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Inhibition versus Over-Activation in Word Selection: Evidence from Aphasia

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ABSTRACT

Inhibition versus Over-Activation in Word Selection: Evidence from Aphasia

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Two nonfluent aphasic patients, ML and AR, and two fluent aphasic patients, LC and LW, along with older controls were tested on tasks involving semantic blocking and lexical selection. In Experiment 1, a repeated picture-naming task manipulating semantic blocking and presentation rate, both nonfluent patients showed growing semantic interference across trials, while the other subjects did not. In Experiment 2, a corresponding comprehension task, ML showed increasing semantic interference while AR showed a lack of repetition priming. Experiment 3 was a category fluency task in which AR performed very poorly and ML performed similarly to the fluent patients. Experiment 4 was a sentence completion task, and no evidence was found that the number or relatedness of lexical competitors caused any difficulty for the nonfluent patients. It was concluded that ML suffers from deficient semantic inhibitory mechanism while AR suffers from an under-activation of lexical representations.
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1. Introduction

For normal subjects, it has been shown that items in semantically blocked sets, in which all items are drawn from the same semantic category, are named more slowly than items in semantically mixed sets, in which items are drawn from several different semantic categories (Damian, Vigliocco, & Levelt, 2001; Kroll & Stewart, 1994) and this effect has been found to be graded by the level of semantic relatedness between items (Vigliocco, Vinson, Damian, & Levelt, 2002). This effect has also been found to spread to semantically related items that are not initially named (Belke, Meyer, & Damian, 2005). These effects have been attributed to over-activation of related representations that causes difficulty in selection or, conversely, to inhibition of non-selected items during selection which persists across trials (see Belke et al. for discussion). Some nonfluent aphasic patients with frontal damage and preserved single word production have been found to have difficulty producing a response for items presented in semantically related blocks and at fast rates of presentation (McCarth & Kartsounis, 2000; Schwartz & Hodgson, 2002; Wilshire & McCarthy, 2002). Some global aphasics, who show severe production and comprehension difficulties, have also shown similar effects for word-picture matching tasks, which test the comprehension of written or spoken words (Crutch & Warrington, 2005a,b; Forde & Humphreys, 1995; Warrington & McCarthy, 1983, 1987). As in production, it has been found for such patients that the difficulty in comprehending items that are semantically blocked spreads to other semantically related items not initially named, and this effect can also spread across modalities (e.g., Forde & Humphreys, 1995, 1997), and even languages (Ferrand & Humphreys, 1996). Similar to the accounts given for normal subjects, accounts of these access deficits for patients fall
into two broad categories: those proposing a prolonged or deepened inhibition of lexical items following their activation and those proposing over-activation of lexical items with repeated retrievals.

Warrington and colleagues have been the most thorough in documenting cases of what they term semantic access patients. Access patients are those who have no loss of semantic knowledge for individual items, but may, because of the context in which an item is presented, be temporarily unable to access relevant information about an item (Warrington & McCarthy, 1983). Access patients are contrasted with storage patients, who are thought to have a permanent loss of semantic knowledge, and they are consistent in their performance on individual items across contextual manipulations (Warrington & Cipolotti, 1996). Refractory access patients are a specific subtype of access patients who show declining or inconsistent performance on individual items with various contextual manipulations (Crutch & Warrington, 2005b). Warrington and colleagues have identified four major variables that differentiate refractory access patients from normal subjects or storage patients: semantic blocking, consistency, presentation rate, and word frequency. Refractory access patients show great difficulty with semantically blocked items, show declining or inconsistent performance across trials, perform much worse at faster rates of presentation, and are seemingly unaffected by word frequency of items (Warrington & McCarthy, 1983, 1987), or may even show inverse frequency effects in the case of one patient reported (Crutch & Warrington, 2005a).

Warrington and colleagues favor an over-inhibition account, in which such refractory access patients show refractory effects due to a deepened or prolonged inhibition of semantic representations, in which “after stimulation, the semantic system
may become temporarily less able to respond to subsequent stimuli" (McCarthy & Warrington, 1994, p. 95). Other researchers have favored over-activation accounts, in which such patients show refractory effects due to difficulty in controlling the level of activation of lexical items, and with some proposing an executive control mechanism which is damaged in the case of such patients, resulting in an inability to resolve competition between lexical competitors (R. C. Martin & Biegler, in press; Schnur, Schwartz, Brecher, & Hodgson, 2006). The patients studied by the two groups of researchers have often differed in terms of both nature and degree of deficit as well as testing modality. Researchers supporting the over-inhibition account have typically reported very impaired patients, often with very little spoken output, and their single-word comprehension abilities have often been tested. Researchers supporting the over-activation account have typically reported less-impaired patients, typically with relatively well-preserved single word production and comprehension but with nonfluent speech, and they have typically been tested on their single-word production.

Due to criticism of the concept of a unifying deficit giving rise to effects of semantic blocking, consistency, rate of presentation, and word frequency (Rapp & Caramazza, 1993), since no refractory access patient up to that point had been documented manipulating all these contextual variables, Warrington and Cipolotti (1996) performed a study comparing a group of access patients with a group of storage patients. Their study did find that their refractory access patients differed from the storage patients in terms of these four variables. Other cases have been reported of patients who show mixed performance on these measures (Hillis, Rapp, Romani, & Caramazza, 1990; Howard, 1985; Howard & Orchard-Lisle, 1984; Warrington, 1981; Warrington &
McCarthy, 1983). There is then the question of whether refractory access deficits are actually due to a single underlying deficit which gives rise to several specific effects, or whether it is a set of deficits which may only have a tendency to occur together.

The following section will discuss the results in the literature related to semantic blocking, consistency of performance, rate of presentation, and word frequency, comparing both the effects on normal subjects and the reported effects refractory access patients on each of these. The over-inhibition and over-activation accounts will be compared at the end as to how each of these accounts for the pattern of deficits reported in patients.

Factors Giving Rise to Refractory Effects

Semantic Blocking

Semantic interference effects have been found for normal subjects under a number of conditions. However, it appears that there may be at least two separable instances in which semantic relatedness interferes with the production of an item: one being an immediate interference effect found at short stimulus-onset asynchronies (SOA) and one occurring over a much longer period which requires an amount of time to build up (Damian & Als, 2006). Dealing first with the short effect, it has been found that the presentation of two semantically related items within short time periods of one another causes interference when making a response to one of the items. Picture naming studies in which auditory or visual distractors are presented within a short time window around when the picture was presented result in interference from semantically related distractors (Damian & R. C. Martin, 1999; Glaser & Düngelhoff, 1984; Starreveld & La Heij, 1996; Schriefers, Meyer, & Levelt, 1990). These findings have been taken as evidence that
concurrently activated lexical representations that are semantically related compete or interfere with one another during production. The semantic interference effect in visual and auditory word distractor tasks occur only within a short time window of the picture presentation, usually on the order of −150 to 0 msec SOA.

Turning to the longer-lasting effect, Kroll and Stewart (1994) reported a semantic blocking effect when subjects named pictures in semantically blocked or mixed lists. It was found that there was a slight advantage in naming times for picture presented in the mixed list over those in the semantically blocked list. No semantic blocking effect was found when words were used instead of pictures, implying that the effect arises from the processes involved in the selection of a lexical item. Further studies found that this effect could not be due solely to visual similarity of items (Damian, Vigliocco, & Levelt, 2001), that the effect was increased as the items were more semantically related (Vigliocco, Vinson, Damian, & Levelt, 2002), and that this effect spread to other items in the category not initially named (Belke, Meyer, & Damian, 2005).

Semantic interference is found at both very short intervals and long intervals persisting over several minutes and many trials. As Damian and Als (2005) pointed out, this is somewhat problematic, as models of semantic priming would predict that semantic priming would only persist of a few hundred milliseconds and then dissipate. It is thus hard to accommodate a short process on the order of a few hundred milliseconds with one that can persist over minutes. Damian and Als’s (2005) proposal was that short-term interference results from differences in temporary levels of activation among lexical competitors, whereas long-term interference results from temporary changes in connection weights between the conceptual representation and name, which eventually
return to baseline weight levels after a period of time has passed. Nevertheless, both the short-term and long-term semantic interference effects appear to result from competition of lexical items.

Similar semantic interference effects have been reported in the case of aphasic patients. Warrington and McCarthy (1983, 1987), Forde and Humphreys (1997), McCarthy and Kartsounis (2000), and Wilshire and McCarthy (2002) have all reported patients who have higher error rates on production or comprehension tasks when items are presented in the context of other related items. This effect has been found to vary with the amount of semantic relatedness between items (Warrington & McCarthy, 1987; Crutch & Warrington, 2003, 2005b) and, as mentioned earlier, to spread across modalities (Forde & Humphreys, 1995, 1997), and even languages (Ferrand & Humphreys, 1996). Warrington and colleagues often report global aphasic patients with very limited verbal production who must be tested in terms of their auditory word-picture or written word-picture matching ability, but other patients with more preserved spoken abilities with semantic blocking effects in production have been reported (McCarthy & Kartsounis, 2000; Wilshire & McCarthy, 2002). The patient FAS, reported by McCarthy and Kartsounis, showed a semantic blocking effect, but only in production. His performance was very poor when items were semantically blocked during a production task, but he was essentially at ceiling with an auditory word-picture matching task. Although FAS may present a case of an access disorder that is different from those reported with comprehension difficulties, it should be noted that his response times were not recorded in the comprehension task, so it is not clear whether he actually might have shown some difference in terms of response times instead of error rates.
Consistency

Warrington and colleagues have documented many cases of refractory access patients who show inconsistency in which items they are able to retrieve across repeated presentations. Warrington and McCarthy (1983) reported a patient VER who showed inconsistency in an auditory word-picture matching task. She showed an inconsistent pattern of performance for individual items, but importantly her inconsistency was not random. Warrington and McCarthy found that she was more likely to make a correct response on the first presentation and an incorrect response on the second presentation than to make an incorrect response on the first presentation and a correct response on the second trial. They took this as evidence that a correct response on one trial was likely to cause difficulty in responding to the same item again in a later trial. Other studies of refractory access patients documenting their performance across several presentations have found that their performance also decreases with repeated presentations (Crutch & Warrington, 2005a), and that this effect is exaggerated by semantically blocking the items (Crutch & Warrington, 2005b), in contrast to normal subjects, who show priming for both the related and unrelated conditions, only being slower to respond in related condition (e.g., Belke, Meyer, & Damian, 2005).

In cyclic naming studies, it is found that response times decrease overall for repeated items, but that items in semantically mixed sets are easier to produce than those presented in blocks of semantically blocked sets (e.g., Belke, Meyer, & Damian, 2005). Thus, there are at least two effects: one involving the priming of an individual item which aids in its later production and another which involves the interference associated with presenting items that are semantically related. This semantic interference effect has been
attributed to greater competition between related items due to their overlapping semantic representations causing a set of lexical representations to become highly active, as was discussed earlier.

Rate of Presentation

In picture naming tasks, it has been found that subjects are more likely to have intrusions from previous items when naming pictures at faster rates of presentation with a naming deadline (Vitkovitch, 1996; Vitkovitch & Rutter, 2000). It would be simple to conclude that perseverative errors in picture naming would support an over-activation account of consistency or semantic blocking effects, but as Vitkovitch (1996) pointed out, the pattern of errors reveals a more complicated story. Vitkovitch (1996) found that subjects produced names of previously presented items, but the errors were never names of items that were produced on the immediately preceding trial. Vitkovitch and Rutter (2000) had subjects perform a picture-naming task in which items all from the category of animals had intervening unrelated pictures. They found that subjects did intrude immediately-preceding animal pictures (with one unrelated picture intervening), and that this effect was exaggerated with a longer response-stimulus interval (RSI). They concluded that items were immediately inhibited following their production, but that this inhibition decayed over time.

Warrington and colleagues have reported on several patients showing effects of presentation rate when responding to items, finding it easier to respond when items are presented at a slower rate of presentation (Warrington & Cipolotti, 1996; Warrington & McCarthy, 1983, 1987; Wilshire & McCarthy, 2002). They have also argued that it is not the rate of presentation itself that is important, but the response-stimulus interval
(Warrington & Crutch, 2005). It has also been found that the effect of rate of presentation does not affect all patients showing an access disorder, but only those who also show refractory effects as well (Warrington & Leff, 2000; Warrington & Shallice, 1979).

**Word Frequency**

Effects of word frequency in normal subjects are found in a wide range of tasks. High-frequency words are responded to faster in visual and auditory lexical decision tasks (e.g., Forster & Chambers, 1973; Taft & Hambly, 1986), are produced faster in picture naming tasks (Bartram, 1974; Humphreys, Riddoch, & Quinlan, 1988; Huttenlocher & Kubicek, 1983; Jescheniak & Levelt, 1994; Lachman, 1973; Lachman, Shaffer, & Hennrikus, 1974; Oldfield & Wingfield, 1965), and are accessed more quickly in reading (e.g., Rayner, 1977). Not surprisingly, similar results are found with many aphasic patients. They are more accurate on high-frequency words (e.g., Butterworth, Howard, & McLoughlin, 1984; Howard, Patterson, Franklin, Orchard-Lisle, & Morton, 1985; Kay & Ellis, 1987) and are faster to respond to high-frequency words as well (Newcombe, Oldfield, and Wingfield, 1965).

Given that both normal subjects and aphasic patients find high-frequency words easier to process, it is surprising that there have been cases reported of patients who show no word frequency effect (Hillis, Rapp, Romani, & Caramazza, 1990; Howard, 1985; Warrington & McCarthy, 1983, 1987), or may even show an inverse frequency effect in some cases (Crutch & Warrington, 2005a; Humphreys & Forde, 2005; Marshall, Chiat, Robson, & Pring, 1996; Marshall, Pring, Chiat, & Robson, 1996, 2001). With inverse frequency effects, it appears that in some patients suffering from a permanent loss of
knowledge, this is due to loss of knowledge for more general superordinate semantic
knowledge, while specific subordinate concepts are retained (Forde & Humphreys, 2005;
Green, 1981). For instance, one patient CA reported by Green (1981) showed incredibly
detailed knowledge of individual animals in a semantic categorization task, but was
unable to categorize them in superordinate groups such as fish, mammals, and birds.
Since words such as “fish” or “animal” are more generic terms used more frequently,
such patients with a permanent loss of superordinate knowledge would show an inverse
frequency effect because they only retained knowledge of the less frequent, more specific
words. Other patients appear to show a lack of frequency effects or inverse frequency
effects due to the temporary unavailability of higher-frequency words. Crutch and
Warrington (2005a) argued that the lack of frequency effects or, in extreme cases, inverse
frequency effects, is due to the larger amount of overall inhibition caused after the
selection of higher-frequency words. They claim that, since high-frequency words
probably have a richer neurological representation, which is connected to many other
concepts, the subsequent inhibition of these items will result in more extensive inhibition
and be more likely to inhibit other items as well. Low-frequency words, on the other
hand, tend to be more semantically isolated, and will not tend to affect or be affected by
other items when they are inhibited after selection.

