An Investigation of Working Memory Influences on Lexical Ambiguity Resolution

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The present study employed a combined semantic judgment and lexical decision priming paradigm to examine the impact of working memory on the inhibitory processes of lexical ambiguity resolution. The results indicated that overall, participants activated one meaning of a presented homograph while not priming the alternative meaning. As hypothesized, participants with high working-memory spans exhibited a pattern of priming for congruent conditions and a lack of positive priming for incongruent conditions. In contrast, participants with low working-memory capacity showed priming for both congruent and incongruent conditions, but only for conditions in which the context was related to the dominant meaning of the homograph. The results suggest that people with low working-memory capacity have difficulty inhibiting inappropriate homograph meanings and further demonstrate that these difficulties may vary as a function of context-meaning dominance.

Keywords: homographs, inhibition, semantic priming

Ambiguities in written language are common and act to make reading comprehension a particularly complex procedure, requiring increased cognitive resources (Miyake, Just, & Carpenter, 1994). Homographs, one type of lexical ambiguity, are words in which the same orthographic representation is associated with more than one meaning. Homographs can be either balanced or biased in terms of meaning frequency. Biased homographs have one meaning that is encountered significantly more frequently than any alternative meanings, whereas all meanings occur with approximately equal frequency in a balanced homograph. The word *bark* is an example of a biased homograph (Twilley, Dixon, Taylor, & Clark, 1994). The dominant or most frequent meaning relates to a financial institution. The subordinate or least frequent meaning, on the other hand, describes the side of a river.

The most appropriate meaning for a homograph is typically dependent upon the context in which the homograph occurs. In a non-neutral sentence, the appropriate meaning of a homograph is usually clear. Consider the following sentence: 'He deposited some money at the *bank*.' Reading this sentence, it is clear which meaning of the homograph is being referenced. Most people do not even consciously retrieve the alternative meaning. Competing models of lexical ambiguity processing argue that (a) only the contextually appropriate meaning is activated (selective access), or (b) an initial stage of multiple-meaning activation occurs prior to selection of the contextually appropriate meaning and suppression of the nonselected representation (exhaustive access), or (c) meaning activation is exhaustive but context-sensitive (see Simpson, 1984).

Exhaustive access models of ambiguity processing gain support from findings that nonselected or inappropriate meanings are actively inhibited to below threshold levels, leaving only the appropriate meaning available (Gernsbacher & Faust, 1991b). Further evidence of this meaning inhibition was reported by Nievas and Mari-Beffa (2002), who designed a single-word priming experiment to measure the levels of activation for the nonselected meaning of the homograph and ascertain whether inhibition was at least partially responsible for meaning selection. Participants were first presented with a display containing two single-word primes, referred to as prime one and prime two. This display was then followed by a target word. In the experimental conditions, prime one was a homograph, such as *fence*. Prime two provided the participant with context, encouraging meaning selection and facilitating disambiguation. For example, the homograph *fence* would be followed by either *garden* (dominant context) or *sword* (subordinate context). Conditions in which the target was related to the context in prime two, as well as the homograph in prime one, were referred to as congruent conditions. On the other hand, conditions in which the target was not related to the context in prime two (although still related to the alternative meaning of the homograph in prime one) were referred to as incongruent conditions.

Upon completion of the experimental procedures, Nievas and Mari-Beffa (2002) divided their participants into three groups based on their speed and accuracy. These groups were (1) participants who responded quickly to the target and had a high error rate, (2) participants who responded more slowly to the target and had a low error rate, and (3) a medium group. Nievas and Mari-Beffa hypothesized that the three groups may have used different strategies to approach the task, thus reflecting the importance of providing participants with instructions emphasizing fast and accurate responses to items, in order to reduce individual differences in strategy use. Increased semantic priming, both positive and...
negative, was found in the slow but accurate group relative to the other two groups. In addition, in the slow but accurate group, negative semantic priming occurred for the nonselected meaning of the homograph, suggesting that inhibition to below resting levels caused increased reaction times when the inhibited meaning was required to be retrieved. This finding was not replicated in the other two groups.

Nievas and Mari-Beffa (2002) showed that the nonselected meaning of a homograph was being inhibited under some conditions. They did not consider, however, the impact that individual differences in working memory may have had upon their results. It has been shown that working-memory capacity is a critical factor in lexical ambiguity resolution (Gunter, Wagner, & Friederici, 2003; Miyake et al., 1994). Miyake et al. (1994) reported evidence to suggest that the larger the working-memory capacity of an individual, the more attention and activation that individual can allocate to sustain multiple meanings of a homograph over time. More specifically, Miyake and colleagues reported that in participants with low working-memory capacity, meaning selection occurs earlier, resulting in activation of the most frequently accessed dominant meaning. On the other hand, participants with a high working-memory capacity still had both meanings of the homograph activated after the eight-word delay. In contrast, Gunter et al. (2003) found evidence that individuals with a high working-memory capacity were more efficient in inhibiting alternative meanings of lexical ambiguities, whereas individuals with a low working-memory capacity maintained both meanings.

