65 (difference in Pr = -.06) which fell within the range of controls (d' difference range: -2.71 - .55; Pr difference range: -.22 - .13). ML obtained the following response bias measure values in the semantically blocked (C = .035, Br = .47) and mixed (C = .289, Br = .22) conditions, suggesting that he performed the task with a somewhat conservative response bias (Neath, 1998). Note, however, that the lower C value and the greater Br value in the semantically blocked condition suggests that ML was, to some extent, more likely to respond that an item was old, relative to the mixed condition (Neath, 1998). When considering the shift in response bias in the semantically blocked and mixed conditions, ML obtained differences (C difference: -.254, Br difference: .24) which fell within the range of controls (C difference range: -.533 - .022; Br difference range: -.02 - .48).

Reaction times. For ML, AR and LW, reaction time data were analyzed using a 2 (semantically blocked v. mixed) x 2 (hits v. correct rejections) between item ANOVA.

For ML's data, reaction times that were three standard deviations above or below the mean (2.1%) were excluded as well. ML obtained a significant main effect of response type (hits v. correct rejections) $F(1, 1060) = 94.41$, $MSe = 36.86$, $p < .001$; however, the main effect of semantic blocking and the semantic blocking x response type interaction were not significant ($Fs < 1$). In the semantically blocked condition, ML was faster to make hits (-98 ms) and slower to make correct rejections (178 ms) relative to the mixed condition; however these differences were not significant, hits, $t(523) = 1.23$, $p = .220$, correct rejections, ($t < 1$).

Patient AR.

Accuracy. AR obtained a 97% hit rate in the semantically blocked condition and a 98% hit rate in the mixed condition. In addition, AR obtained a higher false alarm rate in the semantically blocked condition (10%) relative to the mixed condition (1%) (see Table 5a). AR's hit rates and false alarm rates in the semantically blocked and mixed conditions were within the range of controls. AR obtained a d' score of 3.16 (Pr = .87) in the semantically blocked condition and 4.38 (Pr = .97) in the mixed condition, indicating that he was better able to discriminate between old and new items in the mixed condition relative to the semantically blocked condition. When considering the difference in d' prime scores between semantically blocked and mixed conditions, AR obtained a difference of -1.22 (difference in Pr = -.10) which fell within the range of controls. AR obtained the following response bias measure values in the semantically blocked (C = -.300; Br = .77) in the mixed conditions (C = .136; Br = .33), suggesting that he adopted a more liberal response bias in the semantically blocked condition relative to the mixed condition (Neath, 1998). AR's shift in response bias from the semantically blocked to the mixed condition, as indexed by his value difference scores (C difference = -.436; Br = .44), was within the range of control subjects as well.

Reaction times. Reaction times that were three standard deviations above or below the mean (2%) were excluded. Although the main effect of response type was not significant, ($F < 1$), AR obtained a significant main effect of semantic blocking, F (1, 430) = 6.34, MSe = .798, p =. 012 and a significant semantic blocking x response type interaction, F (1, 430) = 12.41, MSe = 1.57, $p < .001$. AR showed a similar pattern to controls and ML, as he was faster to make a hit response in the semantically related condition (-44ms) relative to the mixed condition, but was 452 ms slower to make a correct rejection in the semantically related condition, a difference that was more than twice as large as the largest difference for controls. In contrast to controls and ML, AR's fastest mean reaction time was to make correct rejections in the mixed condition (1448 ms) rather than his mean hit rate in the semantically blocked condition (1639 ms). Implications for this pattern will be further addressed in the Discussion.

Patient LW.

Accuracy. LW obtained hit rates of 93% in the semantically blocked condition and 95% in the mixed condition. In addition, LW obtained a higher false alarm rate in the semantically blocked condition (21%) relative to the mixed condition (9%) (see Table 5a). LW's hit rates and false alarm rates in the semantically blocked and mixed conditions were within the range of controls. LW obtained a d' score of 2.28 (Pr = .72) in the semantically blocked condition and 2.99 (Pr = .86) in the mixed condition, indicating that he was better able to discriminate between old and new items in the mixed condition relative to the semantically blocked condition. When considering the difference in d' prime scores between semantically blocked and mixed conditions, LW obtained a difference of -.70 (difference in Pr = -.14) which fell within the range of controls. LW had a tendency toward a liberal response bias in both the semantically blocked (C = -.335; Br = .75) and mixed conditions (C = -.152; Br = .64) (Neath, 1998). However, the lower C value and higher Br value in the semantically blocked condition may suggest that he was somewhat more likely to respond that an item was old relative to the mixed condition. LW's shift in response bias from the semantically blocked to the mixed condition, as indexed by his value difference scores (C difference = -.18; Br difference = .11), was within the range of control subjects as well.

Reaction times. Reaction times that were three standard deviations above or below the mean for each condition (1.3%) were removed. LW obtained significant main effects of semantic blocking, $F (1, 1014) = 4.22$, $MSe = .141$, $p = .040$, and response type, $F (1, 1014) = 171.44$, $MSe = 5.74$, $p < .001$, and a significant semantic blocking x response type interaction, $F (1, 1014) = 14.48$, $MSe = .485$, $p < .001$. Although LW did not show a significant difference in making hit responses, he was significantly slower to make correct rejections in the semantically blocked condition (71 ms) relative to the mixed condition, $t (483) = 3.94$, $p < .001$. While LW was significantly faster to make hit responses in both the semantically blocked, $t (485) = 11.65$, $p < .001$ and mixed conditions, $t (529) = 6.74$, $p < .001$, the relative difference between hits and correct rejections (90 ms) was numerically greater in the semantically blocked condition relative to the mixed condition.

Discussion

The accuracy measures, response criterion, and reaction time results for controls suggest that the ability to discriminate between 'old' (studied) and 'new' (non-studied) items was more difficult in the semantically blocked condition relative to the mixed condition. While hit rates were similar between conditions, control subjects were significantly more likely to accept a new item as studied (old), as indexed by false alarm rates and response criterion measures, in the semantically blocked condition. Higher false alarm rates in recognition memory studies for items presented in a related context have been reported previously (e.g., Underwood, 1965; Roediger & McDermott, 1995; Robinson & Roediger, 1997; Watson, Balota, & Roediger, 2003). Using the DRM paradigm, Roediger & McDermott (1995, Experiment 1) found that when several words (e.g., thread, pin, sharp, point) converged onto the meaning of a particular item that did not appear in the study list (the critical lure), subjects were significantly more likely to identify the critical lure as 'old' relative to an unrelated lure. [11] In addition, subjects reported similar confidence levels to indicate that critical lures and 'old' items appeared in the study list.

Although the present experiment and the DRM paradigm presented study items in a related context, some aspects of the DRM paradigm are different. That is, the DRM paradigm used associates that acted collectively as defining characteristics or properties of the critical lure. Conversely, items in the semantic blocking condition shared similar features, but there was no one non-presented item that was related to all of the presented items. Thus, it may be more difficult to recognize an item as new if its particular description is elicited by the combination of all studied items than when it is merely similar to other test items.

While the level of discrimination difficulty may differ between the present experiment and the DRM paradigm, higher false alarm rates for related lures suggest that conceptual representations related to items in a study list are activated to some extent and compete with studied items during recognition memory. Roediger and McDermott (1995) and Watson et al. (2003) have proposed that increased false alarm rates for related lures may result from spreading activation among related concepts when subjects process words in the study list. The accuracy as well as reaction time results obtained for control subjects in the present experiment are consistent with this hypothesis. In the semantically blocked condition, we hypothesize that the sustained levels of activation of among several related concepts led to faster reaction times to recognize a studied item but slower times to reject a non-studied item that is similar to the other activated related concepts. McDermott, Jones, Petersen, Lageman, and Roediger (2000) reported somewhat analogous findings as subjects obtained the fastest reaction times to accept studied items (hits), but were significantly slower to reject lures related to the study list relative to unrelated lures. [12] The findings obtained from control subjects in the present study and from previous studies suggest that interference can occur during a recognition memory task for related items relative to unrelated items in a study list, and that competition resulting from spreading activation among related conceptual representations may operate in a manner similar to lexical network models (Watson et al., 2003).

It is surprising that all three patients performed above the control mean in accuracy rates (with the exception of LW's false alarms, which were still within the control range) and showed non-transformed reaction time effects in the semantically blocked condition for hits and false alarms that were within the range of controls. Based on the assumption that short-term memory is involved, to some extent, in the transfer of information to long-term memory (Martin & Romani, 1999), in addition to other factors including word span, difficulty inhibiting irrelevant verbal information in short-term memory, and semantic interference in the previous naming and matching tasks, we predicted that ML and AR should show a disproportionate amount of interference in the semantic blocking condition in a recognition memory task relative to LW and controls subjects. Although ML, AR and LW displayed semantic blocking effects, they were remarkably similar in magnitude to the effects observed for control subjects. One interpretation of these findings, based on the model of short-term memory proposed by Martin and colleagues (e.g., Martin et al., 1994 and Martin et al., 1999), is that the patients' extended encoding time for each item placed minimal demands on the short-term memory buffer and provided sufficient maintenance and/or encoding to establish a long-term memory trace to the same extent as controls. Indirect evidence for this account is also supported by the finding that AB showed better performance in a recognition task when words were presented visually for two seconds compared with a one second presentation time, suggesting that additional time allowed for deeper processing (Martin & Romani, 1999). In addition, perhaps both the auditory and visual input for each item in the present experiment (obtained from reading the word on the computer screen aloud) provided additional contextual information to the encoded memory trace compared to visual or auditory input alone.

As memory retrieval and recognition are proposed to operate at a conceptual level (e.g., Roediger et al., 1989), the results further suggest that ML and AR are not susceptible to semantic interference at a conceptual level (at least for recognition memory) to the same extent as at a lexical level. However, as ML and AR are non-fluent aphasic patients and displayed the greatest semantic blocking effect in the semantic blocked naming task, perhaps they would show exaggerated semantic blocking effects in a memory task that required production, i.e., a memory recall task. In order to investigate this hypothesis, we conducted a part-list cued recall task in Experiment 6 in order to simulate the repeated presentation of items in the former naming and matching tasks during retrieval. As ML and AR have shown difficulty in selecting a target lexical representation among several competitors in naming tasks, perhaps they would show similar performance when output is required during memory retrieval. Conversely, if subjects retain the phonological and articulatory information, in addition to the semantic information, of an encoded word after producing it during study, perhaps selection at a lexical level is bypassed, and ML and AR would show semantic interference effects that were similar to those observed in Experiment 5.

Experiment 6: Part-list Cued Recall

Method

Subjects.

Fourteen control subjects who participated in Experiments 4 and 5, ML, AR, JJ, and LW participated in Experiment 6 and received $10 per hour of participation. As AR was unavailable during most of the testing period, he was tested on half of the total number of lists. In order to control for lexical effects that could possibly confound recall results, we made sure that the same items were used in both the part-list cued and free recall conditions. JJ was only tested on the first half of the total lists as he became ill and was subsequently unavailable for further testing. The set of lists JJ was tested with did not contain the same items in the part-list cue and recall conditions, as we did not anticipate his unavailability for additional testing. We analyzed the control data for the same set of lists JJ was tested on and obtained effects that were analogous to the results obtained from the entire set of lists. The comparable results suggest that the differences in items between the part-list cued and free recall conditions did not have a different effect on recall performance relative to the effects obtained when the same items were used in both recall conditions. These data are presented in the results section as well.

Materials and Design.

In order to compare performance during a Part-list cueing task to the blocked naming and matching tasks, all subjects received a semantically blocked condition in which part-list cues were drawn from the same category and a mixed condition in which cues were drawn from different categories. The stimuli consisted of 96 items from the 12 categories used in Experiments 1, 2 and 3, in addition to 96 items selected from 12 new categories (see Appendix D). The 12 new categories and items were drawn from Battig and Montague (1969), and were pre-tested to ensure that the patients who participated were familiar with the categories and corresponding items to the same extent as the materials used in the previous experiments. Since AR has shown imageability effects for items in short-term memory tasks, the categories were chosen based on the likelihood of having higher imageability than other possible categories, e.g., emotions or parts of speech.

The experimental design consisted of two conditions with two levels each: relatedness (semantically blocked or mixed) and type of recall or test (free recall or recall with part-list cues). The 24 categories were divided such that 12 categories and corresponding 96 items were semantically blocked, while the remaining 12 categories and corresponding 96 items made up the mixed condition. The same 96 items were used during both part-list cue and free recall phases in the semantically blocked condition to control for common lexical effects, e.g., frequency, neighborhood density, word length, imageability, or concreteness. Likewise, the same 96 items were used during both part-list cue and free recall phases in the mixed condition. Study lists consisted of eight items each. The categories were not counterbalanced across semantically blocked and mixed conditions as the exposure to all items four times during a short period of time could result in practice effects. All patients and eight control subjects received the same categories and corresponding items in the semantically blocked and mixed conditions. However, the remaining six control subjects received the opposite category order in order to assess during data analysis whether the particular categories assigned to the semantically blocked and mixed conditions differed in their level of recall.

The testing was administered over two sessions in which all subjects received 12 categories and 96 corresponding items to make up the semantically related sets and 96 items from the remaining 12 categories to make up mixed sets during each session. Within each session, six of the 12 categories in both the semantically blocked and mixed conditions were assigned to a part-list cue test phase while the other six categories for semantically blocked and mixed sets were assigned to free recall. Furthermore, the categories and corresponding test phases alternated between sessions, i.e., if the category 'animals' was assigned to a part-list cue test phase in the semantically blocked condition in session 1, it was assigned to a free recall test phase during session 2. Corresponding to the four possible conditions listed above, study/test phases were separated into four blocks, with each block containing 16 lists, e.g., Block A: semantically blocked/part-list cue (six categories – 48 items), Block B: semantically blocked/free recall (six categories – 48 items), Block C: mixed/part-list cue (48 items from six other categories to create a mixed set), Block D: mixed/free recall (48 items from remaining six categories to create a mixed set). Subjects received and completed one study list and test phase at a time from each block. The study/test phases from each block were rotated, e.g., if a subject received a study/test phase from Block A, the next study/test phase might be from Block B. Each study phase contained eight items. The administration of block orders was the same for all subjects. The four patients and eight controls assigned to the first category order received the same items in the part-list cued and free recall condition, while the remaining six controls received a different set of items in the part-list cued and free recall condition corresponding to the second category order. In order to counterbalance the serial position order of part-list cues when presented as items during the study phase, study lists were constructed in a pre-randomized order.

Procedure.

Pre-testing Session 1. The following procedure is based on ML's performance during a pre-testing session of an earlier version of this experiment. ML was pre-tested since his semantic short-term memory appears to be the most impaired, and would potentially have the most difficulty recalling list items (Romani & Martin, 1999). Although previously reported part-list cueing studies presented items corresponding to several categories at a time before a test phase (e.g., Roediger, 1973; Watkins, 1975; della Rochetta & Milner, 1993) the current experiment presented only eight items (or one category in the semantically blocked condition) at a time for a study list. During the pre-testing session, ML was presented with a study list that contained three sets of six items (a total of 18 items), with each item being presented for five seconds. This pilot testing design was different from the typical design used in part-list cued recall experiments as no item in the list had any relationship with any other item. Furthermore, each set of six items was preceded with a list number (e.g., LIST #1). The design was set up in this manner as a control for the design in a semantically blocked condition in which a set of six items would be preceded by a category name. When tested, ML had great difficulty grouping items with the correct list number. At the time, ML's performance was interpreted as reflecting a deficit in recalling a long list of items. Consequently, the lists were shortened and were no longer categorized by list number in the mixed condition. It should be noted, however, that grouping sets of items with a corresponding list number, i.e., a classification that has no direct relationship with list items, without any means of organization during retrieval would likely be quite difficult for control subjects. Given ML's performance in the current experiment presented below, it would be interesting to test ML in a future recall experiment using a design that is similar to more typical part-list cued recall designs, i.e., with longer lists of items that are not blocked but could be classified by category.

Pre-testing Session 2. In a separate pre-testing session, LW, JJ, ML and AR read aloud all experimental stimuli, to ensure they could read all of the words correctly.

Patients were corrected if they made an error and asked to read the word aloud again correctly.

Experiment. During the study phase, each item and/or category name was presented in 70 point Helvetica font using Psyscope (Cohen et al., 1993). All patients and controls read each word aloud as it was presented. Because it was assumed that patients would have a difficult time with this task and might perform near floor levels with a presentation time like that used for controls, each item was presented for five seconds for patients and two seconds for controls, with a one second inter-trial interval (ITI) for both patients and controls, in order to boost patient performance such that effects of the manipulations might be observed. Before each study list, all subjects were told that they would be viewing lists of words that they will be asked to recall later during a test phase.

After each study list was presented, an intervening task of counting to 30 (patients counted to 10) was administered in order to prevent rehearsal or recall from short-term memory. After the intervening task, a testing phase occurred, involving either free recall or part-list cue. Subjects were asked to verbally recall the remaining five list items in the part-list cued conditions or all of the items in the free recall condition, and the experimenter manually recorded all responses. Spoken recall was used as some patients have difficulty writing due spelling impairments or to partial or full paralysis of their dominant hand. Following recall, all subjects received another intervening task of counting to 30 and then proceeded to a new study phase consisting of a list of eight new items from a different block. During the test phase for the part-list cued semantically blocked condition, the category name and three part-list cues were presented on the screen; however, only the three part-list cues were presented in the mixed condition. During the semantic blocked free recall condition, only the category name was displayed, while during the mixed free recall condition, the computer screen remained blank and subjects were asked to recall all six preceding items from the study phase. After subjects complete four study and test phases from Blocks A – D, they were given the option to immediately proceed to the next set or take a break for up to 5 minutes.

Results

The following analyses were based on the proportion of the five items recalled from the study list that were not presented as part-list cues. That is, the relevant comparison was investigating the level of recall for the 5 remaining items (in the part-list cued and free recall conditions) with and without the presence of part-list cues. Thus, the proportions reported are based on the total number of items recalled out of 80 items per condition (16 lists per condition multiplied by 5).

Control Subjects.

Errors. In addition to omissions, errors were examined in terms of the kinds of incorrect word errors that subjects made, such as intrusions from prior lists or the substitution of a semantically related word, and were classified into seven main types (see Table 6b)[13]. As shown in Table 6b, the free recall conditions contained more intrusion errors than the part-list conditions. In addition, both mixed conditions contained more intrusion and omission errors relative to both semantically blocked conditions, with the largest number of errors in the mixed free recall condition. Errors that were semantically related to an item in the same list were the most frequent intrusion error type in the semantically related conditions, while the most frequent intrusion error type in the mixed conditions was producing an item from a previous list.

Proportion of items correctly recalled. The proportions of items correctly recalled per condition were analyzed using semantic blocking and type of recall as within subject variables. We also included a between subjects variable based on whether the subject received the same categories in the semantically blocked conditions as the patients or the other set of categories as discussed in the method section. Thus, the overall analysis consisted of a 2 (semantic blocking v. mixed) between subject x 2 (part-list v. free recall) within subject x 2 (group 1 v. group 2) between subject ANOVA. Recall was significantly better in the semantically blocked condition (80%) than in the mixed condition (53%), $F(1, 12) = 83.74$, $MSe = 1.125E^{-02}$, $p < .001$, and significantly better for free recall (70%) than cued recall (63%), $F(1, 12) = 49.06$, $MSe = 1.692E^{-03}$, $p < .001$. The semantic blocking x recall interaction was not significant ($F < 1$). The blocking x group ($F < 1$), recall x group, $F(1, 12) = 1.14$, $MSe = 1.900E^{-03}$, $p = .308$, and blocking x recall x group ($F < 1$) interactions were not significant, indicating that the particular categories used with each group had no significant effect on the effects of semantic blocking and recall (see Table 6c).

As discussed in the method section, performance also analyzed on a subset of lists with which JJ was tested, to ensure that no difference in the pattern of effects would be obtained based on the difference in items across the part-list cued and free recall conditions. A 2 (semantically blocked v. mixed) between subject x 2 (part-list cue v. free recall) within subjects x 2 (subset v. entire list) between subjects ANOVA was used for the eight control subjects who received the same categories as patients. As in the overall analysis obtained above, recall was better for the semantically blocked than mixed condition, $F(1, 14) = 60.59$, $p < .001$, and better for free recall than cued recall, $F(1, 14) = 19.49$, $p = .001$. Again, the semantic blocking x recall interaction was not significant ($F < 1$). In addition, no interactions were obtained with list type (subset v. entire list), as the semantic blocking x list type, recall x list type and semantic blocking x recall x list type interactions were not significant ($Fs < 1$). Thus, we obtained a pattern of results that was analogous to the overall ANOVA. The absence of significant interactions with list type indicates that the different items within the part-list cued and free recall conditions in the subset of lists used to test JJ did not give rise to differential effects of semantic blocking or recall type.