Although there may be some correlation between word frequency and the richness
of a word’s semantic representation, since high-frequency words are concepts that people
tend to have more exposure to, it has been argued that word frequency itself is actually a
measure of the strength of a phonological representation of a word (Griffin & Bock,
1998). One piece of evidence comes from studies using homophones—words with two
or more unrelated meanings that have the same phonological form. For instance, when 
producing the name of a subordinate meaning of a homophone (e.g., bank, but meaning 
riverbank), onset latencies correlated with the frequency of use for that phonological 
form (i.e., /bæNk/, whether talking about a financial institution, a riverbank, a bank shot, 
etc.) rather than the frequency of use for that particular meaning of that word (Jescheniak 
& Levelt, 1994). Also, in studies of speech errors, it has been found that phonological 
errors, in which a word is produced that is phonologically similar to the intended word 
(e.g., saying “mat” when meaning “cat”), tend to result in substituting the intended word 
with a higher-frequency one, whereas semantic errors, in which a word is produced that is 
semantically similar to the intended word (e.g., saying “dog” when meaning “cat”), do 
not tend to result in producing a higher-frequency substitution (del Viso, Igoa, & Garcia-

Even though there is evidence that word frequency reflects the strength of a 
word’s phonological representation, there is probably also a correlation between word 
frequency and the richness of a semantic representation of a word. There is little doubt 
that people have richer representations for higher-frequency items such as “cat” and 
“dog” as compared to very low-frequency items such as “aardvark” and “oryx.” On the 
other hand, the highest frequency words—function words such as ‘a/n,’ ‘the,’ ‘of,’ etc.— 
are basically semantically empty words, having little that could be thought of in the way 
of individual semantic features or a relationship to a certain semantic category. The 
argument that Warrington and colleagues make, that access patients have a lack of 
frequency effects due to difficulty in accessing semantic information, should not 
necessarily be rejected because word frequency seems to correlate most strongly with the
strength of a phonological representation of a word, but it may be the case that this effect would only apply to certain subsets of words which have a more robust semantic representation.

**Over-Inhibition Account of Refractory Effects**

As mentioned earlier, Warrington and colleagues have been the main proponents of an over-inhibition account in explaining refractory access deficits. Their claim is that refractory access patients are suffering from a deficit in which representations of lexical items undergo a period of deep or prolonged period of deactivation, in which the activity level of the representations is reduced below their baseline level. This is conceptualized as being similar to the process that individual neurons undergo, in which a period of high activity is followed by a period of inhibition, where the level of activity is depressed below the baseline activity level, making it more difficult to reactivate the neuron during this period. Semantic blocking effects would be caused by related semantic representations activating one another, resulting in several related items being inhibited below baseline when their level of activity falls. It is claimed that a period of time is required for the activity of the representations to again return to baseline, which gives rise to the rate effects found with different presentation rates. Finally, word frequency has little effect because the richer neurological representation of high-frequency words leads to little benefit, since the whole representation is inhibited below baseline.

**Over-Activation Account of Refractory Effects**

Researchers studying normal subjects, and some studying refractory effects in less impaired patients, favor an over-activation account. In such accounts, several lexical representations would be activated at once, making it difficult to choose among them.
One over-activation account has been put forth by Belke, Meyer, and Damian (2005). They base their specific account on the WEAVER++ model as developed by Roelofs, Levelt, and colleagues (Levelt, Roelofs, & Meyer, 1999; Roelofs, 1992, 1997). In this model, there is a division between a conceptual space representing lexical items as composed of features ("has a") and belonging to different semantic categories ("is a"). There are bidirectional connections between lexical items and both features and categories. Lexical items also have bidirectional connections to a lemma level, which specifies the syntactic properties of the lexical item. It should also be noted that this is a purely activation-driven model; there is no lateral inhibition between items nor any outside inhibition involved in the selection process. Belke, Meyer, and Damian propose that repeatedly producing items causes the lexical nodes representing the concept to become highly activated, which in turn causes the feature nodes and category nodes to become highly activated as well. The category and feature nodes subsequently spread activation to items in the same category and those sharing the same features. The high level of activation from several related nodes makes it difficult to select the correct response from among related competitors. The spread of activation from the common category node and feature nodes explains why semantically related items not initially named will also show a disadvantage as compared to unrelated items. For aphasic patients who show exaggerated difficulty producing items with manipulations of relatedness, damage to the neural system that normally resolves competition could be postulated. The lesser difficulty at slower rates of presentation may be explained by decay of activation over time.
Some researchers dealing with patients who show difficulty in producing items in semantically blocked contexts have proposed similar accounts but with an extra component. R. C. Martin and Biegler (in press) and Schnur et al. (2006) have proposed slightly different mechanisms that participate in selection. R. C. Martin and Biegler proposed a post-selection inhibitory mechanism, which inhibits lexical items after their selection for production. Patients with a malfunction of this mechanism would have difficulty in selecting any lexical item, because several would become over-activated. This effect would be worsened for semantically related items, as they would mutually activate one another and all be at a high level of activation, making selection of any one of them difficult.

Schnur et al. (2005) made a proposal for a language-specific executive selection mechanism, based on the computational model of Gordon and Dell (2003), in which insertion rules for lexical items have the ability to check to see if multiple lexical items are highly activated, and puts insertion on hold until an item reaches a certain threshold. In their study, Schnur et al. had compared the performance of Broca’s aphasics with anterior lesions to aphasics not of the Broca type without anterior lesions, matching both groups in terms of single word processing ability and demographic variables. They found that patients with anterior damage showed significantly greater blocking effects than those without anterior damage, and preliminary comparisons of lesion localizations and the semantic blocking effect indicated that the overall size of the semantic blocking effect was correlated with amount of temporal lobe damage, while the amount of increase in the semantic blocking effect across cycles was correlated with the amount of damage to the left inferior prefrontal cortex. They thus claimed that the findings were consistent with
their proposed executive selection mechanism being located in the left inferior prefrontal cortex, but noted that this claim was still uncertain, as their Broca's patients did also have superior and middle temporal damage in addition to damage in the frontal cortex.

A Model of Single Word Processing

A final note will be made on models of single-word processing. The model of short-term memory developed by Randi Martin and colleagues (R. C. Martin, Lesch, & Bartha, 1999; R. C. Martin, Shelton, & Yaffee, 1994), and based on a model developed by Nadine Martin and colleagues (N. Martin, Dell, Saffran, & Schwartz, 1996; N. Martin & Saffran, 1990, 1992, 1997; N. Martin, Saffran, & Dell, 1996; Saffran & N. Martin, 1990), is a model that has been used for describing dissociations among aphasic patients involving their short-term memory abilities (see Figure 1). Although the work on the relationship between short-term memory and language has been the main focus of the work, it is also a model of single word production and comprehension because of the linguistic knowledge structures in the model. For the patients described as having certain short-term memory disorders, it is also possible that there is some damage to their knowledge structures that may make them differentiable in terms of more than the severity of their short-term memory deficits. Since most of the tasks in the current set of experiments do no require short-term memory retention, the experiments will be testing the ability of patients to access specific lexical items, thus involving the processes which would presumably only involve the knowledge structures.

In making predictions about patients based on the model of single word processing, it is necessary to point out certain aspects. There are several structures that are thought to be shared by both comprehension and production and some that are
separable. The structures that are separable are the phonological structures, in which there is one composing the knowledge of spoken phonology and a separate one composing the knowledge of heard phonology. The structures shared by both production and comprehension are the semantic features of items and their lexical (i.e., lemma) representations. Although there are bidirectional connections between the lexical level and the semantic level, the processes involved in activating different representations are not symmetric. In production, there is a competitive process between lexical items for selection based on a pattern of semantic activation. In comprehension, in contrast, no competition would exist at the level of lexical representations based on semantics, because the lexical representation would be selected based on auditory phonology. Thus,
there should be no effect of semantic relatedness of items at the lexical level, and any semantic blocking effects found in comprehension should be due to some disorder at the semantic level itself.

**Relations to Findings with Patient ML**

A nonfluent aphasic patient ML, with fronto-parietal damage tested in our laboratory, has also been shown to have an exaggerated relatedness effect in repeated naming in a cyclic naming task (Biegler & R. C. Martin, 2006; Freedman, R. C. Martin, & Biegler, 2004), though he only shows such an effect in his response times, and not in his error rates as with the other patients reported. ML has also been shown to have a cognitive inhibition deficit, as shown by his performance on the Stroop and Recent Negative tasks, and this inhibition deficit appears to be limited to the verbal domain (Hamilton & R. C. Martin, 2005). ML has previously described as having a semantic short-term (STM) memory deficit (R. C. Martin & Freedman, 2001; R. C. Martin & He, 2004; R. C. Martin & Lesch, 1996), but the possibility is being explored that ML’s inhibition deficit is actually the source of his semantic STM deficit (Hamilton & R. C. Martin, 2005).

Given ML’s inhibition deficit in the verbal domain, the over-inhibition account, which postulates over-inhibition as the source of exaggerated semantic relatedness effects, seems unlikely as an account for ML’s pattern of performance. ML has previously shown to have intrusions from pervious list items during free recall tasks, which was similar to another semantic STM deficit patient, AB, but unlike a phonological STM deficit patient EA, who showed only one such intrusion (R. C. Martin & Lesch, 1996). In addition, in the Recent Negatives task, which is thought to measure
the amount of interference from previously presented items, ML showed much greater interference as compared to controls (Hamilton & R. C. Martin, 2005). The intrusions of previous list items and interference from previously presented items indicates that ML has some difficulty in prolonged activation of items, presumably due to difficulty in suppressing the activation of items.

As discussed earlier, the specific proposal for what may cause the over-activation of lexical items in the case of ML is a deficient post-selection inhibition mechanism (R. C. Martin & Biegler, in press). Martin and Biegler proposed that an over-activation account, such as the account proposed by Belke, Meyer, and Damian (2005), could account for the findings with ML if a post-selection mechanism was added. In lexical selection, once an item is selected from competitors for production, the post-selection mechanism inhibits the lexical item, though not to baseline, to prevent its reselection (Dell, 1986; MacKay, 1985). This proposed post-selection inhibition mechanism is similar to that hypothesized by Gernsbacher and colleagues (Gernsbacher, 1990; Gernsbacher & Faust, 1991), and they argue that the left hemisphere appeared is heavily involved in this inhibitory mechanism (Faust & Gernsbacher, 1996). If we assume that this post-selection inhibition is less potent for ML that for normal subjects, this would give rise to greater competition with repeated sampling from the same category, and greater difficulty with selection. It should be noted that this post-selection inhibition has been postulated specifically in language production, rather than a general selection mechanism that operates across a number of domains (e.g., Thompson-Schill, 2003).
Purpose of Current Study

The purpose of the current study is to assess the performance of aphasic patients who have earlier shown evidence for semantic blocking effects in cyclic naming to see if they have a pattern of performance similar to those patients described by Warrington and colleagues. One aim is to determine for each patient the level or levels of representation at which there is a deficit that causes their pattern of performance. A second aim is to determine whether the overall pattern for each patient arises from the over-inhibition or over-activation of lexical or semantic representations. Experiment 1 is a single-word production task with pictures presented simultaneously in arrays. This task is mainly meant to replicate previous findings with single-picture presentations in order to compare directly with Experiment 2, a single-word comprehension task. Experiment 2 will address whether the semantic blocking effect found in the patients extends to comprehension as well, which would indicate that their deficit is caused by some disruption in the semantic system itself. Experiment 3 is a task in which subjects generate as many items as they can from a semantic category within one minute. This experiment is meant to see whether there is evidence of semantic interference in this task for those patients who showed exaggerated semantic blocking effects in either of the first two experiments. If they do show a semantic interference effect in this task, they would produce fewer responses, responses of increasing semantic distance from each other and the category, and possibly responses of lower word frequency. Experiment 4 is a sentence completion task in which subjects must provide the last word for an auditorily presented sentence that has the last word missing. In this case it will be seen whether the patients showing semantic blocking effects also have difficulty in selecting a word from a
specific semantic category and are affected by the number or type of competitors for a given response.

**Table 1. Background Information on Patients**

<table>
<thead>
<tr>
<th></th>
<th>ML</th>
<th>AR</th>
<th>LC</th>
<th>LW</th>
<th>Controls (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single Word Production</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Philadelphia Naming Test (accuracy)</td>
<td>98%</td>
<td>93%</td>
<td>99%</td>
<td>96%</td>
<td>96% SD = 7.0%</td>
</tr>
<tr>
<td><strong>Single Word Comprehension</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peabody Picture Vocabulary Test (standardized score)</td>
<td>117</td>
<td>99</td>
<td>120</td>
<td>83</td>
<td>100 SD = 15</td>
</tr>
<tr>
<td>**Stroop (RT in msec)**¹</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Neutral 2470</td>
<td>NA</td>
<td>1362</td>
<td>1014</td>
<td></td>
<td>777</td>
</tr>
<tr>
<td>Congruent 1889</td>
<td>NA</td>
<td>1359</td>
<td>990</td>
<td></td>
<td>828</td>
</tr>
<tr>
<td>Incongruent 3449</td>
<td>NA</td>
<td>2130</td>
<td>1549</td>
<td></td>
<td>974</td>
</tr>
<tr>
<td>Interference (Incon - Neut)</td>
<td>979</td>
<td>NA</td>
<td>768</td>
<td>535</td>
<td>197(101–279)</td>
</tr>
<tr>
<td>**Antisaccade (accuracy)**¹</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prosaccade 93%</td>
<td>NA</td>
<td>95%</td>
<td>93%</td>
<td></td>
<td>97%(93%–100%)</td>
</tr>
<tr>
<td>Antisaccade 80%</td>
<td>NA</td>
<td>73%</td>
<td>58%</td>
<td></td>
<td>72%(59%–94%)</td>
</tr>
<tr>
<td>**Recent Negatives (RT in msec)**¹</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recent Negative 2905</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td></td>
<td>1006</td>
</tr>
<tr>
<td>Nonrecent Negative 2174</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td></td>
<td>915</td>
</tr>
<tr>
<td>Recent Positive 1474</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td></td>
<td>873</td>
</tr>
<tr>
<td>Nonrecent Positive 1416</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td></td>
<td>872</td>
</tr>
<tr>
<td>Interference (RN-NRN)</td>
<td>731</td>
<td>NA</td>
<td>NA</td>
<td></td>
<td>91 (-74–337)</td>
</tr>
<tr>
<td>**Picture-Word Interference (RT in msec)**²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 msec SOA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Related 1453</td>
<td>NA</td>
<td>NA</td>
<td>1049</td>
<td></td>
<td>876</td>
</tr>
<tr>
<td>Unrelated 1224</td>
<td>NA</td>
<td>NA</td>
<td>1049</td>
<td></td>
<td>835</td>
</tr>
<tr>
<td>Difference (Rel-Unrel)</td>
<td>229</td>
<td>NA</td>
<td>NA</td>
<td>0</td>
<td>41 (-40–87)</td>
</tr>
<tr>
<td>300 msec SOA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Related 1814</td>
<td>NA</td>
<td>NA</td>
<td>1074</td>
<td></td>
<td>830</td>
</tr>
<tr>
<td>Unrelated 1074</td>
<td>NA</td>
<td>NA</td>
<td>950</td>
<td></td>
<td>801</td>
</tr>
<tr>
<td>Difference (Rel-Unrel)</td>
<td>740</td>
<td>NA</td>
<td>NA</td>
<td>124</td>
<td>29 (-70–124)</td>
</tr>
</tbody>
</table>

¹ Results from ML and controls reported in Hamilton & R. C. Martin (2005)
² Results from Biegler (in progress)
Patient Descriptions

Performance of the patients on previous studies is presented in Table 1.