Given that differences in working-memory capacity have been linked to differences in lexical ambiguity processing (Gunter et al., 2003; Miyake et al., 1994), the purpose of the present study was to employ the methodology of Nievas and Mari-Beffa (2002) to address the impact of working-memory capacity on the inhibitory aspects of lexical ambiguity resolution. This was achieved by separating participants into groups depending upon their results on a test of working memory. Based on the findings of Gunter et al. (2003), it was predicted that participants with high working-memory capacity would be more efficient at inhibiting the nonselected meaning of a homograph than participants with less working-memory resources.

With respect to specific priming predictions, the present study’s participants were required to respond to trials involving a congruent relationship or an incongruent relationship. As mentioned previously, congruent relationships were formed when both the context and the target related to the same meaning of the homograph. Incongruent relationships were formed when both the context and the target related to different meanings of the homograph. Due to the hypothesized ability of people with high working-memory capacity to inhibit nonselected homograph meanings, participants in the high working-memory group would be expected to demonstrate priming only for congruent conditions. In contrast, participants with low working-memory capacities would be unable to quickly and successfully inhibit the nonselected meaning, so that all homograph meanings would remain activated (Gernsbacher & Faust, 1991b). Accordingly, participants in the low working-memory group would be expected to demonstrate priming for both congruent and incongruent conditions.

Method

Participants

Participants were students completing an undergraduate speech pathology course who were granted course credit for their involvement. The study received ethical clearance from a University of Queensland ethics review committee, and all participants were required to provide informed consent before experimental procedures commenced. As participation was for course credit, all students enrolled in the course were allowed to complete the experiment, regardless of whether they met exclusionary criteria. Data were used only for participants who reported that they were native English speakers with normal or corrected-to-normal vision; that they were right-handed; and that they had no history of neurological trauma, mental illness, or substance abuse. After these exclusionary criteria were taken into account, a total of 45 students contributed usable data. There were 44 women and 1 man, therefore only data from women were analyzed, to avoid this potentially confounding variable. The participants were mainly Caucasian and had a mean age of 21.4 years (SD = 3.33), and had completed a mean of 15.0 years of education (SD = 0.80). Participants completed the experimental procedures in groups of up to eight. Each group completed a working memory task, which was followed by a semantic priming task. Together, the tasks took approximately 1 hour and 10 min to complete.

Working Memory Task

Stimuli. Participants completed a word span task as a measure of working memory capacity. The present word span task was similar to those employed in previous investigations of working memory (e.g., Murphy, Roodenrys, & Fox, 2006; Tehan & Tolan, 2007). Stimuli for the word-span task consisted of 88 unambiguous words, each containing four to five letters and one or two syllables. Words were selected from the Medical Research Council (MRC) database (Wilson, 1987). Stimuli within each list were matched with respect to frequency, concreteness, and imageability. Words were randomly placed into lists of five, six, seven, or eight words. Three experimental lists for each level were created. In addition, two lists of five words were created for practice trials.

Procedure. Participants were asked to listen to a list of words, recall the words, and write them down in the same order. No delay took place between the words being read and the participants recording their response. Two practice trials preceded the experimental trials and participants were offered the opportunity to ask questions about the task prior to the experimental trials commencing. To prevent participants from receiving clues as to how many words they had to remember for each trial, the order of the experimental trials was randomized.

Two groups were formed post hoc according to participants’ individual scores on the working-memory task. In order for a participant to receive credit for a certain word span (from four to eight words), at least two out of the three items for that word span size had to be recalled correctly. Participants who had a word span of more than five items were placed into the high working-memory group (n = 19), while the remaining participants were placed into the low working-memory group (n = 21). Examination of these groups revealed no significant difference with respect to age, t(40) = 1.158, p = .254, however, a significant difference for
mean years of education was detected, \( t(40) = 2.456, p = .018 \). It was interesting to note that the high working-memory group had fewer years of education than the low working-memory group.