Patient ML.

Errors. All of the intrusion errors ML produced in the semantically blocked conditions were semantically related to items in the same list, while the majority of intrusion errors in the mixed conditions were items from previous lists. (see Tables 6a and 6b). It should be mentioned that ML was aware that he had produced an incorrect item in four of the 17 intrusions, and of these four items, he acknowledged that they were from a previous list. The total number of intrusions ML obtained in each condition was within the range of controls, although he was at the high end of the range in both semantically related conditions and below the control means in the mixed conditions.

Proportion of items correctly recalled. The data for ML, AR and LW were analyzed in the following manner. The proportion of correct items per list for each condition was analyzed using a mixed ANOVA with semantic blocking as a between-items factor and set type as a matched-item factor. Similar to controls, ML showed a significant advantage for semantically blocked lists, $F(1, 30) = 32.64$, $MSe = 1.76$, $p < .001$ and during free recall, $F(1, 30) = 15.09$, $MSe = .601$, $p = .001$; however, he did not obtain a significant semantic blocking x recall interaction, $F(1, 30) = 2.65$, $MSe = .106$, $p = .143$. As shown in Table 6c, ML performed close to or above the control subjects' mean in both semantically blocked conditions and in the mixed free recall condition. While he performed below the control subjects' mean in the mixed part-list cued condition, he was within the range of controls. It should also be noted that the difference between cued and free recall was within the range of controls for the blocked conditions, but outside the range of controls for the mixed conditions; however this difference was not significant, $t(15) = 1.59$, $p = .132$.

Patient AR.

Errors. All of the intrusion errors AR produced in the semantically blocked conditions were semantically related to items in the same list (and one was also phonologically related), while his errors in the mixed conditions were more varied as he produced words that were either semantically or phonologically related to an item in the same list or to an item in a previous list.

Proportion of items correctly recalled. The proportion of correct items per list for each condition was analyzed. AR obtained a significant main effect of semantic blocking, $F(1, 14) = 14.93$, $MSe = .720$, $p = .002$; however, the main effect of recall, $F(1, 14) = 1.48$, $MSe = 18.00\ E^{-02}$, $p = .243$, and semantic blocking x recall interaction, ($F < 1$) were not significant. When comparing the relative effects of recall type in each condition, no significant difference was found for semantically blocked, $t(7) = .513$, $p = .623$ or mixed sets, $t(7) = 1.67$, $p = .140$. However, these results should be interpreted with caution since AR was only tested on half of the number of total lists that ML and LW received. As shown in Table 6c, AR performed below the range the range of controls in every condition except the semantically blocked/part-list cued condition in which he fell within the lower end of the range. The difference between performance in the part-list cued condition and the free recall condition was at the mean for controls for the semantically blocked condition and near the extreme end of the range for controls for the mixed condition. Collapsing across both the semantically blocked and mixed condition, AR showed an advantage for free recall that was within the range of controls (14% for AR, range for controls: -1% - 26%).

Patient JJ.

Errors. All of the incorrect word errors JJ produced in the semantically blocked conditions were semantically related to items in the same list, while his errors in the mixed conditions were more varied as he produced words that were either phonologically related to a list item, semantically related to an item from a previous list, or an unclassifiable error type based on the criteria listed in Table 6b. That is, the intrusion was not an item from a previous list and did not have an apparent semantic or phonological relationship with any items in the same list or in any previous list.

Proportion of items correctly recalled. The proportion of correct items per list for each condition was analyzed using a between items analysis for both variables (since JJ did not receive the same items for cued and free recall). JJ obtained a significant main effect of semantic blocking, $F(1, 28) = 69.83$, $MSe = 2.53$, $p < .001$; however, the main effect of type of recall and the semantic blocking x recall interaction were not significant, ($Fs < 1$) (see Table 6c). In addition, JJ did not show a significant effect of recall in the semantically blocked condition, ($t < 1$), although the size of the effect was at the mean for controls. The difference between performance in the semantically blocked and mixed conditions was particularly dramatic for JJ. As shown in Table 6c, JJ performed within the range of controls for the semantically blocked conditions, but substantially below the control range for the two mixed conditions as he recalled on average less than one item per trial. Therefore the absence of an effect of recall type in the mixed conditions is difficult to interpret, given that JJ performed near floor for these lists.

Patient LW.

Errors. LW produced the fewest intrusion errors of the four patients tested (see Table 6a and 6b). The errors LW produced in the semantically blocked/free recall condition were semantically related to items in the same list, while both errors in the mixed conditions were items from a previous list.

Proportion of items correctly recalled. Similar to ML and controls, LW obtained significant main effects of semantic blocking, $F(1, 30) = 67.20$, $MSe = 1.76$, $p < .001$ and type of recall $F(1, 30) = 17.91$, $MSe = 1.56E^{-02}$, $p = .003$; however, the semantic blocking x recall interaction was not significant, ($F < 1$). As shown in Table 6c, LW performed within the range of controls in every condition except the mixed/part-list cued condition. Despite his high level of performance on many of the previous tasks, LW recalled significantly fewer correct items than ML overall, $\chi^2(1) = 10.18$, $p = .001$.

Discussion

The results obtained for control subjects replicate previously reported part-list cued recall effects as they recalled a significantly lower proportion of target items in part-list cued relative to free recall conditions. Based on previous studies on aging, we had predicted that performance would be worse in the semantically blocked part-list cued condition than in the mixed conditions, but the opposite was obtained (% correct blocked part-list cued condition - % correct mixed cued condition = .27) and % correct part-list cued condition - % correct mixed free recall conditions = .19). That is, previous studies have reported that elderly subjects have shown disproportionate difficulty inhibiting irrelevant information that is semantically and/or phonologically related to a target relative to unrelated verbal information when, for instance, reading text passages (Connelly, Hasher, & Zacks, 1991) and generating items to a cue that is preceded by a related prime (Balota, Faust, & Watson, 1996). The observed differences for irrelevant semantically related information between younger and elderly subjects have been attributed to interruptions in normal retrieval processes (Basden & Basden, 1995; Basden, Basden, & Galloway, 1977) or, similar to previously discussed proposals in the language domain, larger interference effects for semantically related distractors, i.e., competitors, relative to unrelated distractors to the target; however, these views differ in whether competition should be conceptualized as suppression (e.g., Anderson & Neely, 1996; Anderson & Spellman, 1995; Anderson et al., 1994) or proactive interference (e.g., Williams & Zacks, 2001; Rundus, 1973).

Post-hoc analyses were conducted to compare the differences between the semantically blocked cued condition and both mixed conditions for controls, which showed that a significantly greater proportion of items were recalled in the semantically blocked cued condition relative to the mixed free recall, $t(13) = 6.81$, $p < .001$ and mixed cued condition, $t(13) = 8.97$, $p < .001$. This pattern of results is somewhat puzzling when considering the previous results reported in the aging literature. Note, however, that in our extensive literature search, we did not find another part-list cued recall study contained this particular design, i.e., presenting study items and test cues in both semantic and mixed contexts within the same subject. The results from the current study seem to suggest that the trace strength for items presented in a semantic context were stronger following encoding (prior to recall) relative to items presented in a mixed context. Even though part-list cues disrupted recall in the semantically blocked cued condition, they appeared unable to disrupt the context in which the items were encoded and retrieval processes to a disproportionate extent. The present results pose an interesting question regarding potential differences in the influence of semantic context and competitors among various tasks. It is possible that in the part-list cued recall paradigm, establishing a strong memory trace during encoding (as obtained when items are meaningfully organized at study) can somewhat overcome disruption from related distractors presented at test, preventing disproportionate inhibitory effects during retrieval. However, in other tasks in which an episodic memory trace is not yet established, perhaps related distractors disrupt, to a greater extent, self-generated search processes in semantic memory or online processing during reading. In addition, perhaps competition among related items is more prominent in tasks that require the retrieval of several category exemplars but place constraints on each trial to produce a specific item, e.g., cued semantic retrieval, relative to free recall tasks in which subjects have more flexibility in the order and particular item they generate at any given time during recall.

It is interesting that control subjects generated more errors in the mixed condition relative to the semantically blocked condition. As discussed in the previous recognition memory experiment, if study items are all from the same semantic category, one could expect other category exemplars to be activated to some extent. As elderly subjects have shown a susceptibility to interference from semantically related distractors, perhaps they would have more difficulty distinguishing among targets (study items) and other partially activated competitors during recall. Based on the types of errors in the semantically blocked and mixed conditions and the design of the semantically blocked condition, i.e., each list was composed of members from a single category, we speculate that fewer errors occurred in the semantically blocked condition as the study lists and corresponding items were more distinct from previous lists relative to study lists in the mixed condition.

The results obtained for the patients were surprising. First, based on previous reports of patients with left frontal lesions in memory retrieval tasks (e.g., della Rochetta & Milner 1993) and the results obtained from Experiments 1 – 4, particularly the semantic blocked naming task, we predicted that ML and AR would show exaggerated retrieval inhibition effects in the semantically blocked part-list cued condition relative to either of the mixed conditions; however, they showed the opposite pattern of performance in both proportion of items recalled and the number of intrusions produced. The number of intrusions ML, AR, JJ and LW produced was within the range of controls in each condition, with the exception of JJ's errors in the semantically blocked cued condition. In the semantically blocked condition, all patients performed just outside or within the range of controls during both types of recall, with ML displaying significantly better performance than LW, a patient with a larger word span and who consistently performed within the range of controls in the previous naming and matching experiments. While JJ was the most impaired in the mixed conditions relative to controls and patients, it is interesting to note the advantage he obtained for semantically blocked sets. Given

JJ's advanced age, relative to the other patients and control subjects, it is difficult to determine the source of his retrieval difficulty in the mixed conditions. Nevertheless, JJ's performance is consistent with the pattern observed in the other patients and controls, and demonstrates the extent to which semantically blocking can aid recall.

As discussed previously, we have not found another part-list cued study with this particular design. While della Rochetta and Milner (1993) reported that patients with left frontal lesions showed a disproportionate degree of difficulty in cued conditions relative to control subjects, it should be noted that each item was displayed for two seconds, rather than the five seconds used in the present experiment. We propose that the extended encoding time permitted items to be processed individually in the short-term memory buffer so that each item was sufficiently encoded and transferred into a longer-term representation. The additional encoding time may have also provided the patients (particularly ML) with the opportunity to perform more elaborative encoding on the lists of related items in the semantic blocking condition. ML's performance is consistent with other memory models proposing separate short-term and long-term memory stores (e.g., Martin et al., 1994; Warrington & Shallice, 1969; Atkinson & Shiffrin, 1968). Notably, ML recalled a greater proportion of items overall than LW, which initially suggests a dissociation between short-term and long-term stores.

It is interesting to compare the results from the recognition task in Experiment 5 and the part-list cued recall task in Experiment 6 for patients ML, AR, and LW. ML and LW displayed similar patterns of performance relative to each other although LW performed at a somewhat lower level than ML in both tasks. Conversely, AR performed at a higher level than ML and LW in the recognition memory task, but performed at a lower level than both patients in the part-list cued task. As discussed previously in the patient description section, AR has shown some evidence of a deficit affecting the output phonological buffer (Martin et al., 1999) as he can perform within the range of controls in short-term memory tasks requiring the maintenance of phonological information (e.g., nonword order probe tasks) but shows great difficulty repeating nonwords. According to the model of short-term memory proposed by Martin and colleagues (1999), phonological short-term memory contains separate input and output buffers, that are connected to long-term lexical-phonological knowledge stores but are separate from the semantic short-term memory buffer and lexical and conceptual representations (see Figure 1). According to this account, although AR also shows evidence of a reduced semantic-short term memory buffer, given extended encoding time, AR would have the preserved ability to sufficiently encode information to establish an episodic memory trace, allowing him to perform quite well in a memory task that does not require production.

Experiment 7: Short-term Memory Serial Recall

Given ML's surprisingly good performance in the part-list cued recall task, despite having a word span of 2 and consistently showing poor performance on previously reported short-term memory tasks, we designed the present experiment to further investigate the source of the dissociation in short-term and long-term episodic memory capacity observed for ML. ML's impaired performance in short-term memory and other language tasks has been attributed to a deficit in inhibiting irrelevant verbal information, including irrelevant items semantically related to a target. Yet, he and the other three patients showed an advantage, rather than impairment, in the blocked part-list cue condition relative to the mixed cue condition. Because of these unexpected results, we conducted the present short-term serial recall task, taking into consideration design differences between the part-list cue and standard short-term memory or span tasks. That is, standard span tasks are often composed of a limited set of unrelated items repeatedly presented across lists, and recall is required shortly after the presentation of studied items. Conversely, long-term memory tasks often include an open set of items, i.e., items that are never repeated in a particular session, and have a fairly long delay between study and recall. Thus, several factors emerge which could differentially influence recall in standard span and long-term memory tasks. In previous experiments conducted in our lab, ML has shown an advantage for non-repeated over repeated items in recall (Martin, Hamilton, Lipszyk, & Potts, 2004). His performance suggests that he has difficulty discriminating among, and inhibiting, items repeatedly presented in previous lists in order to recall the targets of the current list. In addition, if ML's short-term memory impairment can be attributed to a deficit in distinguishing among several active (or overly active) items, perhaps a delay between study and test helps to resolve the interference or allows for more time to reconstruct the study list. Accordingly, we designed the present experiment to contain characteristics of both standard short-term and long-term episodic memory tasks (particularly from the part-list cue task in Experiment 6). Thus, the factors manipulated in Experiment 7 were the following: 1) semantic blocking (semantically blocked or mixed), 2) set type (open or closed), 3) delay type (delay or no delay between study and test) in order to investigate some of the potential factor(s) involved in the differences observed in ML's recall performance in short-term and long-term memory tasks.

Method

Subjects.

Twelve control subjects who participated in Experiments 4 – 7 and patients ML, AR and LW participated in Experiment 7. JJ was unavailable for testing due to illness. All subjects were paid $10 per hour of participation.

Materials and Design.

The items in the present experiment were drawn from 24 categories (12 items from each category) and included stimuli from Experiments 5 and 6 (see Appendix E). The same categories were used to construct the semantically blocked and mixed sets in a manner similar to the previous experiments; however, the same items were not used in all conditions in order to avoid potential practice effects. Thus, items were matched across conditions on frequency, syllable length, and word length. Patients received four items per list in order to have list lengths that were somewhat similar to their word spans; however, control subjects received six items per list in an attempt to prevent ceiling effects. As discussed previously, based on the factors of interest in the present experiment, eight conditions were constructed: blocked open delay (BOD), blocked open no delay (BOND), blocked closed delay (BCD), blocked closed no delay (BCND), mixed open delay (MOD), mixed open no delay (MOND), mixed closed delay (MCD), mixed closed no delay (MCND). There were 12 lists in each condition. Open sets: Lists for open sets were constructed in the same manner for the delay and no delay conditions, and each item only appeared once. Of the 24 categories, twelve categories were placed in the delay condition and 12 in the no delay condition. Of the twelve items from each category, six were selected for the semantically blocked lists and six for the mixed lists.

For the patients' lists, four items were selected from each of the six items that made up semantically blocked and mixed sets for controls. Mixed lists were created by selecting six items from six different categories and were pre-ordered to counterbalance the position in which category members appeared in a list. Mixed lists for patients were constructed in the same manner. We constructed the open sets to closely match the design in Experiment 6 to provide a direct comparison. Thus, for the open sets, semantically blocked and mixed items were intermixed. However, delay and no delay conditions were blocked in order to prevent any potential confusion occurring from continually alternating between delay and no delay conditions across lists. With this design, the main effect of delay was counterbalanced in an ABBA design across the two sessions. However, all of the open sets were in Session 1 whereas all the closed sets were in Session 2. Thus, order effects for the open vs. closed manipulation cannot be ruled out; however, at least two days intervened between Sessions 1 and 2 for all of the subjects. Counterbalancing for order was not possible for all possible interaction effects, as for instance, delay preceded no delay in the open sets whereas no delay preceded delay in the closed sets. Thus, caution should be used in interpreting some of the interaction effects. However, our main interest was in comparing patient performance to that of the controls, who received conditions in the same order as the patients. Thus, we were most interested in any patterns that differed between patients and controls.

The following procedures applied to both control subjects and patients. During each session, subjects received instructions explaining that they would be presented with a list of study items that they would either immediately recall (no delay) or recall after some intervening task (delay). They were also told that they must recall the items in the order in which they were presented to the best of their ability, and were reminded of this requirement periodically during testing. At the beginning of each trial, the prompt, 'STUDY' appeared on the screen to prepare subjects for the upcoming study list. The experimenter then pressed the space bar initiating the presentation of in the study list. Subjects read aloud each item in the study list. In the no delay condition they were then presented with the prompt, 'RECALL'. Next, the experimenter pressed the space bar at which time the screen went blank and subjects recalled the items in serial order to the best of their ability. The delay condition proceeded in a similar fashion, except that following the presentation of the study list, subjects received the prompt, 'Count to 30!' After subjects counted to 30, the experimenter pressed the space bar twice at which time the prompt, 'RECALL' appeared followed by a blank screen. Subsequently, subjects engaged in serial recall of the study list. After completing testing in each condition, i.e., completing 12 test lists, subjects were given the option to take a five minute break or proceed to the next condition.

Results

Scoring.

The dependent measure was number of items correct per list, scored either with or without respect to order. For control subjects, order was scored in a strict fashion. Items were considered correct only if items were recalled in their correct serial position. Relative position did not count (Poirier & Saint-Aubin, 1995). Thus, it was possible for control subjects to obtain zero correct in a list, based on this method of scoring, even if they had recalled all six items out of order. We scored the control data in this manner because some controls displayed ceiling effects, particularly in the blocked conditions, when items were not scored with respect to order. However, even with strict serial scoring, there was one control subject who still managed to obtain 100% lists correct, in serial order, in the blocked, open, no delay condition. For patients, the scoring for order was more liberal. Given ML's and AR's severely reduced word span, positions 2 and 3 were collapsed into one position. Consequently, the total correct by serial position was out of three. Thus, if patients recalled position 1 followed by position 3, they would receive two items by serial position correct for that list.

Control subjects.

Errors. Errors were examined in terms of the kinds of word errors that participants made, such as intrusions from prior lists or the substitution of a semantically related word. The number and types of errors for Groups 1 and 2 are presented in Tables 7a and 7b. The error types were classified in the same manner as in Experiment 6. As shown in Table 7b, both control groups showed the same pattern, producing more incorrect words in the closed sets in both semantically blocked and mixed conditions and the fewest in the BOND condition. The majority of incorrect word errors across conditions for both groups were intruding items from a previous list or items semantically related to items in the same list or in a previous list. The majority of errors in the open conditions were omissions.

Proportion of correctly recalled items without respect to order. The proportions of items correctly recalled per condition were analyzed using a 2 (semantic blocking v. mixed) x 2 (closed v. open set type) x 2 (delay v. no delay) within subject ANOVA. Group 1 scored significantly higher in the semantically blocked (90%) than mixed condition (82%), $F(1, 7) = 40.87$, $MSe = .109$, $p < .001$. significantly higher in the closed

(88%) than open (83%) condition, $F(1, 7) = 8.52$, $MSe = 4.202E^{-02}$, $p = .022$, and significantly higher in the no delay (90%) than delay (82%) condition, $F(1, 7) = 9.51$, $MSe = 9.766E^{-02}$, $p = .018$. The semantic blocking x set type interaction was significant, $F(1, 7) = 32.10$, $8.702E^{-02}$, $p = .001$, while the semantic blocking x delay type interaction was marginally significant, $F(1, 7) = 4.02$, $MSe = 4.556E^{-02}$, $p = .085$. The set type x delay interaction, $F(1, 7) = 2.58$, $p = .152$, and semantic blocking x set type x delay interaction ($F < 1$) were not significant. When collapsing across delay, tests for simple main effects revealed a marginally significantly higher proportion of items recalled for open (91%) relative to closed sets (89%) in the semantically blocked condition, $t(15) = 1.86$, $p = .083$ but a significantly higher proportion of items recalled for closed sets (88%) relative to open sets (76%) in the mixed condition, $t(15) = 5.63$, $p < .001$. While the interaction between semantic blocking and delay was marginally significant, the no delay condition resulted in better performance in both the semantically blocked (no delay – 93%, delay – 87%), $t(15) = 3.40$, $p = .004$, and the mixed condition (no delay – 64%, delay – 57%), $t(15)$ 4.11, $p = .001$.