ML

ML is a 65 year old right-handed male. He suffered a left-hemisphere cerebrovascular accident (CVA) in 1990. Previous descriptions of the extent of his lesion (e.g., R. C. Martin & He, 2004) were based on a CT scan indicating an infarction involving the left frontal and parietal operculum, with atrophy in the left temporal operculum and mild diffuse atrophy. However, a more recent structural MRI, reported in R. C. Martin and Biegler (in press), has revealed more extensive damage, including the left interior and middle frontal gyri and substantial areas of the left parietal lobe, but sparing the left temporal lobe. He had completed two years of college and had previously been employed as a draftsman. His speech is halting and characterized by reduced phrase length. As mentioned above, he has good single word production and comprehension, for instance scoring 98% correct on the Philadelphia Naming Test (PNT), which is above the control mean of 96% correct (Saffran, Schwartz, Linebarger, & Bochetto, 1989). His single word comprehension is also good, having a standardized score of 117 on the Peabody Picture Vocabulary Test (PPVT; Dunn & Dunn, 1981).

AR

AR is a 64 year old right-handed male. He suffered a CVA in 1999. He is a college graduate and was an owner of an engineering business. His speech is halting with reduced phrase length. He has good single word production, scoring 93% correct on the PNT. His standardized score on the PPVT was 99.
LC

LC is a 58 year old right-handed male. He suffered a CVA in 2002. No information is yet available on the localization of his lesion. He had completed one year of college and was the owner of a consulting company. His speech is fluent but somewhat jargonistic, in that it is grammatically correct but he produces occasional neologisms. He shows occasional word-finding difficulties. Other than occasional pronunciation difficulties he has good single word production, scoring 99% correct on the PNT. His standardized score on the PPVT was 120.

LW

LW is a 72 year old right-handed male. He suffered a CVA in 2003. He is a high school graduate and had worked as a car salesman. His speech is fluent with little evidence of a deficit. He performs at a high level on single picture naming tasks, scoring a 96% correct on the PNT. His standardized score on the PPVT was 83.

2. Experiment 1: Picture Array Production

It has been found that refractory effects can arise when patients repeatedly name objects presented in an array of items (McCarthy & Kartsounis, 2000). Since ML has been shown to be affected by relatedness in repeated naming of single pictures, it is expected that he will also show problems in this task as well (Biegler & R. C. Martin, 2006). AR has also shown a very large relatedness effect, and this effect has been found to be much larger for him (Biegler, unpublished). LW is not expected to have effects that different from older controls, because he has not shown much difference from the older controls in the studies that have been conducted on him. LC has not been tested on anything
involving semantic blocking effects, so it was unclear how he would perform. This experiment is also used as a comparison with a similar comprehension experiment in order to better understand at what level a relatedness interference effect is arising in for patients in whom it is found. Also, other studies with patients with refractoriness for related items have also shown a deficit for naming at faster rates of presentation, and it is claimed that the important manipulation is the time between production of one item and presentation of the next, or response-stimulus interval (RSI), rather than the rate of presentation per se (Warington & McCarthy, 1983, 1987). Thus, the time from beginning of response and presentation of the next stimulus will be manipulated. It has been shown that ML shows a refractory effect for blocks of related items in production (Crowther, Biegler, & R. C. Martin, 2005), but the rate of presentation has not yet been manipulated in a repeated naming task to see if he has even more difficulty with faster rates of presentation.

**Methods**

**Participants**

The participants were ML, AR, LC, and LW as well as 9 older controls (8 females, 1 male; age: $M = 68.6$, range: 58 – 79). For all experiments, patients given $12/hour in compensation and older controls were given $10/hour.

**Materials and Procedure**

The pictures were 72 pictures from, 6 each from 12 semantic categories (see Appendix A). The pictures were taken from the International Picture-Naming Project pictures set (Szekely et al., 2004), which includes materials drawn from several different sources.
Subjects were presented with an array of six pictures, either drawn from the same semantic category or each from different semantic categories. Items were probed at either a short (1 second) or long (4 second) RSI. Subjects completed the experiment in two sessions, with one experiment in a session being at the short and the other at the long RSI. Subjects were presented with blocks of related and unrelated arrays in an ABBAABBAABBA design. All subjects performed each experiment in the same order.

In a single trial, subjects would be presented with an array of six pictures, then one would be visually highlighted, and the subject was to name the highlighted object. Once the subject had produced the name, the experimenter would press a key to indicate a naming error, voice-key error, or correct trial. Voice-key errors were monitored by the experiment by means of a small cross that would appear in the top left-hand corner of the screen indicating when the voice-key had been activated. Within a block, each picture was probed 4 times for a total of 24 trials. In a pilot study, it was found that if items were presented in cycles in which all six pictures were probed before repeating any picture, subjects would predict the last item in each cycle. Thus, items were not presented in cycles but instead in a different semi-random order for each block with the constraint that no item could be repeated twice in a row. Each subject received the same random order for every item in a block.

Results

Naming or voice-key errors were removed from the analysis. Response errors constituted 2.00% of responses for ML, 4.86% for AR, 1.65% for LC, 0.26% for LW, and 0.76% for the older controls. The data removed due to voice-key errors constituted 3.30% of the data for ML, 2.95% for LC, 0.35% for LW, and 1.33% for the controls.
Table 2. Experiment 1: Mean Onset Latencies by Condition

<table>
<thead>
<tr>
<th>Relatedness</th>
<th>RSI</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>ML</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Related</td>
<td>Short</td>
<td>1296</td>
<td>1275</td>
<td>1310</td>
<td>1387</td>
</tr>
<tr>
<td></td>
<td>Long</td>
<td>1212</td>
<td>1173</td>
<td>1339</td>
<td>1361</td>
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<tr>
<td>Unrelated</td>
<td>Short</td>
<td>1222</td>
<td>1188</td>
<td>1086</td>
<td>1031</td>
</tr>
<tr>
<td></td>
<td>Long</td>
<td>1166</td>
<td>1021</td>
<td>1008</td>
<td>982</td>
</tr>
<tr>
<td>AR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Related</td>
<td>Short</td>
<td>3290</td>
<td>4646</td>
<td>4015</td>
<td>4583</td>
</tr>
<tr>
<td></td>
<td>Long</td>
<td>3571</td>
<td>3511</td>
<td>3134</td>
<td>3713</td>
</tr>
<tr>
<td>Unrelated</td>
<td>Short</td>
<td>3078</td>
<td>3051</td>
<td>3484</td>
<td>2855</td>
</tr>
<tr>
<td></td>
<td>Long</td>
<td>3184</td>
<td>2354</td>
<td>2447</td>
<td>2757</td>
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<tr>
<td>LC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Related</td>
<td>Short</td>
<td>1090</td>
<td>1026</td>
<td>1023</td>
<td>1017</td>
</tr>
<tr>
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<td>Long</td>
<td>1025</td>
<td>1065</td>
<td>1022</td>
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<tr>
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<td>Short</td>
<td>1052</td>
<td>1045</td>
<td>1048</td>
<td>1000</td>
</tr>
<tr>
<td></td>
<td>Long</td>
<td>947</td>
<td>950</td>
<td>947</td>
<td>952</td>
</tr>
<tr>
<td>LW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Related</td>
<td>Short</td>
<td>995</td>
<td>968</td>
<td>988</td>
<td>903</td>
</tr>
<tr>
<td></td>
<td>Long</td>
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<td>1000</td>
<td>1029</td>
<td>970</td>
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<tr>
<td>Unrelated</td>
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<td>961</td>
<td>915</td>
<td>895</td>
<td>815</td>
</tr>
<tr>
<td></td>
<td>Long</td>
<td>987</td>
<td>943</td>
<td>916</td>
<td>905</td>
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<td>Controls</td>
<td></td>
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<td></td>
</tr>
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<td>918</td>
<td>909</td>
<td>894</td>
</tr>
<tr>
<td></td>
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<td>1018</td>
<td>985</td>
<td>990</td>
</tr>
<tr>
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<td>Short</td>
<td>887</td>
<td>891</td>
<td>865</td>
<td>842</td>
</tr>
<tr>
<td></td>
<td>Long</td>
<td>947</td>
<td>924</td>
<td>913</td>
<td>900</td>
</tr>
</tbody>
</table>

AR’s onset latencies were collected from a sound recording of the experiment, and were used instead because of excessive voice-key errors. Due to the presence of some extreme values in the data, any values were removed which were outside 3.5 standard deviations of the 5% trimmed distribution from the untrimmed mean for each condition of relatedness x RSI x picture presentation number. This resulted in a further 4.25% of the data being removed for ML, 4.34% for AR, 3.47% for LC, 2.43% for LW, and 2.31% for the controls. The distribution of the data was still substantially skewed after removing
Table 3. Experiment 1: Mean of Natural Log Transformed Onset Latencies

<table>
<thead>
<tr>
<th>Relatedness</th>
<th>RSI</th>
<th>Picture Presentation Number</th>
</tr>
</thead>
<tbody>
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<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>ML</td>
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<td></td>
</tr>
<tr>
<td>Related</td>
<td>Short</td>
<td>7.106</td>
</tr>
<tr>
<td></td>
<td>Long</td>
<td>7.072</td>
</tr>
<tr>
<td>Unrelated</td>
<td>Short</td>
<td>7.076</td>
</tr>
<tr>
<td></td>
<td>Long</td>
<td>7.034</td>
</tr>
<tr>
<td>AR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Related</td>
<td>Short</td>
<td>7.785</td>
</tr>
<tr>
<td></td>
<td>Long</td>
<td>7.795</td>
</tr>
<tr>
<td>Unrelated</td>
<td>Short</td>
<td>7.783</td>
</tr>
<tr>
<td></td>
<td>Long</td>
<td>7.798</td>
</tr>
<tr>
<td>LC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Related</td>
<td>Short</td>
<td>6.967</td>
</tr>
<tr>
<td>Unrelated</td>
<td>Short</td>
<td>6.936</td>
</tr>
<tr>
<td>LW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Related</td>
<td>Short</td>
<td>6.846</td>
</tr>
<tr>
<td>Unrelated</td>
<td>Short</td>
<td>6.824</td>
</tr>
<tr>
<td>Controls</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Related</td>
<td>Short</td>
<td>6.768</td>
</tr>
</tbody>
</table>

the extremes, so analyses for all subjects were performed on the natural log transformed data. The untransformed means for each patient and the mean for the controls for each condition of relatedness x RSI x picture presentation number are presented in Table 2 (also see Figures 2 and 3). The means on the natural log transformed data are presented in Table 3. A univariate ANOVA was performed for the transformed data of each patient and the mean onset latencies of the transformed data for older controls (see Table 4). Picture presentation number, relatedness, and RSI were analyzed as fixed factors with items as a random factor.
Figure 2. Experiment 1: Mean Onset Latencies for Relatedness by Rate

*Error bars represent 95% confidence interval of mean
Figure 3. Experiment 1: Mean Onset Latencies for Relatedness by Picture Presentation Number

*Error bars represent 95% confidence interval of the means*
Controls

The controls showed main effects of relatedness, in which onset latencies were longer in the related condition than in the unrelated condition, $F(1,1136) = 75.68, p < 0.001$, RSI, in which onset latencies were shorter at the short RSI than the long RSI, $F(1,1136) = 118.81, p < 0.001$, and picture presentation number, $F(1,1136) = 5.21, p = 0.001$. There was a significant linear trend for decreasing onset latencies over repeated presentations, $t(601.80) = 2.32, p = 0.021$. The older controls were also found to have a significant interaction of relatedness x RSI, $F(1,1136) = 6.31, p = 0.012$, with a larger effect of relatedness at the long RSI. The interaction between picture presentation number and relatedness failed to reach significance, $F(3,1136) = 1.21, p = 0.30$.

ML

ML had main effects of relatedness, in which onset latencies were longer in the related condition than in the unrelated condition, $F(1,1026) = 88.93, p < 0.001$, and RSI, in which onset latencies were longer at the short RSI than at the long RSI, $F(1,1026) = 9.94, p = 0.002$, which contrasted with the results for the controls, who showed the opposite effect. ML showed no main effect of picture presentation number, instead showing a significant interaction of relatedness by picture presentation number, $F(3,1026) = 10.61, p < 0.001$. It was found that ML had a significant linear trend for increasing onset latencies over picture presentations in the related condition, $t(297.24) = 2.22, p = 0.027$, and a significant linear trend for decreasing onset latencies over presentations in the unrelated condition, $t(287.48) = 6.10, p < 0.001$. 
AR

AR had main effects of relatedness, in which onset latencies were longer in the related condition than the unrelated condition, $F(1,1030) = 17.74, p < 0.001$, and RSI, in which onset latencies were longer at the short RSI than at the long RSI, $F(1,1030) = 8.726, p = 0.003$, showing an effect like ML but the opposite of the controls. Like ML, AR also showed no significant main effect of picture presentation number, but AR did fail to show a significant interaction of relatedness by picture presentation number, $F(3,1030) = 2.53, p = 0.056$. AR did however show a significant linear trend for increasing onset latencies in the related condition, $t(509) = 1.984, p = 0.048$, but he had no significant change in onset latencies for the unrelated condition, either in terms of linear trend analysis, $t(529) = 0.704, p = 0.482$, or post hoc analysis, Ryan-Einot-Gabriel-Welsch Test (R-E-G-W Q), $p = 0.652$.