Group 2 performed at a lower level than Group 1 overall, despite having auditory input in addition to visual. Their pattern of performance was similar to Group1 in terms of the effects of the experimental manipulations, though some effects that were significant for Group 1 were only marginally significant for Group 2 - most likely due to the small sample size for Group 2. As with Group 1, Group 2 scored significantly higher in the semantically blocked condition (74%) than the mixed condition (60%), $F(1, 3) = 31.98$, $MSe = .137$, $p = .011$, and showed a marginally significant advantage for closed (72%) relative to open (62%) sets, $F(1, 3) = 7.86$, $MSe = 8.536E^{-02}$, $p = .068$ and no delay (70%) relative to delay (64%), $F(1, 3) = 9.19$, $MSe = 3.212E^{-02}$, $p = .056$. Group 2 also obtained a marginal interaction of semantic blocking x set type, $F(1, 3) = 7.52$, $MSe = 7.16E^{-02}$, $p = .071$; however no other interactions were significant. Similar to Group 1, Group 2 showed an advantage for closed sets (70%) relative to open sets (51%) in the mixed condition but did not show an advantage for open sets in the semantically blocked condition. The three-way interaction of semantic blocking x set type x delay was the closest to significance, $F(1, 3) = 3.65$, $MSe = 5.070E^{-03}$, $p = .152$ (all other $Fs < 1$) (see Table 7c).

Proportion of correctly recalled items in serial order. Group 1 scored significantly higher in the semantically blocked (56%) than the mixed condition (48%), $F(1, 7) = 6.93$, $MSe = .111$, $p = .034$ and showed a marginal advantage for the no delay (56%) relative to the delay condition (45%), $F(1, 7) = 4.86$, $MSe = .353$, $p = .063$; however, the main effect of set type was not significant ($F < 1$). Group 1 obtained a significant semantic blocking x set type interaction $F(1, 7) = 6.86$, $MSe = 4.938E^{-02}$, $p = .034$. This interaction reflected the finding that in the blocked conditions, performance was somewhat better for the open (59%) than closed sets (54%) whereas in the mixed conditions, performance was somewhat better for the closed (51%) than open sets (45%). However, simple main effects of set type failed to reach significance ($ps > .10$) (see Table 7d).

Group 2 did not obtain significant main effects of semantic blocking, $F(1, 3) = 4.61$, $MSe = 2.954E^{-02}$, $p = .121$, delay $F(1, 3) = 2.53$, $MSe = 3.668E^{-02}$, $p = .210$, or set type ($F < 1$). No significant interactions were obtained either (all $Fs < 1$). However, the lack of significant effects is likely due to floor effects. The pattern across conditions was similar to Group 1 in that Group 2 showed slightly better performance for semantically blocked sets (18%) relative to mixed sets (12%) and for the no delay (18%) relative to the delay (11%) condition. In addition, Group 2, like Group 1, showed worse performance for open sets (11%) relative to closed sets (13%) in the mixed conditions but did not show a disadvantage for open sets in the semantically blocked condition.

Summary of Results for Controls

For both control groups and for scoring with and without respect to order, a similar pattern emerged. Performance was better in the semantically blocked than mixed conditions and better in the no delay than delay conditions. Performance also tended to be better in the closed than open sets, though this factor interacted with set type. Specifically, performance was better in the closed than open sets for the mixed condition and either equivalent for the two sets types or better for the open than closed sets in the semantically blocked condition.

Patient ML.

Errors. As shown in Tables 7a and 7b, ML showed a similar pattern to controls regarding the number of incorrect word errors produced per condition with more such errors in the closed than open conditions. ML's errors were predominantly intrusions of items from a previous list. The only other errors ML produced were items semantically related to items in the same list.

Proportion of correctly recalled items without respect to order. The data for ML, AR and LW were analyzed in the following manner. The proportion of correct items per list for each condition was analyzed using a 2 (semantic blocking v. mixed) x 2 (closed v. open set type) x (delay v. no delay) between items ANOVA. ML scored significantly higher in the semantically blocked condition (76%) than the mixed condition (63%), $F(1, 88) = 7.54$, $MSe = .375$, $p = .005$. ML's data also showed a semantic blocking x set type interaction, $F(1, 88) = 6.97$, $MSe = .315$, $p = .010$ and a marginal semantic blocking x delay interaction, $F(1, 88) = 2.82$, $MSe = .128$, $p = .097$. No other main effects or interactions were significant. When collapsing across delay, simple tests showed that ML, like controls, recalled more items in the open sets (80%) than in the closed sets (71%) in the semantically blocked conditions, although the effect was not significant, $t(46) = 1.53$, $p = .134$, but showed the reverse pattern in the mixed condition, recalling significantly more items in the closed sets (70%) relative to open sets (56%) in the mixed condition, $t(46) = 2.17$, $p = .035$. Although ML showed similar effects to controls for blocking and set type, he was unlike controls in showing no deleterious effect of delay. In fact, he did significantly better in the delay (.70) than no delay conditions (.56) in the mixed list conditions $t(46) = 2.17$, $p = .035$, but showed no effect of delay in the semantically blocked condition ($t < 1$). The surprising result for delay will be addressed further in the discussion (see Table 7c).

Proportion of correctly recalled items in serial order. ML obtained a substantially lower proportion of items correct in serial order relative to free recall, which is not unexpected since he has a word span of 2. However, we were interested in whether semantic blocking would improve his ability to recall items in serial order as a semantically related context has helped his performance in free recall tasks. ML performed marginally better in the semantically blocked (35%) than mixed condition (23%), $F(1, 88) = 3.15$, $MSe = .375$, $p = .079$, and significantly better with no delay (37%) than with delay (20%), $F(1, 88) = 5.61$, $MSe = .667$, $p = .020$. All other effects were not significant. Thus, when taking order into account, his performance was impaired after a delay, which contrasts with the results when scoring without respect to order, where delay had no effect (see Table 7d).

Patient AR.

Errors. AR produced fewer incorrect word errors relative to ML and LW, as nearly all of his errors were omissions. He showed a fairly consistent number of incorrect word errors across conditions (see Tables 7a and 7b). In the semantically blocked closed conditions and all of the mixed conditions, AR's incorrect word errors mainly consisted of items from a previous list, while all of his errors in the semantically blocked open conditions were items semantically related to items in the same list.

Proportion of correctly recalled items without respect to order. AR obtained very similar effects to ML. He performed significantly better in the semantically blocked condition (65%) relative to the mixed condition (49%), $F (1, 88) = 18.85$, $MSe = .798$, $p < .001$. His data also showed a semantic blocking x set type interaction, $F (1, 88) = 28.45$, $MSe = 1.20$, $p < .001$ and marginal semantic blocking x delay interaction, $F (1, 88) = 3.46$, $MSe = .146$, $p = .066$ as well. No other main effects or interactions were significant. When collapsing across delay, simple tests showed that AR, like ML and the controls, recalled more items in the open sets (75%) relative to the closed sets (59%) in the semantically blocked conditions, $t (46) = 2.50$, $p = .016$, but showed the reverse pattern in the mixed condition, recalling significantly more items in the closed sets (70%) than in the open sets (51%), $t (46) = 5.22$, $p < .001$. When collapsing across set type, AR showed a significant advantage for no delay in the mixed condition, $t (46) = 2.41$, $p = .043$, but showed no effect of delay in the semantically blocked condition, ($t < 1$). When further testing the effect of delay, AR showed a significant advantage for no delay in the mixed closed no delay relative to mixed open no delay condition, t (22) = 3.05, p = .006.

Proportion of correctly recalled items in serial order.

AR performed marginally better in the semantically blocked condition (22%) relative to the mixed condition (11%), F (1, 88) = 3.52, MSe, .296, p = .096. No other main effects were significant: set type, F (1, 88) = 1.98, MSe = .167, p = .163, delay, (F < 1). He did, however, show a significant semantic blocking x set type interaction, F (1, 88) = 5.50, MSe = .463, p = .021 and a significant semantic blocking x set type x delay interaction F (1, 88) = 6.95, MSe = .667, p = .006. To follow-up on this three-way interaction, simple interaction effects were tested separately in the semantically blocked and mixed conditions. Within the semantically blocked sets, the main effect of set type was significant, F (1, 44) = 5.7, MSe = .593, p = .021; however, the main effect of delay (F < 1) and the set type x delay interaction, F (1, 44) = 2.23, MSe = .231, p = .143 were not significant. Looking at the means in this condition, performance was better for open sets (33%) than for closed sets (11%). In comparison, in the mixed condition, the set type x delay interaction was marginally significant, F (1, 44) = 3.33, p = .075, while the main effect of set type, (F < 1) and main effect of delay, F (1, 44) = 1.20, MSe=8.33 E^{-02}, p = .279 were not significant. The pattern of the means went in the opposite direction to that for the semantically blocked condition – that is, delay had a marginally deleterious effect for recall of the closed sets (delay – 3%, no delay – 25%), t (22) = 2.05, p = .059, but resulted in an advantage in the open sets (delay – 11%, no delay – 6%), t (46) = 2.58, p = .185, that was not significant.

Patient LW.

Errors. As shown in Tables 7a and 7b, LW showed a similar pattern of incorrect word errors across conditions to controls. As with controls and ML, LW produced the most such errors in the semantically blocked closed conditions but fewer errors for semantically blocked open sets relative to the other conditions. LW's errors were predominantly intrusions of items from a previous list. The only other errors LW produced were items semantically related to items in the same list.

Proportion of correctly recalled items without respect to order. LW performed significantly better in the semantically blocked condition (82%) relative to the mixed condition (73%), F (1, 88) = 6.42, MSe = .188, p = .013. He also obtained a significant semantic blocking x set type interaction, F (1, 88) = 9.80, MSe = .287, p = .002. No other main effects or interactions were significant, semantic blocking x set x delay (1, 88) = 1.80, MSe = $5.27E^{-02}$, p = .183 (All other Fs < 1). When collapsing across delay, simple tests showed that LW showed a marginal advantage for recalling items in closed (79%) relative to open sets (67%) in the mixed condition, t (46) = 1.89, p = .065, but obtained a significant difference in the opposite direction in the blocked condition (closed – 77%, open – 87%), t (46) = 2.58, p = .013. This pattern was like that found for all of the other subjects. In comparison to AR, LW recalled significantly more items overall, χ^2 (1) = 6.68, p = .01, but did not recall significantly more items than ML based on this scoring criterion.

Proportion of correctly recalled items in serial order. LW displayed better serial recall performance overall in comparison to ML and AR However, he obtained no significant main effects or interactions, delay, F (1, 88) = 2.06, MSe = .334, p = .154, set x delay, F (1, 88) = 1.21, MSe = .196, p = .275 (all other Fs < 1). Although LW did not obtain significant effects when scoring by serial order, he showed an advantage for no delay in every condition except the mixed open condition (Blocked closed sets – 16%, Blocked open sets – 5%, Mixed closed sets – 25%). LW recalled significantly more items in serial order overall than ML, χ^2 (1) = 8.62, p = .004, and AR, χ^2 (1) = 29.72, p < .001.

Discussion

Experiment 7 was conducted to assess the performance of ML, as well as AR and LW, on a short-term memory task in order to compare it to the findings from the part-list cued recall task. Given the excellent performance of ML on the part-list cued recall task and his typically poor performance on STM tasks, we were interested in determining which factors might account for the discrepancy. Thus, factors manipulated in the STM task that were relevant to the difference between the part-list cueing paradigm and conventional STM tasks. Furthermore, Experiment 7 was conducted to explore whether the patients would show an advantage during immediate serial recall for semantically blocked lists, given the advantage they displayed for semantically blocked lists in Experiment 6. While some conceptualizations of immediate serial recall have focused solely on articulatory rehearsal (e.g., Baddeley, 1986; Baddeley & Hitch, 1974), the dissociations in semantic and phonological retention in short-term memory (e.g., Martin et al., 1994), in addition to lexical or semantic effects such as frequency (Watkins & Watkins, 1977), word class (Tehan & Humphreys, 1988), and semantic relatedness (Poirier & Saint-Aubin, 1995; Crowder, 1979) suggest that factors other than phonological codes can influence short-term memory; however, it should be noted, that lexical or semantic effects in short-term memory have been attributed to different factors, e.g., contributions from long-term memory stores (e.g., Crowder, 1978, 1979; Schweickert, 1993; Poirier & Saint-Aubin, 1995) or separate lexical-semantic and phonological short-term memory capacities (e.g., Martin et al., 1994).

The results obtained in the present experiment are consistent with the proposal that lexical or semantic information can contribute to short-term recall. As Control Groups 1 and 2 obtained a similar pattern of results, with the only apparent difference being that Group 2 performed at a lower level overall, the effects obtained for both groups will be combined in the discussion. When using a free recall scoring criterion, control subjects showed a significant advantage for the semantically blocked conditions (Group 1 – 8%, Group 2 – 14%). Not surprisingly, control subjects also showed an advantage in the immediate recall (no delay) conditions (Group 1 – 8%, Group 2 – 14%). More interesting was the interaction with set type for semantically blocked and mixed conditions, as they showed an advantage for open sets in the semantically blocked condition (Group 1 – 2%) and closed sets in the mixed condition (Group 1 – 12%, Group 2 – 19%). Based on a serial recall scoring criterion, controls showed an advantage for semantic blocking (Group 1 – 8%, Group 2 – 6%) and no delay (Group 1 – 11%, Group 2 – 7%). In addition, Group 1 showed a 6% advantage for open sets in the semantically blocked condition and both groups showed an advantage for closed sets in the mixed condition (Group 1 – 5%, Group 2 – 2%).

In general, one might expect better performance with closed sets as subjects could more easily reconstruct list items from partially degraded information from closed sets, e.g., through redintegration, given the limited set of items to which the degraded information could be matched (Brown & Hulme, 1995; Schweickert, 1993). However, declines in performance for repeatedly sampled items in a semantically related context during immediate serial recall have been reported previously (e.g., Baddeley, 1966). Several studies have shown a greater build-up of proactive interference across lists for semantically related than unrelated lists (e.g., Wickens, Born, & Allen, 1963; Wickens, 1972). In the semantically blocked closed lists, not only are semantically related items being presented on each list, but exactly the same items are being repeatedly sampled in the closed condition. Thus, semantic similarity across lists would be greater in the closed than open sets, which could lead to greater proactive interference in the closed lists. Thus, one might hypothesize that for the semantically blocked lists, a high degree of proactive interference outweighs the advantage for reconstruction for closed lists, whereas for mixed lists, the reconstruction advantage outweighs any proactive interference due to the absence of semantic similarity across lists.

As noted in the results section, the pattern for word intrusions did not mimic that for percent correct, as controls produced more intrusions for closed sets in both the semantically blocked and mixed conditions. As shown in Tables 7a and 7b, the majority of intrusions were items from a previous list, which would be expected when repeatedly retrieving the same small set of items. The combination of better recall and more intrusions in the closed condition for the mixed lists can be explained on the grounds that subjects could more easily reconstruct partially degraded items for the closed sets, and may have a tendency to produce items from the set, either through a guessing strategy or because of greater PI from previous items resulting from the buildup of strength of the repeated items. In contrast, in the mixed open sets, reconstruction would be difficult and subjects would have little basis on which to make a guess for an item that cannot be retrieved. Hence, omissions would be more prominent.

Although lexical or semantic information can impact short-term memory, control subjects appear to rely more heavily on phonological information during immediate memory tasks, which is supported by the finding that control subjects frequently have a larger span in the rhyme probe than the category probe task, and may use phonological information to help reconstruct items in the category probe task in order to access their meaning as well (Martin et al., 1994). It is hypothesized that subjects use the phonological information contained in the items presented to reconstruct the list, especially the serial order. However, it is thought that the phonological trace decays rapidly, which is consistent with the advantage of immediate over delayed recall (Baddeley, 1986). While it would be expected that control subjects obtained lower levels of recall when lists were scored by serial order, it is interesting that semantic blocking had somewhat less of a beneficial effect (Group 2 – 6%) relative to recall without respect to order (Group 2 – 14%) (Group 1 displayed no difference). However, similar findings have been reported previously (Poirier & Saint-Aubin, 1995 (Experiment 3); Crowder, 1979). Although semantic relatedness can aid in the total number of items recalled, order memory, including sentence repetition (Martin et al., 1994), appears to be more dependent on phonological retention, which is consistent with the advantage observed for control subjects during immediate recall for serial order as well. Although set type did not significantly interact with semantic blocking for serial order, the pattern obtained for items correct without respect to order is somewhat similar as control subjects performed slightly better for semantically blocked open sets and mixed closed sets (Group 1 – 6%, Group 2 – no difference).

Turning to the patient results, both ML and LW produced the most intrusions in closed sets, which were somewhat more frequent in the semantically blocked closed condition. In comparison, AR showed a fairly consistent pattern of intrusions across conditions, although slightly higher in the mixed conditions, with most of his errors being omissions. Similar to controls, the majority of intrusions that ML, AR and LW produced were items from a previous list, followed by semantically related items. The number of intrusions all three patients produced was within the range of controls subjects.

When scoring items recalled without respect to order, ML, AR and LW displayed a significant advantage for the semantically blocked conditions and a significant interaction with semantic blocking and set type; however, unlike controls, ML and LW did not show a significant advantage for the no delay condition. It is puzzling that AR showed a significant benefit from having no delay in the mixed closed condition when ML showed a disadvantage for no delay and LW showed no difference in recall for delay and no delay. As discussed previously, evidence suggests that two separate processes may operate simultaneously during serial recall for closed sets, i.e., redintegration and PI. Perhaps the benefits of refreshing degraded phonological information in the mixed closed sets outweigh potential proactive interference for AR. Conversely, the effects of delay for ML in the mixed closed condition may reflect his susceptibility to PI in short-term memory when the same small set of items is repeatedly presented across several lists during short intervals between study and test (Martin et al., 2004).

Despite the effects of delay observed for ML, all three patients showed a pattern of performance for set type that was similar to controls. That is, ML, AR and LW showed an advantage for closed sets in the mixed conditions and open sets in the semantically blocked conditions. We propose that the factors contributing to these effects are the same as those hypothesized for controls. That is, for ML, AR and LW, proactive interference outweighed redintegration or reconstruction for the closed semantically blocked sets, but reconstruction outweighed proactive interference for the mixed closed sets. One might have expected that ML and AR would have shown a disproportionate decrement in performance for blocked closed sets, given that difficulty in resisting PI should have had its most deleterious effect in this condition. However, similar to the differences observed between semantically blocked cued and free recall effects in Experiment 6, ML and AR did not show an exaggerated decline in performance when items are repeatedly sampled from the same category. As discussed previously, memory retrieval has been proposed to occur at a conceptual rather than lexical level. The present experiment, in addition to Experiments 5 and 6, suggest that both patients are not susceptible to semantic interference effects at a conceptual level to the same degree as they are at a lexical level.

As mentioned previously, with the exception of AR in one condition, ML and LW failed to show a significant advantage for immediate over delayed recall for items recalled without respect to order. This would seem to be a remarkable finding, as one would expect that spending 15 – 30 s counting would interfere with item recall. However, a delay between study presentation and recall may help to resolve interference, especially in the mixed condition, from items in a previous list, though one might have expected counting to introduce interference of its own. Perhaps, interference effects resulting from the intervening counting task were minimal given the different types of information (e.g., words versus numbers).

For serial order recall, ML and AR also showed a significant and marginal advantage, respectively, in the semantically blocked condition (ML – 12%, AR – 11%), although LW did not. In contrast to the results for items without respect to order, ML showed a consistent advantage for immediate over delayed recall (17%). In addition, AR showed an advantage for immediate recall for the blocked open (22%) and mixed closed sets (22%) while LW showed an advantage for no delay in every condition except for mixed open sets (blocked closed – 16%, blocked open – 5%, mixed closed – 25%). The observed impairment in the delay conditions for ML, AR and LW in serial recall suggests that order information is lost to a greater degree than item information after a delay. As mentioned previously, phonological information in short-term memory has been hypothesized to decay at a rapid rate (Baddeley, 1986). However, evidence suggests that lexical-semantic information persists, rather than decays in short-term memory, based on proactive interference effects in short-term memory previously reported for ML (Hamilton & Martin, 2005). The contrasting effects for delay are consistent with this hypothesis suggesting that order information for serial recall decays after a delay, but the lexical-semantic information persists even when a delay occurs between list presentation and recall.

LW showed significantly better performance overall for serial order and free recall in Experiment 7 in comparison to ML and AR. This would be expected since LW has a word span of 4 compared to ML and AR who have a word span of 2. It is interesting to point out that while LW showed better performance in the short-term memory task relative to ML and AR, ML outperformed both patients in the part-list cued recall task with lists containing twice as many items. Despite providing conditions in the short-term memory task that mimicked to some extent those in the part-list cueing experiment, all of the patients performed much worse relative to controls in the short-term memory task. One of the main differences between Experiments 6 and 7 is the encoding time. The part-list cued recall task presented each item for five seconds, placing minimal demands on short-term memory and allowed items to be sufficiently processed to establish an episodic trace. Conversely, the present task presented each item for only 1.5 seconds, likely placing several items in short-term memory before they received the deeper processing needed to transfer each item to a longer-term store. Thus, it seems likely that the difference in encoding time between Experiments 6 and 7 is the main factor causing the differing levels of performance in the two experiments for ML. While it is acknowledged that this claim would be stronger if both encoding times had been used in Experiments 5 – 7, given the other similarities in design (including using many of the same items), encoding time appears to be a substantial factor involved in the differences in performance observed for ML, AR and LW across this series of memory recognition and recall tasks.

General Discussion

Summary

The experiments reported here examined the extent to which memory and language retrieval share common processes or mechanisms, particularly when repeatedly retrieving items from the same category. Patients with characteristics similar to ML and

AR, including left frontal lesions and non-fluency, have been reported to have difficulty repeatedly naming pictures in a semantically related context relative to naming pictures in an unrelated context (e.g., McCarthy & Kartsounis, 2000; Wilshire & McCarthy, 2002; Schnur et al., 2006). In addition, both ML and AR have a reduced short-term memory span and show evidence of a deficit in inhibiting irrelevant verbal information, although ML has shown this effect more consistently than AR. Conceivably, producing a target picture would require the suppression of irrelevant verbal information, i.e., semantic competitors, after several related lexical representations have been accessed. Given ML's and AR's verbal inhibition impairment, we investigated whether ML and AR would be disproportionately impaired repeatedly naming pictures in a semantic context. Their performance was assessed relative to age and education matched controls and to two patients (JJ and LW) who also have short-term memory deficits, but, in contrast, are fluent and do not show a similar deficit in inhibiting irrelevant information.

In the semantically blocked naming task in Experiment 1, both ML and AR showed an exaggerated level of difficulty in naming semantically related pictures relative to unrelated pictures that continually increased in magnitude across cycles. These results suggest that they are particularly susceptible to competition among similar lexical representations during lexical selection. JJ also showed a semantic blocking effect that was outside of the range of controls (that could be attributable to age-related atrophy in frontal regions), but to a lesser degree than ML and AR. In contrast, LW showed a semantic blocking effect that was near the range of controls. Given the increasingly disproportionate difficulty ML and AR displayed in the semantically blocked naming task, Experiment 2 was conducted to investigate whether they would show exaggerated effects in a similarly designed study that required word comprehension but not production. In the semantically blocked picture-word interference task in Experiment 2, ML and AR did show an increasing semantic blocking effect with cycle and performed outside of the normal range on two of the four cycles, but the semantic blocking effect was diminished in comparison to Experiment 1. In comparison, JJ displayed a semantic blocking effect that outside of the control range on only one cycle and LW showed an effect within the range of controls. Although this task was designed to tap performance at a conceptual level and no overt production occurred, it is possible that the increasing semantic blocking effect occurred because subjects covertly named the pictures while performing the task to match the auditory input with the picture's name.

We conducted Experiments 3 and 4 in a further attempt to investigate whether interference resulting from competition among same category items would occur at a conceptual level during language processing, and whether ML and AR would show patterns similar to Experiments 1 and 2. Since ML and AR may be required to read by a semantic route under some conditions (which we hypothesized would access conceptual to a greater extent than lexical representations), we investigated in Experiment 3 whether they would show a similar semantic blocking effect in a word-word matching task. Even when comparing natural log transformed scores, ML and AR performed well outside of the range of controls on three of the four cycles. However, the increasing blocking effect was not exaggerated to the same degree as the continuous blocking effect observed in the semantic blocked naming task. In contrast, both JJ and LW performed very near or within the range of controls. In Experiment 4, which was designed to tap subjects' access to fine-grained semantic information at a conceptual level, all four patients (with the exception of ML on one cycle) showed semantic interference effects in natural log transformed scores that were within the control range. Taken together, Experiments 1 – 4 suggest that ML and AR are more susceptible to exaggerated semantic interference effects at a lexical level to a greater degree than at a conceptual level.

Given ML and AR's reduced short-term memory span, proactive interference effects in short-term memory, and the observed relationship between short-term memory and recognition and recall (Romani & Martin, 1999), we investigated whether ML and AR would show exaggerated interference effects in recognition and part-list cued recall tasks that were similar to those observed in the language tasks, particularly production. With extended encoding time in Experiments 5, ML and AR performed at a high level both in regard to hits and false alarms. In comparison, LW showed a slightly lower level of performance, as indexed by his false alarm rates. In addition, ML, AR and LW showed semantic interference effects that were similar to controls. In Experiment 6, ML showed the best performance out of the four patients and performed near or above the control mean in all but the mixed cued recall condition. ML, AR, JJ, and LW showed a large advantage for the semantically blocked lists, performing near or within the normal range, even for the semantically blocked cued condition, relative to the mixed cued and free recall conditions. It is interesting to note that AR and LW showed a much similar level of performance to each other in this task in comparison to the exaggerated differences observed between them in Experiments 1 – 4.

Given ML's surprisingly high level of performance in Experiment 6, and the advantage shown by AR, JJ and LW for semantically blocked sets, we conducted Experiment 7 to investigate potential differences between the part-list cued recall tasks and standard memory span tasks. We manipulated factors that tend to differentiate long-term recall tasks and span tasks to investigate which factors might explain the much better performance on cued and free recall than on standard span tasks. Specifically, semantic relatedness (semantic v. mixed), set type (open v. closed sets) and delay between study and test (delay v. no delay) were manipulated. However, unlike the long-term task, items were presented at 1.5 second rate rather than at a 5 sec rate. We were interested in whether patients with short-term memory deficits, particularly ML and AR, would show an advantage similar to what was observed in the part-list cued recall task or a disproportionate impairment for semantically blocked items, especially when presented in closed sets.

In Experiment 7, all subjects showed an advantage for semantically blocked lists based on a free recall scoring criterion; however, the advantage diminished greatly when scored in serial order suggesting that item information persists to a greater degree than order information. Although ML, AR, and LW showed somewhat worse performance for semantically blocked closed sets relative to open sets, it was not to a greater degree than the differences observed for controls. When items were scored without respect to order, AR and LW showed an advantage for no delay between study and test. In contrast, ML did not show an advantage for no delay and performed significantly worse in the mixed closed no delay condition compared to the mixed closed delay condition. ML's performance is consistent with other findings suggesting that he is susceptible to proactive interference when a small set of items is repeated sampled in short-term memory and no delay occurs between study and test. Conversely, all three patients showed an advantage for no delay based on a serial order scoring criterion. The contrasting effects of delay when items are scored with and without respect to order, particularly for ML, suggest that for him item information persists longer than order information.

In comparison to Experiment 6, ML performed at a much lower level in the short-term serial recall task and AR showed a somewhat lower level of performance as well. In contrast to Experiment 6, LW showed the best performance of the three patients in Experiment 7, particularly for recall in serial order, which would be consistent with his typically larger word span relative to ML and AR. Although encoding time was not specifically manipulated in Experiments 6 or 7, it seems likely that this is the main factor explaining the different levels of performance across the two tasks for the patients.

Several important findings were obtained in the previous set of experiments. First, ML and AR showed effects of semantic context that were similar to controls in the long-term and short-term memory tasks. Second, with extended encoding time, which conceivably placed minimal demands on short-term memory, ML and AR were able to recall a greater number of items beyond their word span. Third, although LW has a larger word span, he did not perform as well as AR and ML in the recognition task nor as well as ML in the part-list cued task. However, when items were presented at a faster rate in Experiment 7, placing larger demands on short-term memory, LW displayed the best performance in both free and serial recall relative to ML and AR. As memory retrieval is presumed to occur at a conceptual level, the results obtained from the previous experiments demonstrate that ML and AR are selectively impaired in resolving competition at a lexical level during word retrieval but not at a conceptual level, at least when sufficient encoding time is allowed. However, the findings showing a lack of semantically related interference at the conceptual level in the long-term memory tasks go against the findings for picture-word matching and associative matching in the language tasks, where patients ML and AR did show some evidence of increasing interference in the semantically blocked conditions, suggesting increasing interference at a conceptual level. It should be noted, though, that the semantic blocking effects in these language tasks were smaller and less consistent than those in picture naming. Also, there were some problematic aspects of the associative task, given a lack of clear-cut criterion for making a yes-no decision. Further research that uses a modified associative task with a picture choice and which manipulates response-stimulus interval should be carried out to further address whether different mechanisms are involved in the language and memory tasks.

Lexical Retrieval and Refractory Access Revisited

As discussed previously, we were interested in the nature of ML's and AR's disproportionate difficulties in lexical access tasks when items are placed in a semantic context. We had proposed that, similar to patients with lesions including left frontal but not left temporal regions who were reported to show exaggerated semantic blocking effects (Schnur et al., 2006), ML's difficulty was likely due to a deficit in lexical selection when several semantic competitors were simultaneously activated. In addition, we have pointed out that an over-inhibition account of semantic competitors would be inconsistent with ML's difficulty inhibiting irrelevant verbal information. In comparison, given AR's extensive left lateralized lesion that includes temporal regions, we hypothesized that perhaps his deficit was due to either conceptual or lexical representations becoming refractory, i.e., overly suppressed, following the repeated retrieval of items from the same category. According to the refractory access account, as put forth by Warrington and colleagues (e.g., Warrington & McCarthy, 1983, 1987), patients with refractory access deficits should show a continuous decline in performance when repeatedly accessing verbal conceptual representations, both in picture-word and word-word matching tasks. While AR displayed a disproportionate semantic blocking effect in the picture naming and picture-word matching tasks that significantly increased across cycles, he displayed semantic blocking effects that were fairly consistent with repeated sampling in the word-word matching task (Experiment 3). In the picture-word associative matching task conducted in Experiment 4, AR's semantic blocking effects fluctuated across cycles, and he displayed a facilitation effect during the second cycle that was of similar magnitude to interference effects obtained in the remaining three cycles. In addition, the semantic blocking effect at cycle 4 was smaller than the effect observed at cycle 1.

Based on the results obtained in Experiments 3 and 4, AR's pattern of performance across several tasks requiring lexical and semantic access does not appear to fit the pattern of performance for patients such as VER or YOT (Warrington & McCarthy, 1983, 1987) who consistently show evidence of refractory behavior on various picture and word matching tasks. It should be noted, however, that refractory access patients are proposed to show a deficit only in their specific impaired categories. One could point out that AR may not show a consistent increasing deficit with repeated sampling in Experiments 3 and 4 because we combined all of the categories when analyzing his performance in a semantic context. However, in other experiments not reported here, we did examine AR's performance in errors and reaction times for individual categories in word-word and picture-word matching tasks with stimuli presented in an array. We were particularly interested in whether he would show specific difficulty repeatedly accessing colors since he has shown extreme difficulty naming color words in other production tasks. In the picture-word matching of colors presented in a semantically blocked array, AR obtained one error when matching colors and showed facilitation in reaction times during cycles 2 – 4 relative to a mixed presentation condition. In an analogous word-word matching task with colors blocked, AR's errors decreased in cycle 4 relative to cycle 1, although a semantic blocking effect in reaction times did increase from cycle 1 to cycle 4. One interpretation of AR's reaction time performance in the word-word matching task might be that, if the semantic representation of colors is somewhat degraded (as suggested in his color production difficulties) and he is mainly reading through a semantic route, it could become increasingly difficult to distinguish among the several color words presented repeatedly throughout the task. He may not show this pattern in the pictured color condition because there is more information present, i.e., the actual colors, to help him make his choice.

Although AR does not show evidence of a refractory access deficit at a conceptual level, one might consider that representations become refractory at a lexical level, based on his performance in the semantic blocked naming task (Experiment 1) and to a lesser extent in the semantic blocked picture-word matching task (Experiment 2). Moreover, since we cannot rule out that subjects implicitly named pictures to perform the task in Experiment 2, AR's semantic blocking pattern in the picture-word matching task may have been due to overly suppressed related lexical-semantic representations during lexical selection. However, if lexical selection requires the suppression of semantic competitors, one would not expect the facilitation observed for AR during cycle 1 in the semantic blocked naming task. We have also maintained that an over-suppression account is inconsistent with previous studies showing that AR has difficulty suppressing irrelevant verbal information (Hamilton, 2004). Instead, we propose that, similar to ML, AR's lexical selection deficit in a semantic context is due to a difficulty selecting a lexical representation among several highly activated lexical-semantic competitors. As discussed previously, Schnur and colleagues (2006) found a significant relationship among the degree of a semantic blocking effect, non-fluency and the extent of the lesion in the left inferior frontal cortex. We speculate that the somewhat larger semantic blocking effect observed for AR relative to ML may correspond with AR's greater degree of non-fluency and perhaps larger damaged portion of the left frontal region.

Retrieval in Memory Recognition and Recall

After considering the lexical selection deficits obtained for the two patients with known left frontal lesions in the previous language processing tasks, the question arises how ML and AR displayed a similar level of performance to control subjects when selecting a target among semantically related items in a recognition task. Evidence from several neuroimaging studies suggests that right or bilateral regions (although some studies find left lateralized) regions of the prefrontal cortex, bilateral inferior and superior parietal regions, and the right or bilateral hippocampal formation are involved in successful retrieval during a recognition task (McDermott et al., 2000; Rugg, Fletcher, Frith, Frackowiak & Dolan, 1996; Squire, Ojemann, Miezen, Petersen, Videen, & Raichle, 1992). Accordingly, ML and AR may have been able to perform so well by relying on these regions in the right hemisphere, in both semantically blocked and mixed conditions. The extended encoding time likely provided the ability to sufficiently encode the context, including both the meaning and perceptual features, e.g., word length, in order to distinguish between studied from new items.

It is interesting to note that, while recognition and recall are thought to involve similar underlying processes (i.e., retrieval from episodic memory), an unrelated context helped performance in the recognition task while a related context helped performance in recall tasks. Since recognition is also thought to rely on familiarity (e.g., Mandler, 1980), perhaps familiarity-based judgments are more difficult when all items in a test list are semantically related, making 'old' items less distinctive from 'new' items. In contrast, pure list recall (e.g., a list of unrelated items without cues) provides no context with which to compare a test item to a previously studied item. As everyday memories typically contain rich contextual information including visual images, sounds, and spatial and temporal components, which converge to form a complex schematic representation for which several various cues could aid retrieval, it follows that the same memory system used to retrieve a list of items with relatively limited contextual information would require a meaningful organization among items to aid in successful retrieval (Mandler, 1979). As discussed previously, it has been observed that normal elderly subjects (and younger subjects) often impose subjective organization including categorization onto lists during free recall, but that patients with frontal lesions (groups contained lesions in either left or right hemispheres) show deficits strategically organizing list items (e.g., Gershberg & Shimamura, 1995). While all four patients showed a substantial benefit for recalling items in the part-list cued recall task that were already meaningfully organized at encoding, the blocking effect was within the range of controls. It should be noted that that ML, a patient with a frontal lobe lesion, showed no relative impairment in recalling items from a mixed or unrelated list compared to controls. However, it is unknown if ML used a different strategy from controls during recall. Although the data were not specifically scored to assess subjective organization, the findings from Experiment 6 initially suggest that frontal lobe lesions may not always entail deficits in retrieving unrelated list items, and that perhaps, hemisphere and lesion size play mediating roles.

The previous results obtained from Experiment 6 suggest that, overall, all four patients were not differentially impaired by part-list cues during recall in the semantically blocked and mixed conditions. Although ML displayed an interference effect for the mixed cued relative to mixed free recall condition that was outside the range of controls, it was not significant in post-hoc tests. Thus, it is unclear how much weight should be given to this finding. If context among items played a substantial role in the part-list cueing effect, one might expect a larger difference between cueing and free recall in the mixed condition since any inter-item association would be more limited in an unrelated context. That is, retrieval may be more difficult in this situation because subjects would not have a strong general list context, e.g., a particular category, to serve as the basis of their search for remaining list items not presented as part-list cues. Models or principles assuming an inverse relationship between the number of items retrieved or cues presented and the number of remaining retrievable items are more consistent with the effects obtained in Experiment 6, since they also assumed that list items contain no direct relationship to each other, suggesting that the magnitude of the inhibition effect should only correspond to the number of list cues presented, not the strength of the inter-item associations (Rundus, 1973; Watkins, 1975; Mueller & Watkins, 1977). It should be noted, however, that the data suggest that ML, AR, and LW showed part-list cue effects in the mixed and semantically blocked conditions like those of controls because they had sufficiently encoded the items. Future research should explore whether these three patients show similar effects when demands on short-term memory are increased during encoding by increasing presentation rate.

Relative to younger subjects, few studies using a part-list cued recall paradigm have been reported for elderly adults. Marsh et al., (2004) have reported that elderly subjects show a similar pattern of part-list cueing effects in comparison to younger subjects, just to a greater degree under some conditions. In Experiment 1, subjects studied lists that contained both categories and exemplars and were blocked by category. At test, only some of the category labels were provided (0, 3, or 6 labels), but subjects were required to recall all of the categories and/or exemplars they could remember from study. They reported that both elderly and younger subjects recalled significantly more exemplars and categories from the cued category labels relative to non-cued categories, and also found that recall significantly decreased for non-cued category labels as the number of cued category labels increased. In addition, this effect was significantly larger in elderly subjects relative to younger subjects. Similar effects were reported for Experiments 2 and 3 when exemplars rather than category names were used. However, Marsh et al. (2004) pointed out that the category labels were not related to each other (e.g., vegetables, animals) but still induced retrieval inhibition during recall. Marsh et al. (2004) proposed that for both elderly and younger subjects, the cues (whether related or unrelated to the remaining to-be-retrieved items) reinforced memory for those particular categories and corresponding items but interfered with retrieving remaining categories and exemplars.

The nature of retrieval processes and inhibition in the part-list cued recall paradigm would be interesting to further explore with the patients tested in Experiments 5 – 7. That is, Experiment 6 only contained exemplars from the previous study list. Thus, the question arises whether patients would still perform similarly to control subjects when 1) the number of cues is systematically varied, 2) the cues are related to list items but were not studied, and 3) the cues are unrelated to list items and were not studied. Given the findings reported by Marsh and colleagues (2004), presumably, elderly control subjects would show similar effects to younger subjects previously tested with paradigms that have manipulated these factors. The findings reported in Experiment 6 initially suggest that a susceptibility to proactive interference in short-term memory does not necessarily translate into disproportionate proactive interference longer-term episodic retrieval. However, additional testing is needed to establish whether longer-term episodic retrieval in patients ML, AR and LW operates in a manner similar to controls in order to further substantiate the observed dissociation in short-term and long-term episodic retrieval.

ML's surprisingly good performance in list recall but exaggerated difficulty in the verb generation task (Martin & Cheng, 2006) may provide some interesting insight into the nature of the relationship between episodic and semantic retrieval. The finding that ML's deficit was attributable to the association strength between the verb and noun but not to the number of semantic verb competitors is not inconsistent with his list recall performance. That is, we have proposed earlier that the advantage observed for retrieving semantically related list items is consistent with spreading activation networks at a conceptual level. Presumably, items within the network would share connections based on various characteristics, e.g., features from the same category, functional properties, size, and color, such that associative as well as semantic relatedness facilitates retrieval. However, it is puzzling that ML showed a disproportionate disadvantage in the verb generation task for retrieving verbs with low association strengths but displayed performance within the range of controls in both the mixed cue and mixed free recall conditions. One interpretation might be that semantic retrieval, without the benefit of a recently established episodic trace, is an extremely effortful form of retrieval that primarily relies on the left inferior frontal cortex without any interaction or support from the hippocampus. In that case, ML would need to rely on more automatic processes that are pre-established by high association strengths to avoid a self-initiated controlled search (Moscovitch, 1989, 1992). However, another potential factor influencing ML's difficulty with the verb generation task may stem from a more general impairment in producing verbs, as shown in an action picture naming task (Biegler, Martin, & Potts, 2005). As ML and AR have shown similar patterns of performance in the previous memory experiments, and based on AR's lesion site, it would be interesting to investigate whether AR shows a similar effect of low association strength in the verb generation task as well.