LC

LC had main effects of relatedness, in which onset latencies were longer in the related condition, $F(1,1043) = 13.23, p < 0.001$, and RSI, in which onset latencies were longer at the short RSI, $F(1,1043) = 20.92, p < 0.001$, showing an effect like ML and AR but the opposite of the controls. LC was found to have a significant interaction of relatedness by RSI, $F(1,1043) = 11.07, p = 0.001$. A post hoc analysis found that his response latencies were significantly shorter for the unrelated long RSI condition than all the other conditions R-E-G-W Q, $p < 0.005$, which weren’t significantly different from each other, R-E-G-W Q, $p < 0.65$, thus there was a significant relatedness effect at the long RSI, but not at the short RSI.
LW

LW had main effects of relatedness, in which onset latencies were longer in the related condition $F(1,1094) = 13.84, p < 0.001$, RSI, in which onset latencies were shorter at the short RSI, as was found with controls, $F(1,1094) = 7.24, p = 0.007$, and picture presentation number, $F(1,1094) = 5.53, p = 0.001$. He was also found to have a significant linear trend for decreasing onset latencies over repeated presentations, $t(600.82) = 3.20, p = 0.001$.

Discussion

Controls

Controls found it easier to name items in semantically unrelated blocks and at the short RSI, and named items more quickly with repeated presentations. The findings in terms of semantic relatedness are consistent with what has been found in other studies using single-picture naming (e.g., Belke, Meyer, & Damian, 2005; Schnur et al., 2006). In terms of rate, people typically perform worse at fast rates of presentation, but in the present study the slow rate might have been too slow, causing subjects to lose focus during the experiment. A similar effect was found by Schnur et al. (2006). As discussed earlier, it is thought that greater difficulty in semantically related blocks of items is caused by difficulty in selecting a lexical representation when several semantically related competitors are activated. It has been proposed that the activation of semantic representations may build up over repeated productions of items, and the current experiment gave evidence that, in the case of normal subjects, it is not the production of items itself which is critical for the effect, but just the activation of the semantic representations whether production occurs or not. In single-picture presentation studies,
Table 4. Experiment 1: ANOVA Results

<table>
<thead>
<tr>
<th></th>
<th>Controls</th>
<th>ML</th>
<th>AR</th>
<th>LC</th>
<th>LW</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>df</td>
<td>MS</td>
<td>F</td>
<td>df</td>
<td>MS</td>
</tr>
<tr>
<td>Rel</td>
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<td>0.879</td>
<td>75.68***</td>
<td>1</td>
<td>5.814</td>
</tr>
<tr>
<td>RSI</td>
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<td>1.380</td>
<td>118.81***</td>
<td>1</td>
<td>0.650</td>
</tr>
<tr>
<td>PicNo</td>
<td>3</td>
<td>0.060</td>
<td>5.21**</td>
<td>3</td>
<td>0.105</td>
</tr>
<tr>
<td>Rel x RSI</td>
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<td>0.073</td>
<td>6.31*</td>
<td>1</td>
<td>0.095</td>
</tr>
<tr>
<td>Rel x PicNo</td>
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<td>0.014</td>
<td>1.21</td>
<td>3</td>
<td>0.694</td>
</tr>
<tr>
<td>RSI x PicNo</td>
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<td>0.005</td>
<td>0.39</td>
<td>3</td>
<td>0.082</td>
</tr>
<tr>
<td>Rel x RSI x PicNo</td>
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<td>0.005</td>
<td>0.40</td>
<td>3</td>
<td>0.015</td>
</tr>
<tr>
<td>Error</td>
<td>1136</td>
<td>0.012</td>
<td>1026.065</td>
<td>1030</td>
<td>0.467</td>
</tr>
</tbody>
</table>

*p < 0.05  
** p < 0.01  
*** p < 0.001
it is typically found that related items are produced no slower than unrelated items, or may even be produced more quickly, on the first time they are named. The present study found that already by the first trial items in the related condition were named more slowly. This could not be attributed to a greater difficulty due to having to search among visually similar items, since there was a visual cue to draw the subject's attention to the picture to be named. The finding in the current study of relatedness interference on the first block is consistent with studies in which subjects have been found to be affected by items presented in their visual periphery and to which they do not direct attention (e.g., Fuentes & Tudela, 1992).

ML

Like controls, ML found it more difficult to name items that were presented in semantically related arrays, but he found it more difficult to name items at the short RSI. ML also showed no overall trend of faster naming time across repeated productions, instead showing this only for the unrelated condition while having more difficulty repeatedly naming items in the related condition. This is consistent with what has been found with ML in a cyclic naming study (Biegel & R. C. Martin, 2006).

As discussed earlier, there have been two major accounts of difficulty with patients in repeatedly responding to items, and how this effect is exaggerated when items are semantically blocked. One account proposes that semantic representations become over-activated for such patients, resulting in difficulty in selecting among related competitors. The other account proposes that semantic representations have a period of refractoriness following their activation, which spreads to related items, making retrieval
of both specific items and related items more difficult over repeated presentations. The refractory account is inconsistent with the current findings for ML, as he became faster in naming items that were not semantically blocked, whereas a refractory account would predict that he would become slower over time, with the effect only being exaggerated by semantic blocking.

AR

The results with AR largely parallel those of ML. AR was slower to name items when they were semantically blocked, was slower to name items at the short RSI, and showed no overall effect of repeated presentations, but showed increasing onset latencies across repeated presentations in the related condition. Unlike ML, AR showed no evidence of becoming quicker to name items across repeated presentations in the unrelated condition.

There were also some important differences between AR and ML during the task that should be pointed out. AR’s onset latencies were much longer than ML’s, and he would occasionally have extremely long onset latencies of up to a minute. Perhaps more importantly, AR was inconsistent in the names he produced for items, for instance calling the picture of a mouse “mouse,” “mice,” and “rat,” and he was even inconsistent in names for some items within single blocks. All subjects did show some degree of inconsistency, for instance calling the picture of an airplane “airplane” on one occasion but “plane” on another, but very rarely did they substitute entirely different words as AR did. Typically they would be inconsistent in the case of compound words such as “airplane,” using either the full compound or the reduced form.
AR performed similarly to ML in the related condition in terms of the pattern of his onset latencies over repeated presentations, so it could be inferred that they are both suffering from over-activation of semantic representations, but because AR shows no priming for items in the related condition, it could be either that he suffers from a deficit in addition to one he shares with ML, or that his performance is caused by a separate deficit altogether. One deficit which would explain the increasing onset latencies in the related condition, the lack of priming in the unrelated condition, and the inconsistency of names for individual items would be an underactivation of lexical items. If this were the case, then a normal level of competition between semantic representations could lead to increasing onset latencies for the related condition, as lexical representations would be more difficult to distinguish. Underactivation of lexical representations would also explain the lack of priming in the unrelated condition, as lexical items would not receive any benefit from priming. Finally, this would explain the inconsistency in names he used for items, as underactivation of lexical items would lead to an increased likelihood that a different lexical item corresponding to the same semantic representation would be selected.

LC

Like the other subjects, LC had more difficulty naming items in related arrays, and like ML and AR, LC was slower to name items at the short RSI. However, LC did not show any evidence on onset latencies changing across presentations, nor did he show an interaction of relatedness by picture presentation number. There was no significant trend for his onset latencies to change over repeated presentations either for the related or unrelated conditions. This in contrast to all the other subjects, in that all showed some
change across presentations in at least the related condition. LC also had an interaction of relatedness by RSI. Like the controls, the difference between related and unrelated was greater at the long RSI than the short RSI, but for LC the semantic blocking effect was solely due to the long RSI, with there being no semantic blocking effect at the short RSI.

Since LC showed no increasing semantic blocking effect across trials, he appears to have no deficit in either the semantic system or lexical selection. One problematic finding was that he failed to any significant priming across repeated presentations. A deficit at the phonological level seems to be the most likely deficit for him, which would be in line with his jargonistic speech, but presumably he would still show priming from repeatedly accessing lexical representations.

_LW_

LW’s results are almost identical to the controls. His onset latencies were longer for the pictures in related arrays and at the long RSI, and he also showed an overall trend for decreasing onset latencies across picture presentations. Unlike the controls, he did not show an interaction of relatedness by RSI, but in every other way his results were the same as controls, with his onset latencies only being comparatively longer.

3. Experiment 2: Picture Array Comprehension

In experiment 1, it was found that ML and AR had a growing relatedness interference effect across presentations, but ML showed priming for items in the unrelated condition while AR showed no priming. LC showed no priming across presentations for either condition. LW and the controls showed priming across presentations for both conditions.
It is not yet clear whether the subjects who show increasing interference or a lack of priming are due to common deficits, only differing in degree, or due to deficits at different levels of representation. The purpose of the current experiment is to test the subjects on a comprehension task that is as similar as possible to the production task, to better understand what level or levels in language processing are responsible for the pattern of deficits seen in the patients. For ML and AR, if a growing relatedness interference effect were found in the context of a comprehension experiment, then this would seem to indicate that the deficit found for these two patients is due to a disruption in the semantic system, common to both production and comprehension. In this case, lexical selection based on a semantic representation is not needed, as the lexical item would be provided by the auditory input, assuming that there is no disruption of the process of selecting a lexical item from the auditory input. AR did show a lack of priming for the unrelated condition, as LC showed for both the related and unrelated conditions. It may be that these two share a common deficit as well, or a similar pattern of performance due to different deficits. If no priming is found as before, this would indicate a disruption at some level common to both production and comprehension, but something that does not involve the competition of lexical items based on activated semantic representations. Making the assumption that the same lexical representations activated in production are activated in comprehension, a lack of priming would indicate that there is some disruption at the lexical level causing difficulty in priming for subsequent activation. Finally, for the case of LC, if priming is actually found in the comprehension experiment, then this would indicate that the lack of priming in the
production experiment was due to a disruption at some later level involved only in
production, presumably being a phonological representation of the word for production.

Methods

Participants

The same groups of patients and normal controls participated in Experiment 2 as did in
Experiment 1.

Materials and Procedure

The materials were the same 72 pictures from Experiment 1. The design of the
experiment was the same as experiment 1 except that subjects would be given an auditory
presentation of a word corresponding to one of the pictures in the array. Subjects pressed
a key on a numeric keypad indicating the position on the screen of the picture that
matched the spoken name.

Results

Any errors were excluded from the analysis. Error rates were very low for the
experiment, being 1.56% for ML, 2.17% for AR, 1.48% for LC, 0.17% for LW, and
0.76% for controls. Because of quite a few extreme values for the subjects, the same
procedure for removing extreme values was used as in Experiment 1, which resulted in
removal of 2.52% of the data for ML, 3.65% for AR, 2.78% for LC, 1.91% for LW, and
2.19% for controls. After the removal of outliers, there was still a substantial positive
skew to the distribution of the data for all subjects, so the natural log transformed were
used in the analysis. The means for each condition are presented in Tables 5 and 6 (also
see Figures 4 and 5). A univariate ANOVA was performed on the natural log
Table 5. Experiment 2: Mean Response Times by Condition

<table>
<thead>
<tr>
<th>Relatedness</th>
<th>RSI</th>
<th>Picture Presentation Number</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
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<td>3</td>
<td>4</td>
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<tr>
<td>ML</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Related</td>
<td>Short</td>
<td>2818</td>
<td>2757</td>
<td>2691</td>
<td>2839</td>
</tr>
<tr>
<td></td>
<td>Long</td>
<td>2106</td>
<td>1991</td>
<td>2099</td>
<td>2184</td>
</tr>
<tr>
<td>Unrelated</td>
<td>Short</td>
<td>2144</td>
<td>2210</td>
<td>2051</td>
<td>1857</td>
</tr>
<tr>
<td></td>
<td>Long</td>
<td>1854</td>
<td>1867</td>
<td>1623</td>
<td>1694</td>
</tr>
<tr>
<td>AR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>3004</td>
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<td>2206</td>
<td>1937</td>
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<td></td>
<td></td>
</tr>
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</tr>
<tr>
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<td>1399</td>
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<tr>
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<td>1328</td>
<td>1238</td>
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<tr>
<td>LW</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td>Long</td>
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<td>Long</td>
<td>1236</td>
<td>1246</td>
<td>1201</td>
<td>1199</td>
</tr>
</tbody>
</table>

transformed data for each patient and the mean response times for controls with relatedness, RSI, and picture presentation number as fixed factors with items as a random factor (see Table 7).

Controls

Controls had main effects of relatedness, in which response times were longer in the related condition than in the unrelated condition, $F(1,1136) = 36.31, p < 0.001$, RSI, in which response times were shorter in the short RSI condition than the long RSI,
$F(1,1136) = 131.10$, $p < 0.001$, and picture presentation number, $F(3,1136) = 10.24$, $p < 0.001$. There was a significant linear trend for shorter response times over repeated presentations, $t(581.82) = 4.99$, $p < 0.001$. Controls were also found to have a significant interaction of RSI x picture presentation number, $F(3,1136) = 2.80$, $p = 0.039$, in which response times decreased much more rapidly across presentations for the short RSI than the long RSI.