Short-term Memory, Semantic Context, and Serial Recall

As mentioned previously, the level of performance observed for ML, AR, and LW in the short-term serial recall task in Experiment 7 coincides with their abilities reported in previous short-term memory tasks. That is, ML and AR, who have spans of 2, showed poorer performance relative to LW, who has a span of 4. AR likely performed at a lower level than ML because he has shown characteristics of having a deficit in retaining output phonology. As discussed previously, semantic blocking significantly benefited recall without respect to order but influenced serial order recall to a much lesser extent. The effects of delay, particularly for ML, suggest that serial order primarily relies on phonological information to reconstruct a study list. Thus, based on Martin et al.'s (1999) model, the lexical-semantic buffer would support item information, while order information would be supported by the phonological buffer. However, based on these findings, it is unclear whether and to what extent the capacities that maintain item and order information are independent. In a long-term memory recall task, Watson et al. (2003) found that semantic and phonological information interacted and produced additive effects in a long-term memory recall task. The number of induced lures, or non-presented critical items (e.g., 'dog'), in conditions containing both semantic and phonologically associated items (e.g., hound, dot) added to more than the sum of non-presented critical items produced in conditions containing only semantic (e.g., hound, puppy) or phonological associates (log, dot). As serial order recall is typically impaired with phonologically similar items, it would be interesting to explore the effects of serial recall and intrusions in short-term memory with lists containing both semantic and phonological associates (e.g., log, dot, paw, collar, dock). Results from such an experiment may provide further insight into the relationship between lexical-semantic and phonological short-term retention capacities.

Thus far, the performance observed in Experiment 7 has been discussed within the framework of the short-term memory model proposed by Martin et al. (1999) (see Figure 1). The model is based on other connectionist type models of lexical and conceptual representations (e.g., Dell & O'Seaghdha, 1992), but assumes that short-term memory is maintained in separate stores that retain semantic information and input and output phonology. The short-term stores act as buffers with a fixed number of slots or place holders to continually maintain information that has been retrieved through connections to long-term knowledge representations. Patients with a reduced short-term memory capacity would have a smaller buffer with fewer place holders. In comparison, other similar short-term memory models feature a single buffer that is proposed to maintain semantic, lexical, and phonological representations which can interact during retention (Barnard, 1985). However, a single buffer model would have difficulty accounting for the dissociations observed in short-term retention for lexical-semantic representations and input and output phonology (Martin et al., 1994; Martin et al., 1999; Martin & He, 2004).

In contrast to conceptualizing short-term memory as a buffer, other models conceptualize short-term retention as the attended portion of currently activated representations in long-term memory (e.g., Crowder, 1993; Cowan, 1995). According to this type of model, long-term memory helps to support short-term recall through redintegration if phonological traces have decayed prior to an item's retrieval. Order information in list retention is represented through episodic links among activated items established during study presentation (Cowan, 1995; 1999; 2001; Baddeley, 2000; 2001). Evidence that primarily supports this view has been reported in ERP or EEG studies showing simultaneous activation among cortical regions that ostensibly subserve storage and retrieval mechanisms (Ruchkin, Berndt, Johnson, Grafman, Ritter, & Canoune, 1999; Cameron, Haarmann, Grafman, & Ruchkin, 2002; Sarnthein, Petsche, Rappelsberger, Shaw, & von Stein, 1998; von Stein & Sarnthein, 2000; Engel & Singer, 2001). However, the ERP and EEG findings that have been reported to substantiate an activation-based model of short-term memory were obtained from neurally intact subjects. It is difficult to differentiate between the two views since it could also be argued that the observed synchronized activity reflects the coordination of a separate retrieval mechanism contributing to the representations maintained in a short-term memory buffer. In order to account for the double dissociations observed for semantic and phonological short-term retention, activation-based models must assume that patients with specific deficits to semantic or phonological short-term memory also have degraded knowledge stores of the same type of information. However, Martin and colleagues (e.g., Martin et al., 1999; Martin & He, 2001) have reported that patients can have preserved knowledge stores of the information they have difficulty retaining in short-term memory. Martin et al. (1999) also point out that, although order information can be represented in an activation-based model of short-term memory, it would be difficult to show how currently activated items (even with newly established episodic links) could represent the number and location of repeated items in a list.

Competition and Selection at Lexical and Conceptual Levels of Representation

One of the main findings from the experiments reported here is that patients who are particularly impaired during lexical selection and retrieval under conditions of high competition are not impaired relative to controls when retrieving items from episodic memory under a similar of degree of competition. Several factors relevant to the observed discrepancy have been alluded to previously. First, selection and retrieval during word processing and memory retrieval have been shown to occur at different levels, i.e., memory retrieval occurs at a conceptual level. Second, lexical retrieval, as it occurred in the previous production and matching tasks, required a specific correct answer on a particular trial. In contrast, several correct potential candidates could be produced during free recall, based on a subject's subjective retrieval strategy. Although serial recall requires specific items on a particular trial, it has been suggested that list order is reconstructed through the phonological representations corresponding to the study items. Furthermore, semantic information appears to have little influence on order reconstruction in serial recall. While picture-word and word-word matching tasks require the recognition of items presented in both modalities in order to evaluate whether the items match, they differ from more conventional recognition tasks as the judgments in a recognition task can be primarily based on the familiarity of an item's presentation during study, but not necessarily specific lexical features of a word.

The mechanisms underlying competition at a lexical level, that is, suppression (e.g., Anderson, Bjork, & Bjork, 1994, 2000; Anderson & Spellman, 1995) or overactivation remain unresolved. An argument against suppression at the lexical level has been outlined based on the results from the semantic blocked naming task. Given the differences in selection at lexical and conceptual levels, however, it is conceivable that they operate in a different manner, e.g., overactivation at a lexical level and suppression at a conceptual level. How would an overactivation or suppression view factor into a deficit in verbal inhibition? According to a suppression account, previously retrieved items, e.g., part-list cues, would suppress the remaining non-cued category exemplars or list items. However, this account appears to be inconsistent with a verbal inhibition deficit since it must assume that ML and AR were sufficiently able to suppress remaining list items in the part-list cued recall task to the same extent as controls. As ML's and AR's impairment in inhibiting irrelevant verbal information has occurred in short-term memory tasks, i.e., at a conceptual level, it is hypothesized that they should show a similar impairment in longer-term memory tasks if suppression is involved. An alternative proposal is more consistent with the verbal inhibition deficits and the pattern of performance observed for ML and AR in Experiment 6. That is, the retrieval of items, e.g., part-list cues, further raises their activation level, causing them to interfere with other non-retrieved studied items. Perhaps another reason why ML and AR were not differentially affected is that selection at a lexical level requires other executive function processes, such as an executive selection mechanism that is subserved by the left prefrontal cortex, but is not necessary during memory retrieval (Schnur et al., 2006). It should also be noted that the induced recall of lures associated with list items is also inconsistent with a suppression account. For instance, Roediger and McDermott (1995) found that the retrieval of a subset of list items prior to test not only increased their retrieval during study, but increased the retrieval of associated lures as well. According to a suppression account, the retrieval of the subset of items should have suppressed the associated competitors.

The differences in the nature of selection and retrieval at lexical and conceptual levels are interesting to consider. Selection at the lexical level may by nature be highly competitive since it is designed to select a specific lexical entry corresponding to a name. Conversely, selection at a conceptual level may be less competitive if one considers that discourse, sentence comprehension, and sentence production would benefit from maintaining several representations activated simultaneously. Moreover, good performance in sentence comprehension and production has been reported to result from the ability to maintain several representations simultaneously (e.g., Just & Carpenter, 1992; Martin & Freedman, 2001b).[14] To return to the introduction, it was proposed that further correspondence between the language and memory domains would be advantageous for both fields. Although lexical and memory retrieval may differ with regard to the processes involved in word selection, models containing analogous principles such as interactive spreading activation (e.g., WEAVER ++) have been useful in providing an account for similar effects observed in language and memory tasks (e.g., Watson et al., 2003).

Footnotes

1. Both interactive and serial stage models have been proposed to account for the various stages involved in speech production (Dell, 1986; Dell, Schwartz, Martin, Saffran, & Gagnon, 1996; Stemberger, 1985; Levelt, 1989; Schriefers, Meyer, Levelt, 1990). Although interactive and serial stage models disagree about the relative influence of later stages of speech production on earlier stages, it is generally agreed that lexical semantic processing begins before lexical phonological processing.

2. The part-list cueing effect also has been found with unrelated cues sampled from unrelated study word lists (e.g., Roediger, Stellon, & Tulving, 1977). Experiment 7 will investigate whether same category cues have a greater inhibiting effect on recall relative to unrelated cues.

3. Brown et al. (2005) found parallel effects when subjects generated several exemplars to the same letter cues (insect: t___, sports: t____). The authors attributed the effects obtained for same category and same letter generation to different mechanisms, i.e., suppression to generating category members and interference to generating instances to letters. They claimed that interference would arise in the letter condition when more instances (correct retrievals) beginning with the same letter are produced at earlier serial positions because items with similar orthography dominate the subjects' attention and interfere with later instances to be generated.

4. Martin and Cheng (2005) reported that undergraduates obtained less than 1% errors, which were too few to analyze.

5. Short-term memory spans are based on non-rhyming auditorily presented lists. Patients' short-term memory spans were determined by calculating at which list length they obtain 50% correct. If the 50% level fell between two list lengths, (e.g., length 3 = 30% and list 2 = 80%), linear interpolation was used to estimate the length at which each patient would score 50% correct (Martin et al., 1994).

6. Interestingly, ML showed no semantic or phonological relatedness effects in reaction time or accuracy for two item lists.

7. LW did show an interference effect (123 ms) in the semantically related condition at an SOA of 300 ms; however, it was within the range of controls. Although several studies (e.g., Schriefers, Meyer, Levelt, 1990; Damian & Martin, 1999) have not found significant interference effects for young subjects at 150 ms or 200 ms SOAs, the results obtained for elderly subjects initially suggest that selection at the lexical-semantic level is slower for elderly adults.

8. Hodgson et al. (2005) also investigated whether aphasic patients would show facilitatory effects when naming phonologically blocked picture sets. In contrast to control subjects, they found inhibitory effects for aphasic patients, i.e., aphasic patients obtained significantly more errors for phonologically blocked sets relative to mixed sets. Hodgson and colleagues attributed the observed inhibitory effects to deficits among lexical-phonological representations. While some patients obtain some benefit when provided with initial phonemes or cues during production, Hodgon et al. (2005) proposed that for other aphasic patients, previously activated lexical-phonological traces remain partially activated, such that they interfere with the production of subsequent items. However, the residual activation is not at a level that would enable self cueing. It should be mentioned that Hodgson et al. (2005) combined the data for both left frontal and left temporal lesion aphasic patients. Thus, the functional and structural locus of impairment cannot be inferred from the results.

9. One interpretation of the reduced effect would be due to repeated exposure to the same stimuli. However, that seems unlikely since at least six months elapsed in between testing sessions for Experiments 1 and 4. In addition, in unpublished lab data, patients LW showed an even greater semantic blocking effect after a second testing session in the semantic blocked naming task.

10. One subject obtained zero false alarms in the mixed condition. In order to compute the d' score, this subject was assigned a false alarm rate of .01

11. The DRM paradigm refers to recall and recognition memory paradigms Roediger and McDermott modeled after studies reported by Deese (1959).

12. The related lures used by McDermott et al. (2003) were compound words composed of study list items, rather than associates or members from the same category. However, Watson et al. (2003) have proposed that the processing of study items can lead to spreading activation among related items at various levels, e.g., semantic or phonological, suggesting that the difficulty to reject a lure(s) increases when it has a lexical or semantic relationship to the study items relative to lures bearing no relationship.

13. None of the patients produced intrusion errors in the part-list cued or short-term memory recall tasks that were nonwords.

14. Although Freedman et al. (2004) found interference for producing a phrase based on two semantically related pictures, it was hypothesized that the observed interference was due to the influence of the second picture on the first, and that the interference occurred at a lexical-semantic level when having to select the particular name corresponding to the first picture.

References

Anderson, M. C. & Spellman, B. A. (1995). On the status of inhibitory mechanisms in cognition: Memory retrieval as a model case. *Psychological Review, 102*, 68 – 100.

Anderson, M. C., & Bjork, R. A. (1994). Mechanisms of inhibition in long-term memory: A new taxonomy. In D. Dagenbach, & T. Carr (Eds.), *Inhibitory processes in attention, memory, and language* (pp. 256 – 326). San Diego, CA, USA: Academic Press.

Anderson, M. C., Bjork, E. L., & Bjork, R. A. (1994). Remembering can cause forgetting: Retrieval dynamics in long-term memory. *Journal of Experimental Psychology: Learning, Memory and Cognition, 20*, 1063 – 1087.

Anderson, M. C., Bjork, E. L., & Bjork, R. A. (2000). Retrieval-induced forgetting: Evidence for a recall-specific mechanism. *Psychological Bulletin & Review, 7,* 522 – 530.

Atkinson, R. & Shiffrin, R. (1968). Human memory: A proposed system and its control Processes. In K. W. Spence & J. T. Spence (Eds.), *The psychology of learning and motivation,* Vol. 2. New York: Academic Press.

Baddeley, A. (1986). *Working memory.* Oxford: Oxford University Press.

Baddeley, A. (2001). Is working memory still working? *American Psychologist, 56,* 851-864.

Baddeley, A. (2002). Levels of Working Memory. In M. Naveh-Benjamin & M. Moscovitch (Eds.), *Perspectives on Human Memory and Cognitive Aging: Essays in Honor of Fergus Craik* (pp. 111-123). Hove: Psychology Press.

Baddeley, A. & Hitch, G. (1974). Working memory. In G.A. Bower (Ed.), *The Psychology of learning and motivation, Vol. 7* (pp. 47 – 90). New York: Academic Press.

Baddeley, A. (1966). Short-term memory for word sequences as a function of Acoustic, semantic, and formal similarity. *Quarterly Journal of Experimental Psychology, 18A,* 362 – 365.

Baddeley, A., Papagno, C., & Vallar, G. (1988). When long-term learning depends on short-term storage. *Journal of Memory and Language, 27*, 586 – 595.

Baldo, J. & Shimamura, A. (1998). Letter and category fluency in patients with frontal lobe lesions. *Neuropsychology, 12*, 259 – 267.

Baldo, J. & Shimamura, A. (2002). Frontal lobes and memory. In Baddeley, A., Wilson, B., and Kopelman, M. (Eds.), *Handbook of Memory Disorders* (2nd Edition). London: John Wiley & Co.

Baldo, J., Shimamura, A., Delis, D., Kramer, J. & Kaplan, E. (2001). Verbal and design fluency in patients with frontal lobe lesions. *Journal of the International Neuropsychological Society, 7*, 586 – 596.

Balota, D., Faust, M., & Watson, J. (1996). *Priming lexical retrieval processes in healthy Young and older adults*. Paper presented at the Cognitive Aging Conference, Atlanta, GA.

Barnard, P. (1985). Interacting cognitive subsystems: A psycholinguistic approach to short-term memory. *In A. Ellis (Ed.). Progress in the psychology of language, Vol. 2* (pp. 197 – 258).

Basden, D. & Basden, B. (1995). Some tests of the strategy disruption interpretation of part-list cuing inhibition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*, 1656 – 1669.

Basden, D., Basden, B., & Galloway, B. (1977). Inhibition with part-list cuing: Some tests of the item strength hypothesis. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 3,* 100 – 108.

Battig, W. F., & Montague, W. E. (1969). Category norms for verbal items in 56 categories: A Replication of the Connecticut Category Norms. *Journal of Experimental Psychology*, 80, 1 – 46.

Belke, E., Meyer, A. S., & Damian, M. F. (2005). Refractory effects in picture naming as assessed in a semantic blocking paradigm. *Quarterly Journal of Psychology A, 58(A),* 667 – 692.

Benton, A. (1968). Differential behavioral effects of frontal lobe disease. *Neuropsychologia, 6*, 53 – 60.

Berndt, R., Mitchum, C., Haendiges, A., & Sandson, J. (1997). Verb retrieval in aphasia. Characterizing single word impairments. *Brain and Language, 56,* 1, 68 – 106.

Biegler, K., Martin, R. C., Potts, G. (2004, April). *A Methodological Comparison of Overt and Covert Action and Object Namingin an ERP Paradigm.* Poster presented at the 12th Annual Meeting of the Cognitive Neuroscience Society, New York, NY.

Bock, K. (1996). Language production: Methods and Methodologies. *Psychonomic Bulletin and Review, 3* (4), 395 – 421.

Bornstein, R. (1986). Contribution of various neuropsychological measures to detect frontal lobe impairment. *International Journal of Clinical Neuropsychology, 8*, 18 – 22.

Brewin, C. & Beaton, A. (2002). Thought suppression, intelligence and working Memory capacity. *Behavior Research and Therapy, 40*, 8, 923 – 930.

Brown, A. S. & Knight, K. (1990). Letter cues as retrieval aids in semantic memory. *American Journal of Psychology, 103*, 101 – 113.

Brown, A. S. (1979). Priming effects in semantic memory retrieval processes. *Journal of Experimental Psychology: Human Learning and Memory, 5(2),* 65 – 77.

Brown, A. S. (1981). Inhibition in cued recall. *Journal of Experimental Psychology: Human Learning and Memory, 7(3),* 204 – 215.

Brown, A. S., Zoccoli, S., & Leahy, M. (2005). Cumulating retrieval inhibition in semantic and lexical domains. *Journal of Experimental Psychology: Learning, Memory, and Cognition. 31(3)*, 496 – 507.

Brown, G. & Hulme, C. (1995). Modeling item length effects in memory span: No rehearsal needed? *Journal of Memory and Language, 31*, 429 – 460.

Brown, J. (1968). Reciprocal facilitation and impairment of free recall. *Psychonomic Science, 10*, 41 – 42.

Cameron, K., Haarmann, H. J., Grafman, J., & Ruchkin, D. S. (2002). Activated long-term memory is the representational basis for the semantic component of verbal short-term memory. Submitted.

Caramazza, A. & Costa, A. (2001a). The semantic interference effect in the picture-word interference paradigm: Does the response set matter? *Cognition, 75,* B51 – B64.

Caramazza, A. & Costa, A. (2001b). Set size and repetition in the picture-word interference paradigm: Implications for models of naming. *Cognition, 80*, 215 – 222.

Caramazza, A., Hillis, A., Rapp, B., & Romani, C. (1990). Multiple semantics or multiple confusions? *Cognitive Neuropsychology, 7*, 161 – 190.

Caramazza, A., Hillis, A., Leek, E., & Miozzo, M. (1994). The organization of lexical knowledge in the brain: Evidence from category- and modality-specific deficits. In L.A. Hirschfeld & S. A. Gelman (Eds.), *Mapping the Mind: Domain specificitiy in cognition and culture* (pp. 68 – 84). New York: Cambridge University Press.

Cohen, J. D., MacWhinney, B., Flatt, M., & Provost, J. (1993). Psyscope: An interactive graphic system for designing and controlling experiments in the psychology laboratory using Macintosh computers. *Behavioral Research Methods, Instruments, & Computers, 25*, 257 – 271.

Connelly, S., Hasher, L., & Zacks, R. (1991). Age and reading: The impact of distraction. *Psychology and Aging, 6,* 533 – 541.

Cowan, N. (1984). On short and long auditory stores. *Psychological Bulletin, 96,* 341-370.

Cowan, N. (1988). Evolving conceptions of memory storage, selective attention, and their mutual constraints within the human information processing system. *Psychological Bulletin, 104,* 163-191.

Cowan, N. (1995). *Attention and Memory, An Integrated Framework.* Oxford: Oxford University Press.

Cowan, N. (1999). An embedded-process model of working memory. In A.Miyake & P. Shah (Eds.), *Models of Working Memory* (pp. 62-101). Cambridge: Cambridge University Press.

Cowan, N. (2001). The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *Behavioral and Brain Sciences, 24,* 87-185.

Crowder, R. (1978). Memory for phonologically uniform lists. *Journal of Verbal Learning and Vebral Behavior, 17*, 73 – 89.

Crowder, R. (1979). Similarity and order in memory. In G.H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory: Vol. 13.* New York: Academic Press.

Crowder, R. (1993). Short-term memory: Where do we stand? *Memory & Cognition, 21,* 142-145.

Crowther, J. (2006). Inhibition versus over-activation in word selection: Evidence from Aphasia. (Masters thesis, Rice University).

Crowther, J. & Martin, R. C. (2006). Deficits naming in context: The role of semantic short-term memory v. lexical retrieval. Poster presentation at the 13th annual meeting of the Cognitive Neuroscience Society, San Francisco, CA.

Crutch, S. & Warrington, E. (2003). Spatial coding of semantic information: Knowledge of country and city names depends on their geographical proximity. *Brain, 126*, 1821 – 1829.

Crutch, S. & Warrington, E. (2004). The semantic organization of proper nouns: the case of people and brand names. *Neuropsychologia, 42*, 584 – 596.

Crutch, S. J. & Warrington, E. K. (2005). Abstract and concrete concepts have structurally different representational frameworks. *Brain, 128,* 615 – 627.Damian & Bowers, 2003;

Damian, M. & Martin, R. C. (1999). Semantic and Phonological Codes Interact in single word production. *Journal of Experimental Psychology: Learning, Memory and Cognition, 25* (2), 345 – 361.

Damian, M. F., Vigliocco, G., & Levelt, W. J. M. (2001). Effects of semantic context in the naming of pictures and words, *Cognition, 81(3),* B77 – B86.

Damian, M. F. (2003). Articulatory duration in single-word speech production. *Journal of Experimental Psychology: Learning, Memory and Cognition, 29 (3)*, 416 – 431.

Damian, M., Bowers, J., & Katz, M. (1997). Are semantic effects in the picture-word Interference task lexically or conceptually based? (submitted for publication).

Dell, G. S. (1986). A spreading activation theory of retrieval in sentence production. *Psychological Review, 93*, 283 – 321.

Dell, G. S. (1988). The retrieval of phonological forms in production: Tests of predictions from a connectionist model. *Journal of Memory and language*, *27*, 124-142.

Dell, G. S. & O'Seaghdha, P. G (1992). Stages of lexical access in language production. *Cognition, 42*, 287 – 314.

Dell, G. S. & O'Seaghdha, P. G. (1991). Mediated and convergent lexical priming in language production: A comment on Levelt et al. *Psychological Review,* 98, 604 – 614.

Dell, G. S. & O'Seaghdha, P. G. (1994). Inhibition in interactive activation models of linguistic selection and sequencing. In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory processes in attention, memory, and language.* (pp. 409 – 453). San Diego, CA, USA: Academic Press.

della Rochetta, A. I. & Milner, B. (1993). Strategic search and retrieval inhibition: The role of the frontal lobes. *Neuropsychologia, 31 (6)*, 503 – 524.

Devlin, J., Gonnerman, L., Andersen, E., & Seidenberg, M. (1998). Category-specific semantic deficits in focal and widespread brain damage: A computational account. *Journal of Cognitive Neuroscience, 10*, 77 – 94.

Druks, J. & Masterson, J. (2000). An Object and Action Naming Battery. Psychology Press.

Dunn, L. & Dunn, L. (1981). *Peabody picture vocabulary test – revised.* Circle Pines, MN: American Guidance Service.

Ehrlich, S. & Rayner, K. (1981). Contextual effects on word perception and eye Movements during reading. *Journal of Verbal Learning and Verbal Behavior, 20,* 641 – 655.

Engel, A. K. & Singer, W. (2001). Temporal binding and the neural correlates of sensory awareness. *Trends in Cognitive Sciences, 5,* 16-25.

Finkbeiner, M. & Caramazza, A. (in press). Now you see it, now you don't: On turning semantic interference into facilitation in a Stroop-like task. *Cortex.*

Ford, E. & Humphreys, G. W. (1995). Refractory semantics in global aphasia: On Semantic organization and the access-storage distinction in neuropsychology. *Memory, 3* (3/4), 265 – 307.

Ford, M. E. & Humphreys, G. W. (1997). A semantic locus for refractory behavior:

Implications for access-storage distinctions and the nature of semantic memory. *Cognitive Neuropsychology, 14*, 367 – 402.

Freedman, J. & Loftus, E. (1971). Retrieval of words from long-term memory. *Journal Verbal Learning and Verbal Behavior, 10*, 107-115.

Freedman, M. & Martin, R. (2001). Dissociable components of short-term memory and their relation to long-term learning. *Cognitive Neuropsychology, 18,* 193 – 226.

Freedman, M. L., Martin, R. C., & Biegler, K. (2004). Semantic relatedness effects in conjoined noun phrase production: Implications for the role of short-term memory. *Cognitive Neuropsychology*, 21 (2/3/4), 245 – 265.

Frisk, V. & Milner, B. (1990). The role of the left hippocampal region in the acquisition and retention of story content. *Neuropsychologia, 28,* 349 – 359.

Gershberg, F. & Shimamura, A. (1995). Impaired use of organizational strategies in free recall following frontal lobe damage. *Neuropsychologia, 13,* 1305 – 1333.

Goodglass H. & Kaplan, E. (1983). Boston Diagnostic Aphasia Examination. PA: Williams & Wilkins.

Gotts, S. & Plaut, D. (2002). The impact of synaptic depression following brain damage: A connectionist account of 'access/refractory' and 'degraded/store' semantic impairments. *Cognitive, Affective, & Behavioral Neuroscience, 2*, 187 – 213.

Hamilton, A. C. & Martin, R. C. (2005). Dissociations among tasks involving inhibition: A single case study. *Cognitive, Affective, & Behavioral Neuroscience, 5,* 1 – 13.

Hamilton, A. C. & Martin, R. C. (in press). Proactive interference in a semantic short-Term memory deficit: Role of semantic and phonological relatedness. *Cortex.*

Hamilton, A. C. (2004). Proactive interference in phonological and semantic short-term memory deficits. (Masters thesis, Rice University, 2004).

Hanley, J., Young, A., & Pearson, N. (1991). Impairment in the visuo-spatial sketchpad. *Quarterly Journal of Experimental Psychology, 43A*, 101 – 125.

Harley, T. (1993). Phonological activation of semantic competitors during lexical access in speech production. *Language and Cognitive Process, 8*, 291 – 209.

Hodgson, C., Schwartz, M., Schnur, T., & Brecher, A. (2005). Facilitation and interference in phonologically blocked cyclic naming. *Brain and Language, 95*, 46 – 47.

Howard, D., Nickels, L., Coltheart, M., & Cole-Virtue, J. (2006). Cumulative semantic inhibition in picture naming: experimental and computational studies. *Cognition, 100(3)*, 464 – 82.

Jankowski, J., Shimamura, A., Kritchevsky, M., & Squire, L. (1989). Cognitive impairment following frontal lobe damage and its relevance to human amnesia. *Behavioral Neuroscience, 103*, 548 – 560.

Kay, J., Lesser, R., & Coltheart, M. (1992). Psycholinguistic Assessment of Language Processing in Aphasia. Psychological Press.

Kintsch, W. (1970). Models for free recall and recognition. In D. A. Norman (Ed.), *Models of human memory* (pp. 331 – 373). San Diego, C.A: Academic Press.

Kroll, J. & Curley, J. (1988). Lexical memory in novice bilinguals: the role of Concepts in retrieving second language words. In M. Grunberg, P. Morris, and R. Sykes (Eds.), *Practical aspects of memory*, Vol. 2. London: Wiley.

Kroll, J. & Stewart, E. (1994). Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations.

Journal of Memory and Language, 33 (2), 149 – 174.

Lesch, M. & Martin, R. C. (1998). Levels of Representation in letter-sound correspondence: Syllabic but not sub-syllabic coding in a phonological dyslexic. *Quarterly Journal of Experimental Psychology, 51A*, 905 – 938.

Levelt, W. Roelofs, A. & Meyer, A. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences, 22*, 1 – 75.

Loftus, G. R. & Loftus, E. F. (1974). The influence of one memory retrieval on a subsequent memory retrieval. *Memory and Cognition, 2,* 467 – 471.

Loftus, E. (1973). Activation of semantic memory. *American Journal of Psychology, 86*, 331 – 337.

Lupker, S. (1988). Picture Naming: An investigation of the Nature of Categorical Priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14* (3), 444 – 455.

MacKay, D. G. (1987). *The organization of perception and action: A theory for language and other cognitive skills*. New York: Springer.

Mayall, K. & Humphreys, G. (1996). A connectionist model of alexia: Covert recognition and case mixing effects. British Journal of Psychology, 87 355 – 402.

McRae, K., de Sa, V., & Seidenberg, M. (1997). On the nature and scope of featural representations for word meaning. *Journal of Experimental Psychology: General, 126*, 99 – 130.

Mandler, G. (1967). Organization and memory. In K.W. Spence (Ed.), *The psychology of learning and motivation.* Vol. 1. New York: Academic Press.

Mandler, G (1980). Recognizing: The judgment of previous occurrence. *Psychological Review, 87*, 252 - 271

Mandler, J. (1979). Categorical and schematic organization in memory. In C. R. Puff (Ed.). *Memory organization and structure.* New York: Academic Press, Inc.

Marsh, E., Dolan, P., Balota, D., Roediger, H. (2004). Part-set cueing effects in younger and older adults. *Psychology and aging, 19(1)*, 134 – 144.

Martin, R.C., & Biegler, K. (in press). Competition and Inhibition in Word Retrieval: Implications for Memory and Language Tasks. In J.S. Nairne (Ed.), The foundations of remembering: Essays in honor of Henry L. Roediger III. New York: Psychology Press.

Martin, R. C. & Cheng, Y. (In press). Selection demands vs. association strength in the Verb generation task. Psychonomic Bulletin & Review.

Martin, R. C. & Freedman, M. (2001a). Short-term retention of lexical-semantic representations: Implications for speech production. *Memory, 9*, 261 – 280.

Martin, R. C. & Freedman, M. (2001b). The neuropsychology of verbal working memory: The ins and outs of phonological and lexical-semantic retention. In H. L. Roediger, J. S. Nairne, I. Neath, & A. Suprenant (Eds.), The Nature of remembering: Essays in honor of Robert G. Crowder (pp. 331 – 349). Washington, D. C: American Psychological Association Press.

Martin, R. C., Hamilton, A. C., Lipszyk, M., & Potts, G. (2004, April). *Manipulation of inhibition demands in a working memory task: Evidence from patient and ERP data.* Presented at Cognitive Neuroscience Society, San Francisco, CA.

Martin, R. C. & He, T. (2004). Semantic short-term memory and its role in sentence processing: A replication. *Brain and Language, 89,* 76 – 82.

Martin, R. C. & Lesch, M. (1996). Associations and dissociations between language impairment and list recall: Implications for models of short-term memory. In S. Gathercole (Ed.) *Models of Short-term Memory* (pp. 149 – 178). Hove, UK: Lawrence Erlbaum Associates Ltd.

Martin, R. C. (1987). Articulatory and phonological deficits in short-term memory and their relation to syntactic processing. *Brain and Language, 32,* 137 – 158.

Martin, R. C. (1993). Short-term memory and sentence processing: Evidence from Neuropsychology. *Memory and Cognition, 21*, 176 – 183.

Martin, R. C., Lesch, M., & Bartha, M. (1999). Independence of input and output Phonology in word processing and short-term memory. *Journal of Memory and Language, 41*, 3 – 29.

Martin, R. C., Shelton, J., & Yaffee, L. (1994). Language processing and working memory: Neuropsychological evidence for separate phonological and semantic capacities. *Journal of Memory and Language, 33*, 83 – 111.

McCarthy, R. A., & Kartsounis, L. D. (2000). Wobbly words: Refractory anomia with preserved semantics. *Neurocase, 6*, 487 – 497.

McDermott, K., Jones, T., Petersen, S., Lageman, S., and Roediger, H. (2000). Retrieval success is accompanied by enhanced actiation in anterior prefrontal cortex during recognition memory: An event-related fMRI study. *Journal of Cognitive Neuroscience, 12(6),* 965 – 976.

Meyer, D. & Schvanevelt, R. (1971). Facilitation in recognizing pairs of words:

Evidence of a dependence between retrieval operations. *Journal of Experimental Psychology, 90*, 227 – 234.

Milner, B. (1964). Some effects of frontal lobectomy in man. In J. Warren and K. Akert (Eds.), *The frontal granual cortex and behavior*, (pp. 313 – 331). New York: McGraw-Hill.

Milner, B. (1975). Psychological aspects of focal epilepsy and its neurosurgical Management. In D. P. Purpura, J. K. Penry & R. D. Walter (Eds). *Advances in Neurology, Vol. 8* (pp. 299 – 321). New York, Raven Press.

Milner, B. (1978). Clues to the cerebra organization of memory. In P. Buser, & A. Roegeul-Buser (Eds). *Cerebral Correlates of Consciousness Experience* (pp. 139 – 153). Amsterdam, Elsevier.

Miyake, A., Friedman, N., Emerson, M., Witzki, A., Howerter, A., Wager, T. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. Cognitive Psychology, 41, 49 – 100.

Monsell, S. (1978). Recency, immediate recognition memory, and reaction time. *Cognitive Psychology, 10*, 465 – 501.

Moscovitch, M. (1989) Confabulation and the frontal systems: Strategic versus Associative retrieval in neuropsychological theories of memory. In H. L. Roediger & F. Craik (Eds). *Varieties of Memory and Consciousness: Essays in Honor of Endel Tulving, (pp. 133 – 160).* Hillsdale, NJ., Lawrence Erlbaum.

Moscovitch, M. (1992). Memory and working-with-memory: A component process model based on modules and central system. *Journal of Cognitive Neuroscience, 4,* 257 – 267.

Mueller, C. & Watkins, M (1977). Inhibition from part-set cueing: A cue overload interpretation. *Journal of Verbal Learning and Verbal Behavior, 16,* 699 – 710.

Neath, I (1998). *Human memory: An Introduction to Research, Data, and Theory.* Brooks/Cole Publishing Company.

Neely, J. (1977). The effects of visual and verbal satiation on a lexical decision task. *American Journal of Psychology, 7*, 283 – 290.

Neely, J., Schmidt, S. & Roediger, H. (1983). Inhibition from related primes in Recognition memory. *Journal of Experimental Psychology: Learning, Memory and Cognition, 9* (2), 196 – 211.

Petrides, M. & Milner, B. (1982). Deficits on subject-ordered tasks after frontal and temporal lobe lesions in man. *Neuropsychologia, 20*, 249 – 262.

Poirier, M. & Saint-Aubin, J. (1995). Memory for related and unrelated words: Further evidence concerning the influence of semantic factors on immediate serial recall. *Quarterly Journal of Experimental Psychology, 48A*, 384-404.

Poldrack, R., Wagner, A., Pruli, M., Desmond, J., Glover, G., & Gabrieli, J. (1999). Functional specialization for semantic and phonological processing in the left inferior prefrontal cortex. *Neuroimage, 10*, 15 – 25.

Raaijmakers, J. & Shiffrin, R. (1980). SAM: A theory of probabilistic search of associative memory. In G. Bower (Ed.), *The psychology of learning and motivation, Vol. 14.* New York: Academic Press.

Raaijmakers, J. & Shiffrin, R. (1981). Search of associative memory. *Psychological*

Review, 88, 93 – 134.

Roach, A., Schwartz, M., Martin, N., Grewal, R., & Brecher, A. (1996). The Philadelphia naming test: Scoring and rationale. *Clinical Aphasiology, 24*, 121 – 134.

Robinson, K. & Roediger, H. (1997). Associative processes in false recall and false recognition. *Psychological Science, 8(3)*, 231 – 237.

Roediger, H. (1973). Inhibition in recall from cueing with recall targets. *Journal of Verbal Learning and Verbal Behavior, 12,* 644 – 657.

Roediger, H. & McDermott, K. (1995). Creating false memories: Remembering words not presented in lists. *Journal of Experimental Psychology: Learning Memory and Cognition, 21(4),* 803 – 814.

Roediger, H. & Neely, J. (1982). Retrieval blocks in episodic and semantic memory. *Canadian Journal of Psychology, 36* (2), 213 – 242.

Roediger, H., Weldon, M., & Challis, B. (1989). Explaining dissociations between implicit and explicit measures of retention: A processing account. In H. L. Roediger & E. Tulving (Eds.), *Varieties of memory and consciousness* (pp. 3 – 41). Hillsdale, NJ: Erlbaum.

Romani, C. & Martin, R. C. (1999). A deficit in the short-term retention of lexical-semantic information: Forgetting words but remembering a story. *Journal of Experimental Psychology: General, 128* (1), 56 – 77.

Rosen, V. & Engle, R. (1998). Working memory capacity and suppression. *Journal of Memory and Language, 39,* 418 – 436.

Rugg, M., Fletcher, P., Frith, C., Frackowiak, R., & Dolan, R. (1996). Differential activation of the prefrontal cortex in successful and unsuccessful memory retrieval. *Brain, 119*, 2073 – 2083.

Rundus, D. (1973). Negative effects of using list items as recall cues. *Journal of Verbal Learning and Verbal Behavior, 12*, 43 – 50.

Ruchkin, D. S., Berndt, R. S., Johnson, R. J., Grafman, J., Ritter, W., & Canoune, H. L. (1999). Lexical contributions to retention of verbal information in working memory: Event-related brain potential evidence. *Journal of Memory and Language, 41,* 345-364.

Saffran, E., Berndt, R., & Schwartz, M. (1989). The quantitative analysis of agrammatic production: procedure and data. *Brain and Language, 37* (3), 440 – 479.

Sarnthein, J., Petsche, H., Rappelsberger, P., Shaw, G. L., & von Stein, A. (1998). Synchronization between prefrontal and posterior association cortex during human working memory. *Proceedings of The National Academy of Sciences of The United States of America, 95,* 7092 - 7096.

Schacter, D., Alpert, N., Savage, C., Rauch, S., & Alpert, M. (1996a). Conscious Recollection and the human hippocampal formation: Evidence from positron emission tomography. *Proceedings of the National Academy of Science, USA, 93*, 321 – 325.

Schacter, D., Reiman, E., Uecker, A., Polster, M., Yun L., & Cooper, L. (1995). Brain regions associated with retrieval of coherent visual information. *Nature, 376*, 587 – 590.

Shallice, T. & Warrington, E. (1970). Independent functioning of the verbal memory stores: A neuropsychological study. *Quarterly Journal of Experimental Psychology, 22,* 261 – 273.

Schnur, T., Lee, E., Coslett, B., Schwartz, M., & Thompson-Schill, S. (2005). When lexical selection gets tough, the LIFG gets going: A lesion analysis study of interference during word production. *Brain and Language, 95*, 12 – 13.

Schnur, T., Schwartz, M., Brecher, B., & Hodgson, C. (2006). Semantic interference during blocked-cyclic naming: Evidence from aphasia. *Journal of Memory and Language, 54(2)*, 199 – 227.

Schriefers, H., Meyer, A. S., & Levelt, W. J. M. (1990). Exploring the time course of lexical access in language production: Picture-word interference studies. *Journal of Memory and Language, 29,* 86 – 102.

Schweickert, R. (1993). A multinomial processing tree model for degradation and redintegration in immediate recall. *Memory and cognition, 21*, 168 – 175.

Shiffrin, R., Murnane, K., Gronlund, S., & Roth, M. (1989). On units of storage and retrieval. In C. Izawa (Ed.), *Current issues in cognitive process: The Tulane Flowerree Symposium on Cognition*. Erlbaum.

Shimamura, A. (1995). Memory and frontal lobe function. In M. Gazzaniga (Ed.), *The Cognitive Neurosciences*. Cambridge, MA: MIT Press.

Shimamura, A. (2000a). The role of the prefrontal cortex in dynamic filtering. *Psychobiology, 28*, 207 – 218.

Shimamura, A., Jurica, P., Mangels, J., et al. (1995). Susceptibility to memory interference effects following frontal lobe damage: Findings from tests of paired associate learning. Journal of Cognitive Neuroscience, 7, 144 – 152.

Slamecka, N. (1968). An examination of trace storage in free recall. *Journal of Experimental Psychology, 76*, 504 – 513.

Slamecka, N. (1969). Testing for associative storage in mulitrial free recall. *Journal of Experimental Psychology, 81*, 557 – 560.

Sloman, S., Bower, G., and Rohrer, D. (1991). Congruency effects in part-list cueing inhibition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17* (3), 974 – 982.

Snodgrass, J. G. & Corwin, J. (1988). Pragmatics of measuring recognition memory: Applications to dementia and amnesia. *Journal of Experimental Psychology: General, 117,* 34 – 50.