**Table 6. Experiment 2: Means of Natural Log Transformed Response Times**

<table>
<thead>
<tr>
<th>Relatedness</th>
<th>RSI</th>
<th>Picture Presentation Number</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>ML</td>
<td>Related</td>
<td>Short 7.821</td>
<td>7.781</td>
<td>7.791</td>
<td>7.840</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Long 7.569</td>
<td>7.522</td>
<td>7.566</td>
<td>7.594</td>
</tr>
<tr>
<td></td>
<td>Unrelated</td>
<td>Short 7.595</td>
<td>7.605</td>
<td>7.556</td>
<td>7.463</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Long 7.470</td>
<td>7.484</td>
<td>7.342</td>
<td>7.389</td>
</tr>
<tr>
<td>AR</td>
<td>Related</td>
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<td>7.988</td>
<td>7.910</td>
<td>8.087</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Long 7.850</td>
<td>7.934</td>
<td>7.867</td>
<td>7.873</td>
</tr>
<tr>
<td></td>
<td>Unrelated</td>
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<td>7.690</td>
<td>7.787</td>
<td>7.757</td>
</tr>
<tr>
<td></td>
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<td>Long 7.656</td>
<td>7.595</td>
<td>7.644</td>
<td>7.536</td>
</tr>
<tr>
<td>LC</td>
<td>Related</td>
<td>Short 7.359</td>
<td>7.311</td>
<td>7.267</td>
<td>7.277</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Long 7.246</td>
<td>7.253</td>
<td>7.230</td>
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<td></td>
<td>Unrelated</td>
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<td></td>
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<td>Long 7.185</td>
<td>7.170</td>
<td>7.104</td>
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<td>LW</td>
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<td>7.027</td>
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<tr>
<td></td>
<td></td>
<td>Long 7.125</td>
<td>7.122</td>
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<tr>
<td></td>
<td>Unrelated</td>
<td>Short 7.033</td>
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<tr>
<td></td>
<td></td>
<td>Long 7.095</td>
<td>7.091</td>
<td>7.053</td>
<td>7.048</td>
</tr>
</tbody>
</table>
ML

ML had main effects of relatedness, in which items in the unrelated condition were responded to more quickly, $F(1,1089) = 65.71, p < 0.001$, and RSI, in which items presented at the short RSI were responded to more slowly, $F(1,1089) = 60.61, p < 0.001$, in contrast to the controls, who showed the opposite effect. ML had a significant interactions of relatedness x RSI, $F(1,1089) = 5.30, p = 0.022$, with a greater relatedness effect at the short RSI than the long RSI. ML also had a significant interaction of relatedness x picture presentation number, $F(3,1089) = 2.71, p = 0.044$, in which no significant difference was found in response times across presentations in the related condition, R-E-G-W Q, $p = 0.618$, but there was a significant linear trend for decreasing response times across presentations in the unrelated condition, $t(339.81) = 3.04, p = 0.002$.

AR

AR had main effects of relatedness, in which items in the unrelated condition were responded to more quickly, $F(1,1069) = 137.09, p < 0.001$, and RSI, in which items presented at the short RSI were responded to more slowly, $F(1,1069) = 26.85, p < 0.001$, like ML, but in contrast to the controls. The interaction of relatedness by picture presentation number failed to reach significance, $F(3,1069) = 2.52, p = 0.057$, but showed no significant difference between any of the picture presentations in either the related or unrelated condition. The difference between related and unrelated were greatest in presentation 2 and 4, and smaller in 1 and 3.
<table>
<thead>
<tr>
<th></th>
<th>Controls</th>
<th>ML</th>
<th>AR</th>
<th>LC</th>
<th>LW</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>df</td>
<td>MS</td>
<td>F</td>
<td>df</td>
<td>MS</td>
</tr>
<tr>
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<td>36.32***</td>
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<tr>
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<td>131.10***</td>
<td>1</td>
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<tr>
<td>PicNo</td>
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<td>0.199</td>
<td>10.24***</td>
<td>3</td>
<td>0.151</td>
</tr>
<tr>
<td>Rel x RSI</td>
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<td>1.7e-4</td>
<td>0.01</td>
<td>1</td>
<td>0.868</td>
</tr>
<tr>
<td>Rel x PicNo</td>
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<td>0.022</td>
<td>1.13</td>
<td>3</td>
<td>0.443</td>
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<tr>
<td>RSI x PicNo</td>
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<td>0.054</td>
<td>2.80*</td>
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<td>0.041</td>
</tr>
<tr>
<td>Rel x RSI x PicNo</td>
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<td>2.2e-3</td>
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<tr>
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<td>1136</td>
<td>0.019</td>
<td>1089</td>
<td>0.164</td>
<td>1069</td>
</tr>
</tbody>
</table>

*p < 0.05  
**p < 0.01  
***p < 0.001
Figure 4. Experiment 2: Mean Response Times for Relatedness by Rate

*Error bars represent 95% confidence intervals of means
Figure 5. Experiment 2: Mean Onset Latencies for Relatedness by Picture Presentation Number

*Error bars represent 95% confidence interval of the means*
LC

LC had main effects of relatedness, in which items in the unrelated condition were responded to more quickly, $F(1,1087) = 43.31, p < 0.001$, RSI, in which items presented at the short RSI were responded to more slowly, $F(1,1087) = 20.22, p < 0.001$, like ML and AR, but in contrast to the controls, and picture presentation number, $F(3,1087) = 3.13, p = 0.025$. There was found to be a significant linear trend for shorter response times over repeated presentations, $r(623.88) = 2.64, p = 0.008$.

LW

LW had main effects of relatedness, in which items in the unrelated condition were responded to faster, $F(1,1112) = 17.61, p < 0.001$, RSI, in which items were responded to more quickly in the short RSI condition, $F(1,1112) = 39.15, p < 0.001$, as was found with controls, and picture presentation number, $F(3,1112) = 12.72, p < 0.001$. It was found that there was a significant linear trend for shorter response times over repeated presentations, $r(544.97) = 5.19, p < 0.001$. LW also had a significant interaction of RSI x picture presentation number, $F(3,1112) = 3.65, p = 0.012$, in which response times decreased much more rapidly across presentations for the short RSI than the long RSI.

Discussion

Controls

Controls had longer onset latencies for responding to items presented in a related context, at the long RSI, and their response times became shorter over repeated presentations. Thus, their main effects are the same as those found in the production study. There was a difference in terms of interactions. In the production study, there was
a relatedness by RSI interaction, whereas in this case there was a RSI by picture presentation number interaction, in which response time decreased over presentations much more quickly at the short RSI than the long RSI. As said about the controls earlier in the production study, this may have been because the task was very easy for the control subjects, and the long RSI was probably too long for them.

ML

All main effects were the same for ML in the comprehension study as in the production one. He was slower to respond to items in the related condition and at the short RSI. ML again showed a main effect of picture presentation number, and showed an interaction of relatedness by picture presentation number. ML did again show a significant linear trend for decreasing reaction time with repeated presentations for the unrelated condition, but in this case showed no change for the related condition. ML also had a significant relatedness by rate interaction, in which the relatedness effect was much greater for the fast rate of presentation than the slow.

In the comprehension task, ML showed no change in response times across repeated presentations in the related condition as he had in the production task, but it should be noted that he did still show an increasing relatedness interference effect since the related items showed no evidence of repetition priming as in the unrelated condition. This gives further evidence that ML is having a disruption in the semantic system, but there was not increasing response times for the related condition, possibly because no lexical representation needed to be selected from semantically related competitors.
AR

AR only showed effects of relatedness and RSI, being slower to make responses in the related condition and at the short RSI. He showed no main effect of picture presentation number. He had a marginal interaction of relatedness by picture presentation number, but this interaction was the result of a noisy pattern of response times across presentations, and showed no overall trend for increasing or decreasing response times for either the related or unrelated conditions looking at them individually, which indicates a lack of significant priming across repeated presentations. For the related conditions, AR has shown a pattern like ML: his onset latencies became longer for repeated presentations in the related condition for production and remained stable across presentations for comprehension. However, AR is different in that in neither case did he show repetition priming for the unrelated condition. As mentioned earlier, this may indicate that he shares a deficit in resolving competition at the semantic level along with a deficit at the lexical level, or that he suffers only from a single deficit. It was argued before, based on the inconsistency in his naming, that AR was having difficulty in repeatedly retrieving specific lexical items. The lack of priming for unrelated items in the comprehension study may reflect a deficit in a lexical system shared by both production and comprehension. There are two possibilities for how underactive lexical representations might result in a lack of priming. One possibility would be the phonological representation not sufficiently activating the lexical representation, and possibly the number of phonologically similar lexical items activated might contribute to this problem. Another possibility would be weak activation from the lexical item into the
semantic representation making activation of the correct semantic representation difficult. Further study would be needed to decide between these two alternatives.

**LC**

LC showed the same main effects of relatedness and RSI as he did in the production experiment, being slower to respond to items that were semantically blocked and being slower to respond at the short RSI. In the production task, he showed no evidence of changing onset latencies across presentations, but in the comprehension task he did have a significant effect of picture presentation number, showing decreasing response times across repeated presentations. In the comprehension experiment, he also failed to show a significant relatedness by RSI interaction as he had in the production experiment.

Since LC showed repetition priming overall across presentations, his pattern in the comprehension was like LW and the controls but different from ML and AR. This gives further evidence that the lack of priming found in the production experiment is due to a deficit at some level other than what is causing the pattern of performance for AR and ML. Since he shows significant priming in comprehension but not in production, this may indicate that he has a disruption at the level of phonology involved in production only. LC certainly does have problems in the phonological processing of heard speech, but this did not seem to interfere with the priming of auditorily perceived words.

**LW**

LW showed a pattern that matched that of controls. He was slower at responding to items that were blocked semantically, was faster to respond to items at the short RSI, he showed a significant main effect of picture presentation number, having a significant
linear trend for decreasing response times across presentations, and he also showed a significant rate by picture presentation number. LW again shows a pattern of performance that is not markedly different from that of controls, being only somewhat slower.

4. General Discussion: Picture Arrays

It has been argued above that these two experiments provide evidence that ML suffers from a disruption at the semantic level, AR suffers from a disruption at the lexical level, possibly in addition to a disruption at the semantic level, LC suffers from a deficit at the phonological level involved in speech production, and that LW has no noticeable deficit in either single-word production or comprehension, except that he is overall slower compared to controls. It is necessary to discuss in more depth what the differences are between the production and comprehension task that may give rise to the slightly different patterns of performance for the patients between the two tasks, and what this may indicate about the specific nature of their deficits.

A typical characterization of single-word production involving picture naming would be that the visual presentation of the picture activates a semantic representation, and to a lesser extent related semantic representations. The semantic representation in turn activates several lexical representations, and other lexical representations are also activated to a lesser extent by related semantic representations. A selection process eventually chooses one lexical representation, which in turn activates a phonological representation of the word. In terms of single-word comprehension, it is generally believed there is a similar process in reverse, in which a phonological representation
activated by the auditory presentation activates a lexical representation, which in turn activates a semantic representation. For the comprehension task in the current study, there is a complication to the task, in that participants must also match the spoken word to a visually presented picture. Thus, there needs to be some level at which the auditory word and the visual picture are compared to one another to see if they match. It is not obviously clear, at what level this comparison would occur, or, more problematic, if it is possible for the comparison to take place at different levels. Participants could compare the two representations at the highest level possible, the semantic level, or a name for the individual pictures could be retrieved and compared to the auditory word at the lexical or phonological level. Even though a comparison between semantic representations seems to be the most likely point at which the comparison is being made, no strong claim is going to be made about this since more evidence would need to be brought to bear on the issue.

The results from ML across the two experiments seem to indicate a deficit in the semantic system in which representations become over-activated, resulting in difficulty in selecting a lexical item in the case of items that are semantically blocked. In both tasks, he became quicker to respond to items in the unrelated condition across presentations, and if it were the case that he had a deficit in which items became inhibited after their activation then he would be expected to become slower in responding across repeated presentations in general, regardless of whether the items were semantically blocked or not. There was a difference between the experiments in terms of the relatedness by picture presentation number interaction, in that ML’s onset latencies increased over repeated presentations in the production task but did not change significantly in the
comprehension task. This may be due to the comprehension task not necessarily requiring the selection of a lexical representation from several competing ones.

AR was similar to ML for the semantically blocked items, in that he showed increasing onset latencies across presentations in the production task and no priming for related items in the comprehension task. He did differ, in that he showed no priming for the items in unrelated arrays in either experiment. This seems to indicate that either that he shares a deficit arising at the semantic level with ML, in addition to another deficit affecting the level of activation of unrelated items, or that he has a separate deficit giving rise to his pattern of performance for both the related and unrelated conditions. The most parsimonious explanation would be that he has a single deficit at the lexical level which results in the lexical representations being at a lower level of activation as compared to normal. In this case, he would not need to have over-activation of semantic representations to show increasing onset latencies across presentations, but instead a normal level of competition would be sufficient to interfere with lexical retrieval due to the under-activation of lexical representations. This may also explain his tendency to be noticeably inconsistent in the names he provided for pictures in the production task. For normal subjects, it may be the case as well that the activation of semantic representations does continue to build up as well across repeated presentations, but this is overwhelmed by the priming of lexical representations.

LC failed to show any significant change in onset latencies across presentations for either the related or unrelated conditions in the production task, but did show faster response times across presentations in both conditions in the comprehension task. Since he showed a lack of priming only in the production task, and that there was no interaction
between relatedness and picture presentation, this seems to indicate a lack of priming at a level after lexical selection has occurred, presumably a phonological level involved only in production. It might be expected that he would show priming from other levels of representation. For instance, assuming that he has no disruption at the lexical level, the repeated selection of a lexical item should make it easier to activate later, which would presumably make the phonological representation easier to access as well. It is not clear why a disruption at the phonological level would wipe out any evidence of priming effects in naming, and more research would need to be conducted to see if it really is the case that LC only has a disruption at this level.

Finally, LW did not show a pattern of performance that was markedly different from that of controls, besides being slower overall. His results were expected, given that he shows little evidence of a deficit on most tasks, and did not show any evidence of growing interference for related items in a cyclic single-picture naming study (Biegler & R. C. Martin, 2006).

5. Experiment 3: Category Fluency

As mentioned earlier, some aphasic patients have been shown to produce words that are of lower frequency than normal, and it is possible that such a tendency derives from difficulty in resolving competition between high-frequency items. Marshall et al. (2001) reported that their patient JP produced very low-frequency responses in a task of generating members of certain semantic categories. However, it was also found that the mean frequency of JP’s responses did not differ significantly from the mean frequency of the last 5 items given by control subjects. As subjects generate members of categories, it
becomes more difficult to generate additional members, and their responses also tend to
go down in both word frequency and typicality. This may be caused by items produced
earlier interfering with the retrieval of ones later. JF may have produced low-frequency
responses sooner because of greater difficulty than normal in resolving competition
between the high-frequency items of a category, so a lower frequency response is chosen
instead. Normal subjects would not reach a point where they have such difficulty
resolving competition until later. If ML does have a problem in selecting among
semantically related competitors, then it would be expected that he would perform poorly
on this task, producing responses that are lower in word frequency and typicality and
responses that are more semantically distant from one another as compared to the
controls.

Methods

Participants

The participants were again the patients ML, AR, LC, and LW as well as 10 older
controls (8 females, 2 males; age: $M = 66.1$, range: 58 – 79).

Materials and Procedure

Participants were given the name of different semantic categories and asked to
produce the names of as many items from that category as they could within one minute.
There were thirteen categories: mammals, flowers, vegetables, furniture, kitchen utensils,
countries, forms of transportation, musical instruments, tools, clothing, birds, fishes, and
things to drink.
Table 8. Experiment 3: Results by Subject

<table>
<thead>
<tr>
<th></th>
<th>ML</th>
<th>AR</th>
<th>LC</th>
<th>LW</th>
<th>Controls (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Responses</td>
<td>8.92*</td>
<td>4.92**</td>
<td>9.83***</td>
<td>9.00***</td>
<td>15.04 (9.67 – 20.33)</td>
</tr>
<tr>
<td>Mean Word frequency</td>
<td>2.54</td>
<td>2.94</td>
<td>2.28</td>
<td>2.75</td>
<td>2.36 (1.83 – 2.70)</td>
</tr>
<tr>
<td>Inter-item similarity</td>
<td>.274</td>
<td>.351</td>
<td>.263</td>
<td>.342</td>
<td>.319 (.29 – .41)</td>
</tr>
<tr>
<td>Item-Category similarity</td>
<td>.351</td>
<td>.368</td>
<td>.324</td>
<td>.372</td>
<td>.351 (.32 – .39)</td>
</tr>
</tbody>
</table>

*** P < 0.001 compared to controls

Results

The results from the flowers category were not analyzed because the responses given by many of the control subjects were often very low-frequency items that had no listings in the databases used to tabulate results.

Several paired t-tests were performed comparing individual patients to the controls. The number of responses, word-frequency of responses, inter-item similarity, and category-item similarity were analyzed. Since this meant that 16 t-tests were performed, a sequential Bonferroni correction was made to control the alpha level. First analyzed was the number of responses provided by subjects. It was found that all patients produced significantly fewer responses than the controls (see Table 8), though LC was within the range of controls and both ML and LW were just below the range for controls. Because of the difference between subjects and categories in the number of items produced, only the first six responses from each category were used in the subsequent analyses. Next analyzed was the mean word-frequency of the first six responses. Paired t-tests for each patient comparing to controls revealed no significant differences. Last analyzed were the semantic similarity between items and the semantic similarity between
items and the category. Semantic similarity was computed by using latent semantic analysis software designed by the latent semantic analysis LSA research group at the University of Colorado-Boulder (Latent semantic analysis research group, 1998). Latent semantic analysis compares the co-occurrence of words in different documents to compute a value (between −1.00 and 1.00) for their semantic relatedness (Landauer & Dumais, 1997; Landauer, Foltz, & Laham, 1998). Paired t-tests were performed comparing the patients to the controls on both the mean semantic similarity between items produced and the mean semantic similarity between the category and items produced, but no significant differences were found.

**Figure 6. Experiment 3: Mean Absolute Times for First Six Responses**
Discussion

The current experiment was meant to compare the patients with the controls primarily in terms of the word frequency of their responses and the semantic relatedness between responses. It was thought that if any of the patients were suffering from difficulty in resolving competition between related items, then they may produce lower frequency responses because of competition between high-frequency items, and they may also produce items that are more semantically distant from one another, because of interference from other semantically related competitors.

It was only found that the patients produced less responses on average than the controls. However, it appeared that AR had a comparably greater difficulty with this task, producing far fewer responses than the other patients and taking much longer to make individual responses.

6. Experiment 4: Sentence Completion

Sentence completion is another task in which previous studies have demonstrated difficulty in selecting from competitors for some left frontal patients (e.g., Burgess & Shallice, 1996; Robinson, Shallice, & Cipolotti, 2005). The purpose of a sentence completion experiment was to see whether ML would have any difficulty in selecting from a number of lexical competitors or difficulty in selecting from different syntactic interpretations of a sentence. In an earlier sentence completion task, ML showed little difficulty in the task, but did produce responses that were significantly lower in frequency than the controls or other patients, and he did produce some responses that were quite unusual, though grammatically and semantically acceptable (Crowther, Biegler, & R. C.
Martin, 2005), but the reason for this finding is not clear. It could be that he is having difficulty in selecting among several related responses. However, in a verb generation task, R. C. Martin and Cheng (2006) found no effect of the number of competitors for ML or controls. In the verb generation task, the possible responses are not necessarily semantically related (e.g., salad might elicit “eat” or “toss”). ML might show difficulty if he has to choose from among many competitors that are highly related to one another rather than many that are only related associatively, or not at all. It could also be that ML’s unusual pattern in sentence completion is related to difficulty in his comprehension of the sentences due to an inability to suppress inappropriate information in sentence interpretation, as Gerbsbacher and colleagues have found for less-skilled comprehenders (Gernsbacher et al., 1990). For the unusual responses given by ML in the Crowther, Biegler, and R. C. Martin (2006) study, most seemed to be a result of unusual interpretations of the sentences, which may have been due to difficulty in suppressing irrelevant information in the sentence.

The two possibilities of either difficulty in inhibiting related competitors or suppressing irrelevant information were investigated by manipulating the number of semantically related competitors, the number of unrelated competitors, and the competition between different conceptual interpretations of a sentence. There were five sentence types used in the experiment: high-constraint, low-constraint, lexical competition, ambiguous phrase, and ambiguous word. In the high-constraint sentences, there was one response that was given overwhelmingly by subjects, and thus it was not thought that there would be much, if any, competition between related competitors for selection. For instance, for the sentence “The dirty child had to take a ____,” nearly all
subjects produced the response “bath,” and this was thought to reflect that there was little competition between different lexical items. In the low-constraint sentences, there was a range of possible responses given by subjects and the responses were not limited to a single semantic category. For the low-constraint sentence “While standing on the street, the man and the woman saw a __,” subjects produced responses such as “dog,” “car,” “accident,” etc., which were not semantically related to one another. In the lexical competition sentences the responses are constrained to a certain semantic category. For the sentence “When he left home for work, the man forgot to put on his __,” subjects produced responses such as “hat,” “belt,” “shirt,” etc., which were restricted to the semantic category of clothing. The lexical competition sentences were in essence low-constraint sentences, as subjects could give a range of responses, but constraining the responses to a certain semantic category would presumably increase interference from competing responses. In the ambiguous phrase sentences, the sentences ended with what could be a commonly used figurative phrase (“He could see the light”), but was inappropriate in the context of the sentence (“Even in the dark, he could see the ____”).

It was noted in the previous sentence completion experiment that ML would occasionally interpreted the final phrase in a sentence as a common figurative phrase. Such an interpretation was not grammatically or semantically incorrect, but very few controls made such interpretations. The purpose of this condition was meant to determine if ML was, in fact, relying on such commonly used phrases because of difficulty in interpreting the sentences. In the ambiguous word sentences, there was an ambiguous word for which most information in the sentence suggested one interpretation; however, one piece of syntactic or semantic information constrained the word to another meaning. For instance,
for the sentence "At the museum, the painter framed the innocent ____." the words
"museum," "painter," and "framed" are all related to one another, which may lead one to
initially think that the painter is framing a painting. However, the adjective "innocent"
constrains the ambiguous word "framed" to be interpreted instead as meaning to frame
someone for a crime, since "innocent" would be used to describe a person, not an
inanimate object. The purpose of this condition was to determine if the post-selection
inhibitory mechanism that has been proposed to be dysfunctional in ML may be involved
in the inhibition of inappropriate meanings of words a well, similar to the mechanism
proposed by Gernsbacher and colleagues (Gernsbacher, 1990; Gernsbacher & Faust,

Methods

Participants

The participants were the patients ML, AR, LC, and LW as well as 30 older controls (23
females, 7 males; age: $M = 67$, range: 54 – 86).

Materials

Sentences of the five different types were constructed: high-constraint, low-constraint,
lexical competition, ambiguous phrase, and ambiguous word (see Appendix B). The
high-constraint sentences were ones in which there was one single response with a Cloze
probability of 0.70 or higher, with the Cloze probability being the probability producing
the most common response among controls (Taylor, 1953). Low-constraint sentences
were ones in which no response had a Cloze probability 0.53 and that the responses were
not constrained to a single semantic category. Lexical constraint sentences were low-
constraint sentences in which the responses were constrained to a single semantic
category. Ambiguous phrase sentences were ones in which the sentence ended with a commonly used phrase, but the sentence context biased a literal interpretation of the phrase. Ambiguous word sentences were ones in which there was an ambiguous word in which the sentence allows for two possible interpretations of the word, but semantic or grammatical aspects of the sentence constrain it to only one meaning. 40 sentences of each kind were developed.

Results

It was found that the responses of controls did not match those predicted beforehand so some of the sentences were excluded from the analysis. This left 31 high-constraint sentence, 36 low-constraint sentences, 39 lexical constraint sentences, 32 ambiguous phrase sentences, and 34 ambiguous word sentences.

Table 9 shows the type of error for each subject by each sentence types. Note that errors on some sentences may have been multiple types, so the total number errors represents the number of sentences on which errors were made, and the number of errors for each type represents both errors of that individual type and errors mixed with another type. Only AR showed a number of errors that was outside the range of controls. For all sentence types except the high-constraint sentences, the number of times that he failed to produce any response that was outside the range for controls. He was just outside the range of controls for the lexically constrained sentences, but for the low-constraint, ambiguous phrase, and ambiguous word conditions, he had substantially more cases where he failed to produce a response.

The ambiguous phrase and ambiguous word conditions were analyzed in terms of the kinds of responses subjects produced, whether or not they relied on the idiomatic
phrase in the ambiguous phrase condition and whether or not they correctly interpreted
the ambiguous word in the ambiguous word condition. No correlation was found
between these two conditions in terms of the kinds of responses subjects produced. The
responses of the patients were compared to the responses of the controls. The patients
did not differ significantly from the controls for the ambiguous phrase condition. For the
ambiguous word condition, LC surprisingly gave significantly more appropriate
responses than the controls, $t(28) = 2.37, p = 0.024$.

The mean word-word frequencies for each sentence were compared to the
responses given by patients. Comparing across all sentence types, it was found that ML
produced responses that were significantly lower frequency than those provided by
controls, $t(118) = 1.25, p = 0.017$. An analysis of the individual sentence types using a
Bonferroni correction for the alpha-level, however, yielded no significant differences
between ML and the controls.

The mean time to produce responses for each sentence type was compared for
each subject (see Figure 7). A post hoc analysis was performed using the R-E-G-W Q
test comparing the response times for each condition. For controls, all conditions were
significantly different from each other ($p < 0.05$), except the low-constraint and
ambiguous phrase conditions ($p = 0.516$). For ML, responses were made significantly
faster to the high-constraint sentences than the low-constraint sentences ($p < 0.05$). No
significant differences between any of the conditions were found for AR ($p = 0.058$),
presumably because of the high proportions of failures to respond and the wide range in
response times. For LC, it was found that responses were made significantly faster ($p <
0.05$) for the high-constraint sentences than all other sentence types expect for the
ambiguous phrase condition ($p = 0.146$). For LW, the high-constraint sentences were responded to significantly faster than all other sentence types ($p < 0.05$), with all other sentence types not being significantly different from each other ($p = 0.664$).

**Figure 7. Experiment 4: Onset Latencies for Subjects by Sentence Type**
### Table 9. Experiment 4: Errors by Error Type for each Subject