Snodgrass, J. G. & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory, 6(2),* 174 – 215.

Squire, L., Ojemann, J., Miezen, F., Petersen, S., Videen, T., & Raichle, M. (1992). Activation of the hippocampus in normal humans: A functional anatomical Study of memory. *Proceedings of the National Academy of Sciences, U.S.A. 89,* 1837 – 1841.

Starreveld, P. & Le Heij, W. (1995). Semantic interference, orthographic facilitation, and their interaction in naming tasks. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*, 686 – 698.

Stemberger, J. P. (1985). An interactive activation model of language production. In A.W. Ellis (Ed.), *Progress in the Psychology of Language: Volume 1.* London: Lawrence Erlbaum.

Stroop, J. R. (1935). Studies of Interference in serial verbal reactions. *Journal of Experimental Psychology, 18,* 643 – 662.

Tehan, G. & Humphreys, M. (1988). Articulatory loop explanations of memory span and pronunciation rate correspondences: A cautionary note. *Bulletin of the Psychonomic Society, 26,* 293 – 296.

Thompson-Schill, S. L., D'Esposito, M., Aguirre, G., K., & Farah, M. J. (1997). Role of left inferior prefrontal cortex in retrieval of semantic knowledge: A reevaluation. *Proceedings of National Academy of Sciences, USA, Neurobiology, 94*, 14792 – 14797.

Thompson-Schill, S. L., Swick, D., Farah, M. J., D'Esposito, M., Kan, I. P., & Knight, R. T. (1998). Verb generation in patients with focal frontal lesions: A neuropsychological test of neuroimaging findings. *Proceedings of National Academy of Sciences, USA, Psychology, 95, 15855 – 15860.*

Todres, A. & Watkins, M. (1981). A part-set cueing set effect in recognition. *Journal of Experimental Psychology: Human Learning and Memory, 7*, 91 – 99.

Troyer, A., Moscovitch, M., Winocur, G., Alexander, and Stuss, D. (1998). Clustering and switching on verbal fluency: the effects of focal frontal and temporal lobe lesions. *Neuropsychologia, 36,* 494 – 504.

Tulving, E. & Osler, S. (1968). Effectiveness of retrieval cues in memory for words. *Journal of Experimental Psychology, 77*, 593 – 601.

Tulving, E. & Pearlstone, Z. (1966). Availability versus accessibility of information in memory for words. Journal of Verbal Learning and Verbal Behavior, 5, 381 – 391.

Underwood, B. (1965). False recognition produced by implicit verbal responses. *Journal of Experimental Psychology, 70*, 122 – 129.

von Stein, A. & Sarnthein, J. (2000). Different frequencies for different scales of cortical integration: from local gamma to long range alpha/theta synchronization. *International Journal of Psychophysiology, 38,* 301-313.

Warren, R. (1970). Stimulus encoding and memory. (Doctoral dissertation, University of Oregon, 1970). *Dissertation Abstracts International*, 32, 599B.

Warren, R. (1977). Time and spread of activation in memory. Journal of Experimental Psychology: Human Learning and Memory, 4, 458 – 466.

Warrington, E. & McCarthy, R. (1983). Category specific access dysphasia. *Brain, 106,* 851 – 878.

Warrington, E. & McCarthy, R. (1987). Categories of Knowledge: Further fractionations and an attempted integration. *Brain, 110*, 1273 – 1296.

Warrington, E. & Shallice, T. (1969). The selective impairment of auditory verbal short-term memory. *Brain, 92*, 885 – 896.

Watkins, M. J. (1975). Inhibition in recall with extralist "cues." *Journal of Verbal Learning and Verbal Behavior, 14,* 294 – 303.

Watkins, O. & Watkins, M. (1977). Serial recall and the modality effect: Effects of word Frequency. *Journal of Experimental Psychology: Human Learning and Memory, 3,* 712 – 718.

Watson, J., Balota, D., & Roediger, H. (2003). Creating false memories with hybrid lists of semantic and phonological associates: Over-additive false memories produced by converging associative networks. *Journal of Memory and Language,* *49,* 95 – 118.

Wechsler, D. (1987). *Wechsler Memory Scale – Revised.* New York: Psychological Corporation.

Wickens, D. (1972). Characteristics of word encoding. In A. W. Metlton & E. Martin (Eds.), *Coding Processes in Human Memory*, Washington, DC: Winston.

Wickens, D., Born, D., Allen, C. (1963). Proactive inhibition and item similarity in short-term memory. *Journal of Verbal Learning and Verbal Behavior, 2* 440 – 445.

Williams, C. & Zacks, R. (2001). Is retrieval-induced forgetting an inhibitory process? *American Journal of Psychology, 114* (3), 329 – 354.

Wilshire, C. & McCarthy, R. (2002). Evidence for a context-sensitive word retrieval disorder in a case of nonfluent aphasia. *Cognitive Neuropsychology, 19*, 165 – 186.

Wu, D., Martin, R. C., & Damian, M. (2002). A Third Route for Reading? Implications From a case of phonological dyslexia. *Neurocase, 8,* (4), 274 – 295.

Appendix A

Categories and exemplars used in Experiments 1 – 3.

Animal	bear	**furniture**	bed	**Nature**	cloud
animal	cat	**furniture**	chair	**Nature**	mountain
animal	dog	**furniture**	couch	**Nature**	pond
animal	goat	**furniture**	crib	**Nature**	sun
animal	horse	**furniture**	stool	**Nature**	volcano
animal	skunk	**furniture**	table	**Nature**	waterfall
body parts	arm	**utensils**	cup	**Roles**	nurse
body parts	chin	**utensils**	pitcher	**Roles**	judge
body parts	ear	**utensils**	glass	**Roles**	soldier
body parts	nose	**utensils**	knife	**Roles**	bride
body parts	thumb	**utensils**	fork	**Roles**	clown
body parts	toe	**utensils**	spoon	**Roles**	nun
clothing	coat	**plant**	bush	**Toys**	ball
clothing	dress	**plant**	cactus	**Toys**	bat
clothing	glove	**plant**	fern	**Toys**	blocks
clothing	hat	**plant**	flower	**Toys**	doll
clothing	skirt	**plant**	mushroom	**Toys**	kite
clothing	sock	**plant**	tree	**Toys**	top
food	bread	**Appliance**	iron	**Shapes**	arrow
food	cake	**Appliance**	scales	**Shapes**	circle
food	cheese	**Appliance**	radio	**Shapes**	cone
food	pie	**Appliance**	toaster	**Shapes**	cross
food	shrimp	**Appliance**	vacuum	**Shapes**	heart
food	soup	**Appliance**	Fan	**Shapes**	star

Appendix B

List of categories and stimuli from Experiment 4

Category	**Picture**	**Associated word**
animal	bear	honey
animal	cat	yarn
animal	dog	Kennel
animal	skunk	odor
animal	horse	saddle
animal	lion	jungle
body parts	ear	noise
body parts	nose	smell
body parts	finger	ring
body parts	eye	blink
body parts	leg	kick
body parts	mouth	lipstick
clothing	coat	winter
clothing	shoe	walk
clothing	jersey	sport
clothing	cap	baseball
clothing	tie	office
clothing	shorts	summer
food	bread	basket
food	popcorn	movie
food	spaghetti	Italy
food	pie	slice
food	shrimp	ocean
food	eggs	Easter
furniture	bed	sleep
furniture	desk	study
furniture	lamp	bulb
furniture	crib	baby
furniture	shelf	book
furniture	table	dinner
utensils	cup	sugar
utensils	pitcher	lemonade
utensils	pan	fry
utensils	Oven	bake

Appendix B (Continued)

utensils	kettle	steam
utensils	spoon	stir
plant	herb	cook
plant	cactus	desert
plant	rose	thorn
plant	flower	bee
plant	mushroom	fungus
plant	tree	shade
Appliance	iron	wrinkle
Appliance	scales	weight
Appliance	radio	music
Appliance	toaster	burn
Appliance	vacuum	carpet
Appliance	fan	cool
Nature	cloud	fluffy
Nature	mountain	hike
Nature	pond	fish
Nature	sun	beach
Nature	rain	umbrella
Nature	lightning	strike
Roles	nurse	hospital
Roles	judge	court
Roles	soldier	army
Roles	bride	wedding
Roles	clown	circus
Roles	nun	convent
vehicles	car	Ford
vehicles	bus	school
vehicles	airplane	stewardess
vehicles	train	conductor
vehicles	boat	port
vehicles	tractor	field
Toys	ball	bounce
Toys	bat	swing
Toys	blocks	build
Toys	kite	wind

Appendix B (Continued)

Toys	balloon	pop
Toys	top	spin
Fruit	apple	teacher
Fruit	banana	monkey
Fruit	orange	Florida
Fruit	pineapple	Hawaii
Fruit	pumpkin	witch
Fruit	lemon	tea
building	house	mortgage
building	tent	camp
building	cave	bat
building	igloo	eskimo
building	tepee	indian
building	castle	princess
weapon	knife	stab
weapon	gun	shoot
weapon	bomb	explode
weapon	bow	target
weapon	rope	strangle
weapon	axe	cut
vegetable	carrot	rabbit
vegetable	corn	harvest
vegetable	cabbage	patch
vegetable	pea	soup
vegetable	pepper	spicy
vegetable	potato	starch
tools	hammer	nail
tools	paintbrush	drip
tools	saw	wood
tools	wrench	plumbing
tools	screwdriver	turn
tools	ladder	climb
birds	canary	sing
birds	duck	swim
birds	turkey	Thanksgiving
birds	penguin	snow
birds	rooster	farm

Appendix C

List of categories and items for Experiment 5.

vehicles	**insects**	**musical instruments**	**precious stones**	**tools**	**US states**
train	louse	drum	quartz	ruler	Indiana
cart	horsefly	bugle	pearl	chisel	Kansas
tank	mosquito	accordion	turquoise	hatchet	Vermont
skates	moth	horn	jade	ladder	Oklahoma
trolley	roach	bass	Peridot	pliers	Utah
scooter	centipede	saxophone	amber	drill	Wisconsin
taxi	gnat	cello	emerald	bench	Illinois
subway	mite	trombone	diamond	bolt	Ohio
elevator	hornet	tambourine	opal	wood	Main
carriage	wasp	oboe	aquamarine	sandpaper	Alabama
sled	termite	organ	topaz	brick	Kentucky
rocket	caterpillar	percussion	silver	vise	New York
trailer	fly	tuba	sapphire	cement	Florida
tractor	cricket	bells	zircon	clamp	Hawaii
car	locust	clarinet	amethyst	nails	Colorado
bicycle	ant	fiddle	granite	wheelbarrow	Oregon
bus	scorpion	violin	marcasite	crowbar	Alaska
skis	june bug	harp	garnet	axe	Delaware
helicopter	flea	guitar	gold	wrench	Nevada
airplane	tick	trumpet	ruby	blueprint	Virginia
truck	spider	harmonica	crystal	lever	Michigan
boat	bee	banjo	onyx	hammer	Iowa
submarine	grasshopper	piano	rhinestone	saw	California
wagon	butterfly	flute	platinum	screwdriver	Texas

Appendix C (Continued)

animal	**body parts**	**clothing**	**food**	**Furniture**	**Kitchen Utensils**
bull	elbow	belt	burrito	shelf	glass
giraffe	arm	jacket	chips	stool	sifter
rabbit	throat	hat	cereal	bookcase	pitcher
pig	tooth	purse	steak	table	spoon
mouse	nose	robe	soup	ottoman	griddle
donkey	hand	pants	bread	curtains	spatula
monkey	leg	sock	candy	desk	bowl
deer	chin	vest	milk	chair	grill
beaver	shoulder	swimsuit	salad	couch	kettle
wolf	toe	pajamas	eggs	cabinet	knife
horse	stomach	scarf	crackers	hammock	stove
sheep	ankle	coat	pizza	counter	saucer
bear	eye	sweater	shrimp	dinette	cup
dog	heart	tie	cheese	closet	pan
elephant	thumb	girdle	pie	bed	broiler
moose	lung	glove	bacon	mirror	tongs
rat	hair	stockings	popcorn	rocker	fork
camel	tongue	dress	pancakes	dresser	ladle
cat	ear	blouse	chicken	bench	pot
lion	head	skirt	hamburger	crib	platter
skunk	mouth	shorts	pasta	cupboard	dish
goat	brain	shoes	soda	hutch	sponge
fox	waist	suit	cake	carpet	skillet
cow	neck	slip	potato	chest	roaster

Appendix C (Continued)

Buildings	**sea creatures**	**sports**	**weather**	**weapons**	**flower**
cathedral	octopus	diving	wind	missile	snapdragon
hotel	sardine	hockey	storm	hatchet	geranium
mansion	guppy	rugby	hail	dagger	Bluebonnet
dorm	herring	swimming	thunder	rope	lilac
monastary	bass	surfing	humidity	gun	buttercup
trailer	halibut	hunting	cloud	dart	orchid
hut	marlin	archery	overcast	bomb	tulip
prison	tuna	baseball	mist	poison	lily
cottage	shark	pool	snow	sword	dandelion
lodge	clam	tennis	typhoon	bazooka	iris
skyscraper	dolphin	bowling	cyclone	club	azalea
castle	lobster	boxing	rainbow	axe	poppy
church	crab	wrestling	rain	harpoon	sunflower
house	swordfish	soccer	sleet	cannon	violet
cabin	salmon	badminton	blizzard	arrow	pansy
tepee	barracuda	ping-pong	sunny	grenade	peony
hospital	minnow	basketball	earthquake	whip	Mistletoe
apartment	flounder	gymnastics	lightning	spear	poinsetta
cave	whale	skiing	drought	tank	rose
castle	eel	football	tornado	chain	magnolia
shack	shrimp	golf	temperature	blade	daffodil
igloo	scallop	tennis	cold	scissors	goldenrod
temple	trout	polo	hurricane	rifle	carnation
tent	oyster	track	fog	torpedo	petunia

Appendix C (Continued)

home appliances	**Nature**	**roles**	**toys**	**vegetable**	**disease**
printer	ravine	dentist	crayons	parsley	tetanus
microwave	valley	soldier	checkers	avocado	cancer
vacuum	waterfall	clerk	jacks	pepper	ulcer
refrigerator	volcano	bride	bat	carrot	AIDS
iron	lake	engineer	skates	cucumber	fever
heater	rock	mayor	whistle	celery	plague
stove	plain	janitor	doll	cabbage	leukemia
washer	ocean	nun	marbles	cauliflower	cholera
radio	prairie	accountant	book	mushroom	syphilus
clock	mountain	salesman	ball	turnip	malaria
computer	creek	policeman	blocks	broccoli	virus
mixer	cavern	sheriff	chess	pea	mumps
dryer	island	governor	rattle	spinach	asthma
television	stream	mechanic	seesaw	garlic	hepatitus
toaster	crater	farmer	playhouse	onion	allergy
camcorder	river	nurse	game	corn	cough
oven	pond	judge	top	tomato	polio
blender	sand	clown	kite	beets	measles
fan	desert	teacher	puppet	squash	epilepsy
barbeque	hill	banker	cards	radish	flu
telephone	glacier	fireman	puzzle	asparagus	rabies
stereo	forest	carpenter	swingset	bean	smallpox
lamp	cliff	professor	yo-yo	eggplant	infection
freezer	canyon	plumber	balloon	lettuce	diabetes

Appendix D

List of categories and exemplars in Experiment 6.

vehicles	**insects**	**fruit**	**precious stones**	**tools**	**US states**	**money**	**fields**
car	fly	apple	diamond	hammer	New York	dollar	chemistry
bus	ant	orange	ruby	saw	California	penny	math
airplane	bee	banana	emerald	nails	Florida	dime	psychology
train	mosquito	peach	sapphire	screwdriver	Illinois	nickel	english
truck	spider	grape	pearl	wrench	Texas	quarter	engineering
bicycle	roach	cherry	opal	pliers	Virginia	currency	anatomy
boat	wasp	plum	jade	chisel	Maine	stock	physics
scooter	moth	lemon	topaz	drill	Ohio	bond	history

plant	**appliance**	**disease**	**roles**	**toys**	**shapes**	**crimes**	**beverage**
bush	iron	cancer	nurse	ball	arrow	murder	milk
cactus	scales	measles	judge	bat	circle	robbery	water
fern	radio	polio	soldier	blocks	cone	arson	soda
flower	toaster	flu	bride	doll	cross	kidnap	juice
mushroom	vacuum	mumps	clown	kite	heart	treason	sprite
tree	fan	plague	nun	top	star	fraud	malt
sunflower	computer	allergy	doctor	skate	triangle	cheating	cocoa
herb	television	fever	lawyer	puzzle	square	blackmail	tea

Appendix D (Continued)

animal	body parts	clothing	food	furniture	utensils	musical instruments	metal
bear	arm	coat	bread	bed	cup	piano	iron
cat	chin	dress	cake	chair	pitcher	drum	copper
dog	ear	glove	cheese	couch	glass	trumpet	steel
goat	nose	hat	pie	crib	*bowl*	violin	gold
horse	thumb	skirt	*pasta*	stool	fork	flute	silver
skunk	toe	sock	soup	table	spoon	guitar	bronze
lion	leg	pants	pizza	dresser	pan	clarinet	aluminum
pig	eye	shoes	popcorn	cabinet	spatula	saxophone	mercury

relatives	type of buildings	sea creatures	sports	weather	weapons	time	nature
aunt	house	trout	football	hurricane	knife	hour	cloud
uncle	apartment	shark	baseball	tornado	gun	minute	mountain
father	tent	salmon	basketball	rain	rifle	second	pond
mother	cave	tuna	tennis	snow	bomb	year	sun
brother	hotel	whale	swimming	storm	club	day	volcano
sister	castle	shrimp	soccer	wind	sword	month	waterfall
cousin	church	lobster	golf	cyclone	cannon	week	lake
nephew	temple	dolphin	boxing	hail	spear	decade	forest

Appendix E

List of Categories and exemplars in Experiment 7.

vehicles	car	plane	**beverage**	milk	lemonade
	bus	boat		soda	cocoa
	truck	train		sprite	tea
	scooter	bicycle		malt	juice
plant	cactus	tree	**toys**	bat	ball
	fern	flower		top	doll
	mushroom	bush		kite	blocks
	sunflower	herb		skate	puzzle
appliance	toaster	iron	**relative**	father	aunt
	vacuum	scale		uncle	mother
	fan	radio		cousin	brother
	computer	TV		nephew	sister
buildings	house	church	**body parts**	arm	leg
	apartment	hotel		nose	eye
	cave	tent		thumb	ear
	castle	temple		toe	chin
insects	fly	mosquito	**kitchen utensils**	glass	fork
	bee	spider		cup	spoon
	ant	roach		pitcher	pan
	wasp	moth		bowl	spatula
sickness	cancer	measles	**clothing**	glove	coat
	fever	polio		sock	dress
	flu	mumps		pants	hat
	plague	allergy		skirt	shoes
precious stones	diamond	ruby	**food**	bread	cake
	emerald	sapphire		pizza	pie
	pearl	opal		pasta	soup
	jade	topaz		popcorn	cheese
animal	horse	bear	**furniture**	table	chair
	goat	dog		bed	couch
	skunk	cat		cabinet	crib
	pig	lion		stool	dresser
roles	nurse	doctor	**weather**	wind	rain
	judge	lawyer		storm	snow
	clown	soldier		tornado	hurricane
	nun	bride		cyclone	hail
shapes	star	circle	**sports**	baseball	golf
	arrow	square		football	tennis
	cone	cross		soccer	basketball
	triangle	cylinder		boxing	swimming

Appendix E (Continued)

tools	hammer	wrench	**musical instrument**	piano	guitar
	saw	pliers		drum	violin
	nail	chisel		flute	trumpet
	screwdriver	drill		clarinet	saxophone
money	quarter	dollar	**weapons**	gun	knife
	currency	Penny		rifle	club
	stock	Dime		sword	bomb
	bond	Nickel		spear	cannon

Table 1.

Experiment 1: Semantic Blocked Single Picture Naming (Onset Latencies in ms).