<table>
<thead>
<tr>
<th>Sentence Type</th>
<th>Error Type</th>
<th>ML</th>
<th>AR</th>
<th>LC</th>
<th>LW</th>
<th>Controls (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-Constraint</td>
<td>No Response</td>
<td>0/31</td>
<td>2/31</td>
<td>0/31</td>
<td>0/31</td>
<td>0.2/31 (0-2)</td>
</tr>
<tr>
<td></td>
<td>Too many words</td>
<td>0/31</td>
<td>0/31</td>
<td>0/31</td>
<td>0/31</td>
<td>0.17/31 (0-2)</td>
</tr>
<tr>
<td></td>
<td>Grammatical</td>
<td>0/31</td>
<td>0/31</td>
<td>0/31</td>
<td>0/31</td>
<td>0.3/31 (0-0)</td>
</tr>
<tr>
<td></td>
<td>Semantic</td>
<td>0/31</td>
<td>0/31</td>
<td>0/31</td>
<td>0/31</td>
<td>0.1/31 (0-1)</td>
</tr>
<tr>
<td></td>
<td>Unusual Response</td>
<td>1/31</td>
<td>0/31</td>
<td>0/31</td>
<td>0/31</td>
<td>0.07/31 (0-1)</td>
</tr>
<tr>
<td></td>
<td>Total Errors</td>
<td>1/31</td>
<td>2/31</td>
<td>0/31</td>
<td>0/31</td>
<td>0.53/31 (0-3)</td>
</tr>
<tr>
<td>Low-Constraint</td>
<td>No Response</td>
<td>0/36</td>
<td>11/36</td>
<td>0/36</td>
<td>2/36</td>
<td>0.13/36 (0-2)</td>
</tr>
<tr>
<td></td>
<td>Too many words</td>
<td>5/36</td>
<td>1/36</td>
<td>1/36</td>
<td>0/36</td>
<td>1.27/36 (0-4)</td>
</tr>
<tr>
<td></td>
<td>Grammatical</td>
<td>0/36</td>
<td>0/36</td>
<td>0/36</td>
<td>0/36</td>
<td>0.03/36 (0-1)</td>
</tr>
<tr>
<td></td>
<td>Semantic</td>
<td>0/36</td>
<td>0/36</td>
<td>0/36</td>
<td>0/36</td>
<td>0.03/36 (0-1)</td>
</tr>
<tr>
<td></td>
<td>Unusual Response</td>
<td>1/36</td>
<td>0/36</td>
<td>1/36</td>
<td>0/36</td>
<td>0.07/36 (0-1)</td>
</tr>
<tr>
<td></td>
<td>Total Errors</td>
<td>5/36</td>
<td>12/36</td>
<td>3/36</td>
<td>2/36</td>
<td>1.53/36 (0-6)</td>
</tr>
<tr>
<td>Lexically Constrained</td>
<td>No Response</td>
<td>0/39</td>
<td>3/39</td>
<td>0/39</td>
<td>1/39</td>
<td>0.07/39 (0-1)</td>
</tr>
<tr>
<td></td>
<td>Too many words</td>
<td>0/39</td>
<td>2/39</td>
<td>1/39</td>
<td>0/39</td>
<td>0.67/39 (0-4)</td>
</tr>
<tr>
<td></td>
<td>Grammatical</td>
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<td>0/39</td>
<td>0/39</td>
<td>0/39</td>
<td>0/39 (0-0)</td>
</tr>
<tr>
<td></td>
<td>Semantic</td>
<td>0/39</td>
<td>0/39</td>
<td>0/39</td>
<td>0/39</td>
<td>0.03/39 (0-1)</td>
</tr>
<tr>
<td></td>
<td>Unusual Response</td>
<td>0/39</td>
<td>1/39</td>
<td>0/39</td>
<td>1/39</td>
<td>0.2/39 (0-2)</td>
</tr>
<tr>
<td></td>
<td>Total Errors</td>
<td>0/39</td>
<td>6/39</td>
<td>1/39</td>
<td>2/39</td>
<td>0.9/39 (0-5)</td>
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<tr>
<td>Ambiguous Phrase</td>
<td>No Response</td>
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<td>11/34</td>
<td>0/34</td>
<td>1/34</td>
<td>0.1/34 (0-2)</td>
</tr>
<tr>
<td></td>
<td>Too many words</td>
<td>1/34</td>
<td>2/34</td>
<td>0/34</td>
<td>0/34</td>
<td>0.6/34 (0-3)</td>
</tr>
<tr>
<td></td>
<td>Grammatical</td>
<td>1/34</td>
<td>2/34</td>
<td>0/34</td>
<td>0/34</td>
<td>0.1/34 (0-1)</td>
</tr>
<tr>
<td></td>
<td>Semantic</td>
<td>1/34</td>
<td>1/34</td>
<td>1/34</td>
<td>1/34</td>
<td>0.4/34 (0-2)</td>
</tr>
<tr>
<td></td>
<td>Unusual Response</td>
<td>1/34</td>
<td>1/34</td>
<td>2/34</td>
<td>0/34</td>
<td>0.23/34 (0-1)</td>
</tr>
<tr>
<td></td>
<td>Total Errors</td>
<td>3/34</td>
<td>15/34</td>
<td>3/34</td>
<td>2/34</td>
<td>1.43/34 (0-4)</td>
</tr>
<tr>
<td>Ambiguous Word</td>
<td>No Response</td>
<td>0/32</td>
<td>18/32</td>
<td>3/32</td>
<td>3/32</td>
<td>0.57/32 (0-3)</td>
</tr>
<tr>
<td></td>
<td>Too many words</td>
<td>2/32</td>
<td>1/32</td>
<td>2/32</td>
<td>0/32</td>
<td>1.6/32 (0-8)</td>
</tr>
<tr>
<td></td>
<td>Grammatical</td>
<td>7/32</td>
<td>3/32</td>
<td>5/32</td>
<td>4/32</td>
<td>5.07/32 (1-8)</td>
</tr>
<tr>
<td></td>
<td>Semantic</td>
<td>8/32</td>
<td>2/32</td>
<td>2/32</td>
<td>5/32</td>
<td>5.53/32 (1-10)</td>
</tr>
<tr>
<td></td>
<td>Unusual Response</td>
<td>4/32</td>
<td>0/32</td>
<td>1/32</td>
<td>0/32</td>
<td>0.23/32 (0-1)</td>
</tr>
<tr>
<td></td>
<td>Total Errors</td>
<td>15/32</td>
<td>22/32</td>
<td>11/32</td>
<td>11/32</td>
<td>9.63/32 (3-17)</td>
</tr>
<tr>
<td>All Sentence Types</td>
<td>No Response</td>
<td>0/172</td>
<td>45/172</td>
<td>3/172</td>
<td>7/172</td>
<td>1.07/172 (0-8)</td>
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<tr>
<td></td>
<td>Too many words</td>
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<td>4/172</td>
<td>0/172</td>
<td>4.3/172 (0-15)</td>
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<tr>
<td></td>
<td>Grammatical</td>
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<td>5/172</td>
<td>5/172</td>
<td>4/172</td>
<td>5.2/172 (2-8)</td>
</tr>
<tr>
<td></td>
<td>Unusual Response</td>
<td>7/172</td>
<td>2/172</td>
<td>4/172</td>
<td>1/172</td>
<td>0.8/172 (0-3)</td>
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<tr>
<td></td>
<td>Total Errors</td>
<td>24/172</td>
<td>57/172</td>
<td>18/172</td>
<td>17/172</td>
<td>14.03/172 (5-26)</td>
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Discussion

ML

ML, as in a previous sentence completion experiment, produced responses that were significantly lower-frequency than the mean for controls. Although he produced responses of lower frequency as compared to controls across all the sentence types, his responses were only significantly of lower frequency in the high-constraint sentences. If the tendency to produce items of lower frequency was due to a difficulty in selecting among semantically related items, then it would be expected that this effect would be significant and largest in the sentence type which was constrained to one lexical category, but this was not the case. The experiment gave no evidence that ML has any great difficulty in selection involving either selecting a single item from a category or selecting a single response from a wide range of responses, as in the case of the low-constraint sentences.

AR

AR had great difficulty in this task, often being unable to generate a response and he had very long response times as compared to the other subjects. In terms of errors, he was not substantially different from controls in the high-constraint and lexical-constraint sentences, but showed a great number of failures to respond in the low-constraint, ambiguous phrase, and ambiguous word conditions. Looking at just the high-, low-, and lexical-constraint sentences, this may be further evidence that he is having difficulty in selecting lexical items, but that this is due to underactivation of items rather than some difficulty in resolving competition per se. Griffin and Bock (1998) argued that contextual constraint, for instance the discourse or grammatical constraints, specifically affects the
lexical level by biasing certain representations to be selected. For the high-constraint sentences, the context would be highly constraining to one lexical item, which would make it easier to retrieve that item. The lexical-constraint sentences, in which the response is constrained to a certain semantic category, would be very difficulty for patients suffering from a deficit making selection from several competitors difficult, but for AR, who I have argued suffers from the underactivation of lexical items, may not have too much trouble in eventually generating a response since the sentence does generate at least a subset of possible responses. The low-constraint sentences, on the other hand, are not particularly constraining to anything, and because of this AR may have found it particularly difficult to generate a response to this condition.

LC

The only effect found for LC that was significantly different from controls was that he was able to correctly select the more appropriate meaning for an ambiguous word significantly more often than the controls. LC did have difficulty in comprehending the sentences, and often had to have the experimenter replay them again. It could be the case that he simply paid more attention to the sentences than the controls, who often went through the sentences much more quickly. However, it should be noted that he only complained of difficulty in understanding the phonology of specific words, whereas controls were often confused about the semantic or grammatical aspects of the ambiguous word sentences, due to difficulty in correctly interpreting the ambiguous words.

LW

On this experiment, as in the previous ones, LW was largely similar to controls, with his response times only being longer.
7. General Discussion

The present study sought to explore in more detail the nature of semantic blocking effects found in some frontal aphasic patients with preserved single-word processing, and to see if these patients have a similar, though less severe, deficit as described by Warrington and colleagues with their refractory access patients. The study also sought to see whether patients showing semantic blocking effects in the current study also have a common deficit differing in severity or separate deficits giving superficially similar patterns of performance. Across the set of experiments, it appears that the two frontal patients in the current study, ML and AR, do differ from each other, but it needs to be addressed whether either one of them could be described as a less severe refractory access patient.

ML showed effects of semantic blocking in the repeated probing of items in both Experiment 1 and 2. In the production experiment, this was increasingly long onset latencies in the related condition, and in the comprehension experiment, this was an increasing semantic interference effect with no change in response times for the related but significant priming across trials for the unrelated condition. These findings seem to indicate that he has a deficit arising in the semantic system which is characterized by the over-activation of semantic representations due to a malfunction in the normal mechanisms which would either control the level of activation for semantic representations or inhibit a highly activated representation somewhat after its selection. In the production task, this results in increasingly long onset latencies, because over-active semantic representations in turn make several lexical items activated, making
selection of any one difficult, and more difficult as activation builds up. No priming was found in the related condition in comprehension, because this extra step of selecting a lexical item is unnecessary, and the selection need only be between semantic representations. The evidence that the semantic blocking effects are caused by over-activation, rather than some refractory effect as described by Warrington and colleagues, is that ML showed priming in the unrelated conditions across presentations. An over-inhibition account of his deficit would predict that he should show no priming, or increasing response times, across presentations, and that this effect should be exaggerated by blocking the items semantically. In the sentence completion experiment, ML did not show any evidence of producing items that were less related to the sentences than controls, nor did his response times show much difference from LC or LW, though caution should be warranted due to the small number of items and large variance in the data. He showed no evidence of having difficulty selecting items whether there were several semantically related competitors or many unrelated competitors.

ML's lack of difficulty when having to select among activated semantically related competitors in the sentence completion study appears to conflict with the strong effect of semantic interference found in Experiments 1 and 2. It could be that the difference found between Experiments 1 and 2 on the one hand and Experiment 4 on the other is that activation takes repeated presentations to build up. Further, a likely explanation for why several activated items in the lexically constrained sentences did not substantially interfere with selecting a response may be one proposed by R. C. Martin and Biegler (in press) relating to findings with verb generation studies. It may be that the relationship between the number of responses in a verb generation or sentence
completion task is essentially a fan effect, with activation of any individual item being smaller the greater the number of other responses associated to the context, as has been proposed in retrieval from long-term memory (e.g., Anderson, 1974). Such account also fits with findings in studies of sentence constraint. For instance, Schwanenflugel and Shoben (1985) compared onset latencies in reading the final word in either a sentential or neutral context while manipulating the sentence constraint and whether the final word was the most commonly given completion (expected) or a semantically related, rarely given completion (unexpected). They found (Experiment 3) that the expected completions were primed more in the high-constraint sentences than the low-constraint sentences, but unexpected completions were read significantly slower in the high-constraint sentences as compared to a neutral context, while unexpected completions were primed similarly to the expected completions. This indicated that activation in the high-constraint sentences was concentrated in one likely response, but activation in the low-constraint sentences was diffused among possible completions.

It does not appear that ML could be described as being like the refractory access patients reported by Warrington and colleagues. Going back to the four major factors defining refractory access patients—consistency, semantic blocking, rate of presentation, and word frequency—ML does not fit with the pattern of refractory access patients on these factors. Although ML did show an exaggerated semantic blocking effect, with an increasing semantic interference across presentations, and was affected by the presentation rate, which are consistent with a refractory access disorder, he also showed a pattern of declining response times for the unrelated condition in both experiments and a
normal word frequency effect in the production experiment, which would be inconsistent
with a refractory access account.

AR seemed to be similar to ML, and it at first appeared that he may have a similar
deficit to ML differing only in severity, but a careful look at his performance revealed
that his deficit is qualitatively different from ML’s. He, like ML, showed increasing
onset latencies in the production experiment for the related condition and no priming in
the comprehension experiment for the related condition. ML, however, showed priming
for the unrelated condition in both experiments, while AR showed no priming. This
seems to indicate that AR has a deficit that affects both production and comprehension,
but which does not necessarily involve the semantic system. Although he may have
some semantic disorder, the simplest explanation for his pattern of results would be that
he has a deficit at the level of lexical representations which is an underactivation of
lexical representations making selection of them difficult in production and activation
difficult in comprehension. This did not appear to be refractoriness of the lexical
representations per se, since he showed increasing response times only for the related
condition of the production experiment, whereas the other conditions showed no
significant change in response times in either direction. If he did have a refractory
disorder, it would be expected that his response times would increase over time, or at
least he would show a growing semantic interference effect in the comprehension study.
The increasing response times in the related condition for the production experiment
could be explained by a level of competition not different from the controls, but resulting
in increasing effect due to the low baseline activation level of lexical representations.
Experiment 3 and 4 provided results that were consistent with this interpretation. AR
showed great difficulty in the category fluency task, often only being able to produce the most common members of categories. In Experiment 4, the sentence completion task, he showed difficulty in the sentence types involving the least constraint, which would be predicted if he does have difficulty in selecting lexical items due to underactivation and if constraint plays a role in the selection of lexical items, as has been argued by some (Griffin & Bock, 1998). AR's results in the sentence completion study would also be in line with the fan effect account sentence completion. If activation is spread among possible responses, with activation of individual items diminishing as more candidate responses are added, then activation among lexical candidates may be spread so thin that no item is selected.

In terms of his pattern of performance, AR seemed to be more similar to the refractory access patients described by Warrington and colleagues. He was inconsistent in his performance, had a semantic blocking effect which increased across presentations, and was affected by the rate of presentation. He was, however, affected by the word frequency of responses in the production task. It could be possible that he is suffering from a refractory deficit, but is still affected by the word frequency of items. There is evidence that speaks against a refractory account for AR. Refractory effects supposedly arise from the repeated presentation of items, but AR shows evidence of lexical selection difficulties arising in a single trial. His difficulty in the sentence completion task with low-constraint and lexically constrained sentences seems to indicate that lexical representations are already at a low level of activation for him, rather than becoming underactivated with repeated selection of lexical items.
One question that might be raised about AR’s performance is whether it is valid to compare his data with those of the other subjects. AR showed incredibly long onset latencies and reaction times in Experiments 1 and 2, and the question is whether he is even performing the same task as the other subjects, and if not, how could conclusions be drawn about the nature of his deficit given his performance? It would not be surprising at all if AR were actually attempting to perform these tasks in a manner different from the other subjects. Since he often finds it difficult to retrieve words, he has probably adopted some strategy in tasks such as naming pictures to perform the task. One strategy he likely employs is to just produce another name for the picture (for instance, calling a picture of a rabbit a “bunny”). Despite the likely adoption of alternative strategies to perform language tasks, I do not think that this would invalidate the interpretation of his results in this case. Producing the name of a picture or comprehending the meaning of a word is an automatic task which occurs without awareness of the steps involved or the nature of the representations that are retrieved. Thus, such automatic language tasks are very different from cases where one would be more concerned about subjects adopting different cognitive strategies, such as logic and reasoning tasks or some working memory tasks. Regardless of any alternative strategies he may employ in such basic language tasks, AR presumably must still retrieve the same linguistic representations and carry out the same steps as unimpaired people, and it should be possible to deduce from his performance on different tasks what representation he has difficulty retrieving or what step he is having difficulty in carrying out.

LC showed a different pattern of performance which indicated yet a different deficit for him. He showed no priming for either the related or unrelated conditions in
the production experiment, but priming for both conditions in the comprehension experiment. This seemed to indicate that he has a deficit at a level specific to the phonological processing of words for production. A deficit in the phonological level for production is consistent with his jargonistic speech, reflecting his difficulty in forming phonological representations of words for production. He also has difficulty in phonological processing of comprehended speech, but apparently this did not cause an abnormal pattern of performance in the comprehension task, which is would not be unexpected given that the words in the comprehension experiment were typically not very phonologically similar, thus limiting confusability. It is somewhat strange that he failed to show any priming at all in the production experiment. It would seem that he would have priming from some earlier level of representation—semantic, lexical, or both—which would make the phonological formation of the words easier after repeated productions, but apparently this was not the case. In the sentence completion experiment, a very surprising result was that LC was able to think of the more appropriate interpretation of ambiguous words more often than all but one of the controls. As mentioned earlier, he did have difficulty understanding the sentences auditorily, and had to have several repeatedly played for him, which may have caused him to focus more on the sentences, whereas the older controls often went through the sentences very quickly. His difficulty in auditory comprehension of words did not seem to adversely affect his performance in Experiment 2, probably because the words were repeatedly presented and were not easily confusable with one another.
Finally, LW was very similar to the controls across all the experiments, as was predicted from the outset, based on his performance in earlier studies (Biegler & R. C. Martin, 2006; Crowther, Biegler, & R. C. Martin, 2005).

There are some other issues that need to be addressed in future research, specifically related to open questions about the cognitive processes involved in repeated production and comprehension. The first issue, which was discussed in the introduction, was the issue of whether the semantic blocking effects found in repeatedly naming tasks result from the same kind of processes of semantic interference effects found in auditory and visual distractor naming tasks. Damian and Als (2006) pointed out that the auditory and visual distractor tasks cause semantic interference only within a short window of time, operating on the order of a few hundred milliseconds within the presentation of the target item, while the semantic blocking effect found in repeatedly naming of single picture presentations requires several trials to build up and is preserved with delays of several seconds between trials, with interleaved unrelated items, and even with intervening distractor tasks. It is also difficult to explain the similar effects in these two kinds of tasks in terms of only the activation of lexical items. Activation-based models, for example the Levelt, Roelofs, and Meyer WEAVER++ model (Levelt, Roelofs, & Meyer, 1999; Roelofs, 1992, 1997) or Anderson’s ACT* model (Anderson, 1983), could account for the semantic interference effects occurring over short SOA’s or the semantic blocking effects occurring over long periods of time, but they cannot account for both. In the case of short SOA effects, the item and its semantic neighbors become activated over a short time period and this activation then quickly dissipates. In the case of longer term effects, activation would have to build up more slowly and then remain for a longer
period of time. Damian and Als (2006) proposed that the short SOA effects may be due to a short period of activation which quickly dissipates, whereas the longer term semantic blocking effects may be due to an incremental learning process, in which each presentation of an item results in some form of episodic learning. One kind of model they thought might best explain this learning procedure was a weight-based learning model like that proposed by Becker et al. (1997), in which each presentation of an item results in a change of the weights between different items. Damian and Als suggested that a similar change in weights in the connection between individual items and their semantic category could result in the items becoming competitors with one another due to their increased connection to the category node, rather than a higher level of activation of individual items.

A second issue deals with possible effects of set size and expectancy. Damian and Als (2006) dismiss expectancy as a factor involved in the semantic blocking effects in their study. They claimed that expectancy would be more likely to make a related context easier, since the items are all of one category and thus easier to keep track of. They also say that since the effect was not changed when unrelated items were interleaved in a related block, this is evidence that expectancy was not an important factor. Finally, they claim that any effects of expectancy would be overridden by larger effects caused by episodic encoding. However, there is the possibility that expectancy does play some role in such experiments. It was noted for Experiments 1 and 2, that a strict cyclic presentation could not be employed, because in an earlier version of the experiment the subjects would predict the last item of each cycle. A strict cyclic presentation was not adhered to in order to eliminate this effect, but that does not mean
that subjects were not still generating expectancies in this experiment, or any of the other repeated naming studies. Although it is assumed that expectancy plays no role, and that any expectancies should only appear as noise in the data, it is conceivable that expectancy may interact with relatedness, or possibly even the set size for the number of individual items (i.e., pictures) in each block. It seems unlikely that, during the task, subjects are not generating at least some expectancies, and these would probably be something of the nature of keeping track of items that have recently been presented and those that have not been presented for some time. After the first presentation cycle in the case of single picture presentations and after the first trial in the case of multiple picture presentations, the subject has already been exposed to the whole set of items and will change their expectancies for the likelihood of each item being presented as the experiment progresses. If this is so, then it would be expected that there would be a greater difficulty in the related condition, since there would be increased proactive interference from having to deal with continuously updating information about related items. If it is the case that subjects are using expectancies, then it would be predicted that expectancy would also interact with the number of different pictures used in each block, with there being greater difficulty with more items, since a greater number of items will put more strain on working memory capacity.

A final issue concerns the effect of presentation rate in the experiment. This effect was not discussed in too much detail with regards to the patients in the present study, because it was difficult to determine what was causing this effect to only appear in the patients who had a pattern of performance that differed from the controls. According to the over-inhibition account, a slow rate of presentation would be beneficial to
refractory access patients as this allowed more time for the items to come out of their refractory state, whereas the over-activation account would posit that a slower rate of presentation would allow activation more time to dissipate making items easier to differentiate during selection. Some account like this might be relevant for ML, or possibly AR if there is actually some semantic involvement in his deficit, but this does not seem to be relevant for LC, who showed an effect of presentation rate like ML and AR, but did not show any evidence of a growing semantic blocking effect across trials. It may be the case that the rate of presentation affects performance based on how difficult the task is for the subject, so it would then be expected that a similar rate effect can be found with normal subjects, but employing faster rates of presentation for them.

8. Conclusions

In summary, these series of experiments seem to indicate that the two frontal patients, ML and AR, who have superficially similar semantic blocking effects have deficits that differ in quality and not simply degree. ML appears to have a deficit in the semantic system involving over-active semantic representations. ML’s results give evidence for an inhibitory mechanism in the semantic system which reduces the level of activation for semantic representations when they are no longer relevant to the task at hand. AR appears to have a deficit caused by underactive lexical representations or difficulty in activating lexical representations. Although ML and AR show some similarities to the refractory access patients described by Warrington and colleagues, their results do not support an account in which semantic or lexical representations undergo a period of over-inhibition following their activation.
The question thus arises as to whether over-inhibition is necessary to account for the performance of any patients, or whether an over-activation account or other account can be applied to the patients reported by Warrington and colleagues (e.g., Warrington & Cipolotti, 1996; Warrington & McCarthy, 1983, 1987). Unlike ML and AR, the patients reported by this group show increasingly poor performance on even unrelated items in the blocked comprehension task. For some patients, this decrease in comprehension across cycles for unrelated items can be quite dramatic (e.g., Crutch & Warrington, 2005b). Given the large lesions and severe language deficits of the patients reported by Warrington and colleagues, it is possible, however, that a thorough investigation of individual cases would give rise to alternative hypotheses about the source of their so-called refractory pattern. If further investigation supported the refractory account, it would be important to determine if evidence of a refractory period could be established for normal subjects as well. Otherwise, it might be possible that what is observed for the patients is reflective only of a severely damaged system and does not reflect an operation that is part of the normal language processing system. Warrington and Cipolotti (1996) suggested anoxia (or, technically speaking, hypoxia), in which there is damage to structures involved in supplying neurons in certain regions with oxygen. Gotts and Plaut (2002), who created a connectionist model of spoken word comprehension which was lesioned to produce the access/storage dissociation, have suggested damage to structures involved delivering neurotransmitters (they suggested specifically acetylcholine and norepinephrine) that may act to reduce the effects of the normal process of synaptic depression following a period of high activity in a neuron. From the perspective of language processing, the refractory access patients, though not having a loss of
information, would then appear to have a form of damage to the representations, in that it is the level of individual representations themselves in which there is a dysfunction. For ML, it would appear that he has damage to an inhibitory selection mechanism which is independent of the representations themselves.
References


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Appendix B: Sentences Used in Experiment 4

High Constraint

While trapped in the desert, the thirsty man was lucky to find some _____.
The fisherman opened up the oyster to get the _____.
After school, the teenager went to mow his neighbor's _____.
The man was called by the woman on the _____.
At the tailor's, the young businessman bought new _____.
The family bought some logs to burn in the _____.
The boy cried when he tripped and stubbed his _____.
The men went to the bar to have a _____.
The whole family traveled to the air show to see all the _____.
When the power went out, the family lit some _____.
The tourists were stranded alone on the desert _____.
The pilots were able to safely land the _____.
The neighbors were woken by the loud _____.
The dirty child had to take a _____.
The man filled his car up with _____.
The fisherman went out to catch some _____.
The boy hated having to brush his _____.
During class, the teacher made the student write the answer on the _____.
The young woman spoke to the tall _____.
He couldn't read the paper without his _____.
The old shopkeeper forgot to lock the _____.
The mechanic wasn't able to fix the _____.
The man dried himself with a _____.
The lumberjack cut down a maple _____.
The young children enjoyed the puppet _____.
At the observatory, the girl looked at the planet through the _____.
The mother combed her daughter's _____.
That winter, the family's electricity was turned off by the electric _____.
The parents were concerned that their children were watching too much _____.
At the park, the boy watched the squirrel climb the _____.

Low Constraint

While standing on the street, the man and the woman saw a _____.
She was surprised, because he told her about the _____.
The man picked it up and dropped it in the _____.
On his way home, the boy picked up some _____.
The man at the store paid for the cheap _____.
He was frustrated by the woman at the _____.
At the store, the woman couldn't find the new _____.
The man stood at the window to watch the _____.
The crowd gasped when they were surprised by _____.
She went outside to take a picture of the _____.
The husband and wife sat on the couch to talk _____.
The child thought that the cloud looked like _____.
While waiting for the bus, the man saw a _____.
The boy went after school to buy a green _____.
The family disliked watching the commercial for _____.

The reporter on the news questioned the ____.
The old man was distracted by the ____.
The worker forgot to bring over the ____.
The doctor wasn't able to find the ____.
After work, the man went to the pawnshop
to get a ____.
The man filled his house with ____.
The carpenter couldn't go there without his ____.
None of the little children could stand the ____.
The man was not prepared for the ____.
The woman wasn't able to understand the ____.
The little girl played outside with the small ____.
There was nothing wrong with the ____.
The little children played in the ____.
The man already knew about the ____.
The car crashed into the ____.
The angry senator defended the ____.
At the gallery, the painting in the exhibit
was of a ____.
In the letter to his sister, the brother
mentioned something about the ____.
Because the man was tired, he didn't feel like ____.
On their vacation, the family took a picture
of the ____.
Because he tripped and fell, the boy
dropped the ____.

Lexically Constrained

When he left home for work, the man
forgot to put on his ____.
The boy was teased because he often drank ____.
The man rode to work every day on the ____.
On Saturdays, the family got together to play ____.
The woman drinking in the bar had a ____.
The boy went to school to become a ____.
The criminal was accused by the witness
of ____.
At the university, the student took a class
on ____.
The couple took a trip to Italy to eat ____.
He thought the gem in the necklace was a ____.
The woman was tired so she sat on the ____.
The man working in the backyard went to
the tool shed to get a ____.
The man decided his next car would be a ____.
The judge was angry, so he yelled at the ____.
The man drove all the way to the ____.
The carpet in the house was colored ____.
He was sad to be selling the antique ____.
The athlete said his favorite sport was ____.
The man at the bar sometimes felt ____.
The flower the gardener picked was a ____.
The family went on a vacation to ____.
The boy's favorite thing for breakfast was ____.
In the morning, the first thing the boy did
was ____.
The family's house was destroyed by the ____.
The secretary at the firm copied the ____.
The repairman gladly came to fix the ____.
The old woman said she liked to eat ____.
The family visited the farm to see a ____.
The worker at the zoo was chased by a ____.
He drew the picture with a ____.
The farmer in the country grew ____.
The children's favorite thing for dessert
was ____.
The young couple named their daughter ____.
At the concert, the musician played a song
on the ____.
The girl loved her pet ____.
Out in the woods, the birdwatcher was surprised to see a ____.
The man went to the park so that he could read a ____.
He forgot that the month he went on vacation was ____.
On the street, the man attacked the policeman with a ____.

*Ambiguous Phrase*

When he got home from work, the man threw his hat into the ____.
He was uneasy because the walls had ____.
The child pulled the injured rabbit out of the ____.
At the ranch, the cowboy was back in the ____.
The hunter out with his sick friend caught a ____.
The woman accidentally let the cat out of the ____.
The old man had a pain in his ____.
At the service, the minister was preaching to the ____.
The dog was upset because the cat had his ____.
The lawyer found that the proof was in the ____.
The old man accidentally put one foot in the ____.
The man resting in the woods had his back against the ____.
The grocery clerk put a price on his ____.
The forgetful man thought it was beside the ____.
People said the queen had the golden ____.
The carpenter pounded another nail in the ____.
The employees were all in the same ____.
The maid swept the toy under the ____.
The middle-aged man walked over the ____.
In the woods, the camper lost his supplies when they fell by the ____.

The papers were cut from the same ____.
The teacher gave her student the third ____.
The teacher was happy to make the ____.
The old gardener had ants in his ____.
The mechanic was stuck by a bolt from the ____.
The camper forgot to take a ____.
The medic pulled out all the ____.
The construction worker hammered out the ____.
Even in the dark, he was able to see the ____.
The housewife brought home the ____.
Along the entire beach, the man saw that the coast was ____.
The sailor couldn't stand the heat so he got out of the ____.
Because he dropped the note, it fell between the ____.
In the playground, all of the children were following the ____.

*Ambiguous Word*

While out walking one sunny day, she saw the son/sun and his ____.
The children thought the parents' presence/presents was ____.
The woman wrote down the man's lengthy address at the ____.
At the museum, the painter framed the innocent ____.
The man working at the toll booth waived/waved the ____.
The icy stairs/stairs tripped up the boy during his ____.
At the church, the priest preyed/prayed on the trusting ____.
The teacher thought the grade was too steep to ____.
The lawyer noticed that the claws/clause were in the ____.
The cast in the play was put on the girl's ____.
The audience was impressed by the actor's roll/role across the ____.
The writer used the pen to catch a ____.
The plain/plane by the airport was overgrown ____.
The woman thought the man's feat/feet was very ____.
The game ran off quickly into the ____.
The lawyer dropped the case on the ____.
The man put a new coat on the ____.
At the concert, he noticed that the queen's band was made of ____.
The organ was transported from the ____.
The farmers use that flower/flour to make ____.

The gardener dug up some dirt on his ____.
The musician played on the base/bass of the ____.
The coach was waiting outside the ball for the ____.
The dog wouldn't heal/heel from the ____.
The man picked up the issue at the ____.
The trashman dumped his long-time ____.
That night, the boy saw all the famous stars at the ____.
At the baseball game, the man used the batter to make ____.
The people were afraid during the turbulent reign/rain of the ____.
The man pulled the frightened hare/hair right out from its ____.
Because of the light, the teacher's pupils were ____.
At the dinner, the guests thought the man's toast was too ____.