		Cycle 1	Cycle 2	Cycle 3	Cycle 4
Controls	Blocked	720	673	666	673
	Mixed	747	665	651	644
	Difference	-27 Range: -64 to 6	8 Range: -1 to 26	15 Range: -1 to 30	28 Range: -9 to 50
	Difference (nat log)	-.033 Range: -.007 to .01	.011 Range: .002 to .038	.024 Range: -.004 to .049	.046 Range: .011 to .084
ML	Blocked	1124	1117	1286	1331
	Mixed	1064	952	932	894
	Difference	60	165	354	437
	Difference (nat log)	.005	.100	.254	.204
AR	Blocked	2445	2978	3741	2869
	Mixed	2960	2292	2210	1799
	Difference	-515	686	1531	1070
	Difference (nat log)	-.074	.118	.307	.359
JJ	Blocked	1422	1474	1499	1489
	Mixed	1627	1447	1363	1273
	Difference	-205	27	136	216
	Difference (nat log)	-.098	.006	.062	.128
LW	Blocked	876	749	761	743
	Mixed	837	736	691	693
	Difference	39	13	70	50
	Difference (nat log)	.038	.015	.092	.07

Table 2

Experiment 2: Semantic Blocked Single Picture – Word Matching (Onset Latencies in ms).

		Cycle 1	Cycle 2	Cycle 3	Cycle 4
Controls	Blocked	1048	1010	985	1006
	Mixed	1030	959	952	959
	Difference	18 Range: -146 to 137	51 Range: -34 to 180	33 Range: -24 to 107	47 Range: -3 to 191
	Difference (nat log)	.019 Range: -.097 to .092	.048 Range: -.028 to .113	.031 Range: -.03 to .104	.039 Range: -.01 to .101
ML	Blocked	1226	1131	1241	1078
	Mixed	1112	991	971	901
	Difference	114	139	270	177
	Difference (nat log)	.069	.088	.188	.145
AR	Blocked	1951	1741	2078	1787
	Mixed	1697	1545	1485	1539
	Difference	253	196	592	248
	Difference (nat log)	.049	.079	.225	.136
JJ	Blocked	1583	1616	1449	1486
	Mixed	1628	1390	1408	1345
	Difference	-45	226	41	141
	Difference (nat log)	-.037	.130	.020	.086
LW	Blocked	1429	1305	1333	1299
	Mixed	1310	1312	1174	1191
	Difference	119	-7	159	107
	Difference (nat log)	.086	-.001	.120	.083

Table 3

Experiment 3: Semantic Blocked Single Word-Word Match (Onset Latencies in ms).

		Cycle 1	Cycle 2	Cycle 3	Cycle 4
Controls	Blocked	990	954	949	964
N = 10	Mixed	983	960	950	949
	Difference	8	- 6	- 1	15
		(Range: - 96 to 52)	(Range: - 71 to 62)	(Range: -57 to 57)	(Range: -102 to 70)
	Diff (nat log)	0.011	-0.005	0.003	0.02
		(Range: -.006 to .05)	(Range: -.003 to .08)	(Range: -.002 to .06)	(Range: -.01 to .07)
ML	Blocked	1484	1165	1223	1365
	Mixed	1158	1099	1032	1029
	Difference	325	66	191	336
	Diff (nat log)	0.183	0.071	0.129	0.206
AR	Blocked	2207	2008	2150	2152
	Mixed	2267	1772	1872	1881
	Difference	-59	236	278	271
	Diff (nat log)	-0.038	0.115	0.122	0.121
Errors (collapsed across cycle)	Blocked 18%	24%	17%	18%	14%
	Mixed 5%	4%	4%	3%	7%
JJ	Blocked	1362	1254	1368	1311
	Mixed	1280	1284	1271	1262
	Difference	89	- 30	97	49
	Diff (nat log)	0.049	-0.025	0.072	0.030
LW	Blocked	1137	1095	1065	1091
	Mixed	1148	1108	1045	1104
	Difference	- 11	- 12	20	- 13
	Diff (nat log)	-0.005	-0.005	0.020	-0.007

Table 4a

Experiment 4: Semantic Blocked Single Picture -Word Associative Match - % errors. (Parentheses include total error rates collapsing across cycles).

		Cycle 1	Cycle 2	Cycle 3	Cycle 4
Controls N = 14	Blocked (4%)	7% (Range: 0 to 31%)	8% (Range: 0 to 37%)	9% (Range: 0 to 33%)	9% (Range: 0 to 41%)
	Mixed (5%)	8% (Range: 0 to 35%)	8% (Range: 0 to 48%)	10% (Range: 0 to 48%)	10% (Range: 0 to 41%)
ML	Blocked (14%)	11%	15%	24%	6%
	Mixed (11%)	9%	6%	20%	7%
AR	Blocked (20%)	31%	17%	13%	19%
	Mixed (22%)	20%	20%	26%	20%
JJ	Blocked (19%)	20%	13%	22%	19%
	Mixed (14%)	11%	15%	20%	9%
LW	Blocked (35%)	30%	39%	35%	35%
	Mixed (26%)	19%	30%	22%	33%

*All percentages at the high end of the range are from one subject. The next highest error rate in any condition was 15%.

Table 4b

Experiment 4: Semantic Blocked Single Picture -Word Associative Match (Onset Latencies in ms).

		Cycle 1	Cycle 2	Cycle 3	Cycle 4
Controls	Blocked	1284	1183	1164	1119
N = 14	Mixed	1280	1157	1135	1072
	Difference	4	26	30	47
		(Range: -196 to 249)	(Range: -67 to 232)	(Range: -141 to 276)	(Range: -132 to 145)
	Diff (nat log)	0.007	0.022	0.026	0.057
		(Range: -.003 to . 15)	(Range: -.01 to .16)	(Range: -.01 to .17)	(Range: -.0003 to .15)
ML	Blocked	2095	2120	2175	1908
	Mixed	2118	1867	1674	1761
	Difference	- 23	253	501	147
	Diff (nat log)	-0.0196	0.1078	0.1968	0.0387
AR	Blocked	2957	2980	2930	3045
	Mixed	2733	3302	2593	2837
	Difference	224	-322	336	208
	Diff (nat log)	0.042	-0.038	0.133	0.052
JJ	Blocked	2431	1902	2243	2310
	Mixed	2230	2036	1775	1814
	Difference	201	- 134	468	496
	Diff (nat log)	0.049	-0.086	0.190	0.209
LW	Blocked	1521	1342	1349	1541
	Mixed	1491	1407	1268	1317
	Difference	29	- 66	81	225
	Diff (nat log)	0.001	-0.049	0.047	0.133

Table 5a

Experiment 5: Recognition Memory (% hits, % false alarms, discrimination ability, and response criterion in semantically blocked and mixed conditions)

		Hits	False Alarms	d'	C	Pr	Br
Controls N = 13	Blocked	90% (Range: 76% to 99%)	14%* (Range: 2% to 58%)	2.73 (Range: 1.60 to 4.22)	-.080 (Range: -1.45 to .459)	.76 (Range: .42 to .97)	.51 (Range: .18 to .99)
	Mixed	88% (Range: 66% to 98%)	8% (Range: 0% to 35%)	3.09 (Range: 1.44 to 4.67)	.234 (Range: -.968 to .481)	.80 (Range: .64 to .97)	.29 (Range: .02 to .97)
ML	Blocked	92%	7%	2.88	.035	.85	.47
	Mixed	93%	2%	3.53	.289	.91	.22
AR	Blocked	97%	10%	3.16	-.300	.87	.77
	Mixed	98%	1%	4.38	.136	.97	.33
LW	Blocked	93%	21%	2.28	-.335	.72	.75
	Mixed	95%	9%	2.99	-.152	.86	.64

Table 5b

Experiment 5: Recognition Memory (RTs)

		Hits	Correct Rejections
Controls N = 13	Blocked	946	1285
	Mixed	991	1138
	Difference	-45 (Range: -136 to 51)	147 (Range: 38 to 495)
ML	Blocked	1884	2743
	Mixed	1982	2565
	Difference	-98	178
AR	Blocked	1639	1900
	Mixed	1683	1448
	Difference	-44	452
LW	Blocked	880	1072
	Mixed	899	1001
	Difference	-19	71

Table 6a

Experiment 6: Part-list Cue Recall – Errors (% errors in parentheses)

	Blocked Cue	Blocked Free	Mix Cue	Mix Free
Controls N = 14	Total: 269 (24%)	Total: 190 (17%)	Total: 571 (51%)	Total: 482 (43%)
ML	21 (26%)	12 (15%)	54 (68%)	32 (40%)
AR	19 (48%)	16 (40%)	32 (80%)	26 (65%)
JJ	17 (43%)	14 (35%)	38 (95%)	38 (95%)
LW	31 (21%)	22 (28%)	60 (75%)	46 (58%)

Table 6b

Experiment 6: Part-list Cue Recall – Error Types

	Blocked Cue	Blocked Free	Mix Cue	Mix Free
Controls N = 14	Phon Rel: 1 Prev List: 5 Same List: 1 Sem Rel: 23 Unknown: 3 Omissions: 236	Prev List: 1 Same List: 5 Sem Rel: 42 Omissions: 142	Phon Rel: 4 Prev List: 31 Same List: 1 Sem Prev List: 1 Sem Rel: 17 Unknown: 2 Omissions: 515	Phon Rel: 5 Prev List: 40 Sem Prev List: 2 Sem Rel: 20 Unknown: 10 Omissions: 405
ML	Sem Rel: 7 Omissions: 14	Sem Rel: 5 Omissions: 7	Prev List: 1 Omissions: 53	Phon Rel: 1 Prev List: 3 Omissions: 28
AR	Sem Rel: 2 Omissions: 17	Sem Rel: 3 Sem & Phon: 1 Omissions: 12	Prev List: 1 Sem & Phon: 1 Omissions: 30	Sem Rel: 1 Phon Rel: 1 Omissions: 24
JJ	Sem Rel: 12 Omissions: 5	Sem Rel: 5 Omissions: 9	Phon Rel: 1 Sem Prev: 1 Unknown: 1 Omissions: 35	Phon Rel: 1 Sem Prev: 1 Omissions: 36
LW	Omissions: 31	Sem Rel: 2 Omissions: 21	Prev List: 1 Omissions: 59	Prev List: 1 Omissions: 45

Table 6b (Continued)

Error types;

- Phon Rel: Error was phonologically related to item in same list
- Prev List: Error was from previous list
- Same List: Repeated an item twice in the same list
- Sem Prev List: Error was semantically related to item in previous list
- Sem Rel: Error was semantically related to item in same list
- Sem & Phon: Error was both semantically and phonologically related to item in same list
- Unknown: Error was not from previous lists and had no apparent relationship to items in the same or previous lists.
- Omissions: No word produced

Table 6c

Experiment 6: Part-list Cue (Proportion of correct items recalled)

	Blocked Cue	Blocked Free	Difference	Mixed Cue	Mix Free	Difference	Blocked v. Mixed Effect
Controls N=13	.76 (Range: .49 to .99)	.83 (Range: .61 to 1)	- .07 (Range: -.21 to .08)	.49 (Range: .29 to .98)	.57 (Range: .39 to .95)	- .08 (Range: -.15 to .04)	.01 (Range: -.25 to .21)
ML	.74	.85	- .11	.33	.60	- .27	.16
AR	.53	.60	-.07	.20	.34	-.14	.07
JJ	.58	.65	-.07	.05	.05	0	-.07
LW	.61	.73	- .12	.25	.43	- .18	.06

Table 7a

Experiment 7: Serial STM Recall: # of Errors (% errors in parentheses)

	Blocked/ Closed/ Delay	**Blocked/ Closed/ No Delay**	**Blocked/ Open/ Delay**	**Blocked/ Open/ No Delay**	**Mixed/ Closed/ Delay**	**Mixed/ Closed/ No Delay**	**Mixed/ Open/ Delay**	**Mixed/ Open/ No Delay**
Controls N = 8	81 (14%)	46 (8%)	69 (12%)	35 (6%)	92 (16%)	52 (9%)	173 (30%)	109 (19%)
Subset Controls N = 4	86 (30%)	63 (21%)	83 (29%)	72 (25%)	92 (32%)	81 (28%)	156 (54%)	130 (45%)
ML	14 (29%)	14 (29%)	10 (21%)	9 (19%)	10 (21%)	19 (40%)	19 (40%)	23 (48%)
AR	18 (38%)	22 (46%)	13 (27%)	11 (23%)	23 (48%)	13 (27%)	33 (69%)	30 (63%)
LW	12 (25%)	10 (21%)	5 (10%)	8 (17%)	10 (21%)	10 (21%)	21 (44%)	18 (38%)

Table 7b

Experiment 7: Serial STM Recall: Error types

	Blocked/ Closed/ Delay	**Blocked/ Closed/ No Delay**	**Blocked/ Open/ Delay**	**Blocked/ Open/ No Delay**	**Mixed/ Closed/ Delay**	**Mixed/ Closed/ No Delay**	**Mixed/ Open/ Delay**	**Mixed/ Open/ No Delay**
Controls N = 8	Prev list: 28 Omissions: 53	Prev list: 30 Same list: 1 Sem rel: 1 Sem/phon: 1 Omissions: 13	Prev list: 1 Sem rel: 7 Sem rel prev list: 1 Omissions: 59	Omissions: 35	Prev list: 30 Omissions: 62	Prev list: 22 Omissions: 30	Phon rel: 2 Prev list: 4 Sem rel: 1 Sem/phon: 1 Omissions: 165	Phon rel: 6 Prev list: 5 Sem rel: 3 Omissions: 95
Subset Controls N = 4	Prev list: 36 Sem rel: 2 Omissions: 48	Prev list: 42 Omissions: 21	Prev list: 6 Sem rel: 22 Omissions: 55	Prev list: 1 Sem rel: 14 Sem rel prev list: 13 Omissions: 53	Phon rel: 1 Prev list: 41 Omissions: 50	Phon rel: 1 Prev list: 34 Omissions: 46	Phon rel: 2 Prev list: 18 Sem rel: 3 Sem/phon: 1 Unknown: 2 Omissions: 130	Phon rel: 4 Prev list: 8 Sem rel: 7 Sem rel prev list: 3 Unknown: 2 Omissions: 106
ML	Prev list: 6 Omissions: 8	Prev list: 9 Omissions: 5	Sem rel: 1 Omissions: 9	Sem rel: 1 Omissions: 8	Prev list: 4 Omissions: 6	Prev list: 2 Omissions: 16	Prev list: 2 Sem rel: 1 Omissions: 16	Prev list: 2 Omissions: 21
AR	Prev list: 3 Omissions: 15	Prev list: 1 Omissions: 21	Sem rel: 3 Omissions: 10	Sem rel: 3 Omissions: 8	Prev list: 4 Omissions: 19	Prev list: 2 Omissions: 11	Prev list: 1 Sem rel: 1 Omissions: 31	Prev list: 2 Omissions: 28
LW	Prev list: 10 Sem rel: 2 Omissions: 0	Prev list: 7 Sem rel: 2 Omissions: 1	Prev list: 2 Omissions: 3	Sem rel: 1 Omissions: 7	Prev list: 8 Omissions: 2	Prev list: 7 Omissions: 3	Prev list: 3 Omissions: 18	Prev list: 4 Omissions: 14

Table 7c

Experiment 7: Serial Recall STM: Proportion of correct items without respect to order

	Blocked/ Closed/ Delay	**Blocked/ Closed/ No Delay**	**Blocked/ Open/ Delay**	**Blocked/ Open/ No Delay**	**Mixed/ Closed/ Delay**	**Mixed/ Closed/ No Delay**	**Mixed/ Open/ Delay**	**Mixed/ Open/ No Delay**
Controls N = 8	.86 Range: (.76 to .96)	.92 Range: (.81 to .96)	.88 Range: (.76 to .99)	.94 Range: (.88 to 1.00)	.84 Range: (.76 to .90)	.91 Range: (.85 to .97)	.70 Range: (.51 to .90)	.81 Range: (.68 to .97)
Subset Controls N = 4	.70 Range: (.53 to .83)	.78 Range: (.71 to .85)	.71 Range: (.58 to .78)	.75 Range: (.61 to .85)	.68 Range: (.49 to .83)	.72 Range: (.63 to .78)	.46 Range: (.39 to .53)	.55 Range: (.50 to .60)
ML	.71	.71	.79	.81	.79	.60	.60	.52
AR	.63	.54	.73	.77	.52	.73	.31	.38
LW	.75	.79	.90	.83	.79	.79	.63	.71

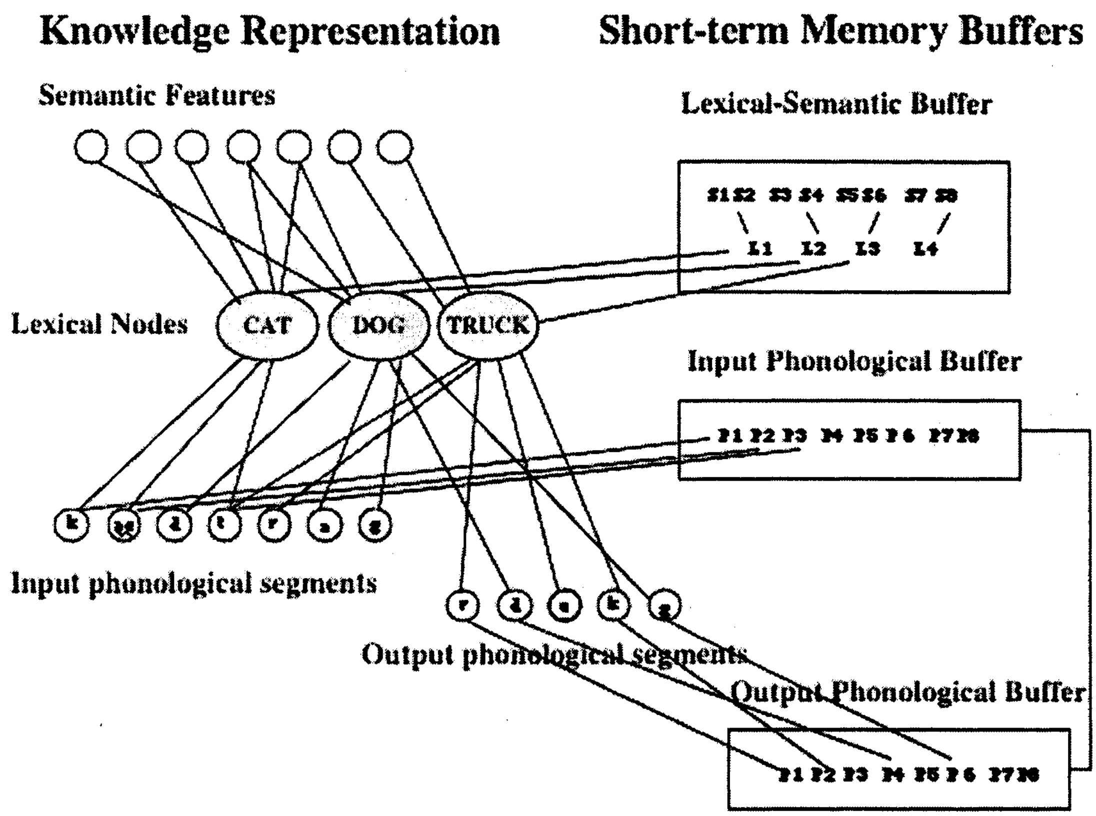
Table 7d

Experiment 7: Serial STM Recall: Proportion of correct items with respect to order

	Blocked/ Closed/ Delay	**Blocked/ Closed/ No Delay**	**Blocked/ Open/ Delay**	**Blocked/ Open/ No Delay**	**Mixed/ Closed/ Delay**	**Mixed/ Closed/ No Delay**	**Mixed/ Open/ Delay**	**Mixed/ Open/ No Delay**
Controls N = 8	.48 Range: (.09* to .93)	.59 Range: (.03 to .81)	.50 Range: (.21 to .85)	.67 Range: (.11 to .1)	.41 Range: (.07 to .86)	.60 Range: (.10 to .90)	.39 Range: (.15 to .97)	.50 Range: (.06 to .88)
Subset Controls N = 4	.13 Range: (.10 to .18)	.21 Range: (.01 to .42)	.13 Range: (0 to .36)	.23 Range: (.03 to .39)	.10 Range: (0 to .19)	.15 Range: (.03 to .19)	.08 Range: (.03 to .14)	.13 Range: (0 to .24)
ML	.17	.33	.33	.56	.17	.31	.14	.28
AR	.19	.03	.22	.44	.03	.25	.11	.06
LW	.42	.58	.42	.47	.33	.58	.42	.42

*All proportions at the low end of the range are from one subject.

Figure 1


Knowledge Representation
Short-term Memory Buffers
Semantic Features
Lexical-Semantic Buffer
Lexical Nodes
CAT
DOG
TRUCK
Input Phonological Buffer
Input phonological segments
Output phonological segments
Output Phonological Buffer