**Priming Task**

**Stimuli.** Seventy-two homographs were selected as experimental stimuli. Only biased homographs were selected from norms of relative meaning frequency by Twilley et al. (1994). As previously mentioned, a biased homograph is a homograph that has a dominant and a subordinate meaning, rather than two or more approximately equally occurring meanings. Twilley et al. (1994) considered a meaning of a homograph to be the dominant meaning if over 70% of people gave that response to a word-association task. If a meaning occurred for fewer than 30% of responses, it was considered to be a subordinate meaning (Twilley et al., 1994). For each homograph, two words associated with the dominant meaning, and two words associated with the subordinate meaning were also selected. This process produced a further 288 stimulus words. These associates were all unambiguous nouns, taken from a collection of free association norms (Nelson, McEvoy, & Schreiber, 1998). Each homograph and associate was then matched to an unrelated control word (see Table 1) on the basis of word length, frequency, concreteness, and imageability, using the MRC Psycholinguistic Database (Wilson, 1987). In addition, 572 pronounceable nonwords were obtained from the Australian Research Council (ARC) Nonword Database (Rastle, Harrington, & Coltheart, 2002) and were matched to the control words for length.

Stimulus words were then arranged into word triplets. Each word triplet consisted of two prime words followed by a target (See Figure 1). Twelve conditions were created from the selection of stimulus words, as shown in Table 1. In each condition, the prime word in the initial position could be either a homograph or an unambiguous word. The prime word in the second position could be a word semantically related to the initial ambiguous prime (providing a context for the initial prime) or an unrelated word. If this word was semantically related to the initial prime, it could be related to either the dominant or subordinate meaning. This provided a dominant or a subordinate context and was designed to trigger retrieval of one meaning of the homograph in the initial prime position. Unrelated dominate and subordinate targets were created by repairing dominant and subordinate related targets with unrelated contexts.

The target word in the final position could be a word semantically related to the initial prime (to either the dominant or subordinate meaning), an unrelated word, or a nonword. When a dominant context was followed by a subordinate target, or vice versa, an incongruent condition was created. Congruent conditions occurred when both the context and target were either dominant or subordinate. Conditions in which there was no relationship between the prime words and the target were included in order to design a completely balanced experiment and to avoid any form of response bias. Stimuli in these conditions consisted of two unrelated prime words followed by either a nonword or another unrelated, unambiguous word as a target. Analysis of the entire stimulus set showed the relatedness proportion (defined as the number of related word targets divided by the number of related plus unrelated targets) for each condition for each list.

<table>
<thead>
<tr>
<th>Context</th>
<th>Target</th>
<th>Example</th>
<th>Trials*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Related</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dominant</td>
<td>dominant</td>
<td>bank, save</td>
<td>money</td>
</tr>
<tr>
<td>Dominant</td>
<td>subordinate</td>
<td>bank, save</td>
<td>lake</td>
</tr>
<tr>
<td>Subordinate</td>
<td>dominant</td>
<td>bank, river</td>
<td>money</td>
</tr>
<tr>
<td>Subordinate</td>
<td>subordinate</td>
<td>bank, river</td>
<td>lake</td>
</tr>
<tr>
<td>Unrelated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dominant</td>
<td>dominant</td>
<td>bank, save</td>
<td>garden</td>
</tr>
<tr>
<td>Dominant</td>
<td>subordinate</td>
<td>bank, save</td>
<td>sword</td>
</tr>
<tr>
<td>Subordinate</td>
<td>dominant</td>
<td>bank, river</td>
<td>garden</td>
</tr>
<tr>
<td>Subordinate</td>
<td>subordinate</td>
<td>bank, river</td>
<td>sword</td>
</tr>
<tr>
<td>Dominant</td>
<td>nonword</td>
<td>bank, save</td>
<td>flerg</td>
</tr>
<tr>
<td>Subordinate</td>
<td>nonword</td>
<td>bank, river</td>
<td>flerg</td>
</tr>
<tr>
<td>Unrelated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonword</td>
<td>desk, flower</td>
<td>flerg</td>
<td>24</td>
</tr>
<tr>
<td>Unrelated</td>
<td>word</td>
<td>desk, flower</td>
<td>wheel</td>
</tr>
</tbody>
</table>

Note. A condition was said to be congruent if both Prime 2 (the second word in the target display) and the target word related to the same meaning of the homograph in Prime 1 position. This meaning could either be the dominant or the subordinate meaning.

* Number of trials in each condition for each list.

![Figure 1](image-url) Illustration of the experimental design, containing both a semantic relatedness judgment task and a lexical decision task.
unrelated word targets) to be 0.5. The nonword ratio (defined as
the number of word prime/nonword targets divided by the number
of word prime/unrelated word targets) was calculated to be 0.66. Although nonword ratios of less
than 0.5 are important to reduce the influence of any postlexical
processing mechanisms and to encourage automatic processing, it
was not possible to reduce this ratio further without affecting the
balanced nature of the experiment.

Word triplets were split into four lists. Each participant was
randomly allocated to one of the four lists. The lists were designed
so that no participant saw any stimulus word more than twice
across 288 trials and each participant was presented with the same
number of trials from each condition. Each stimulus list was then
divided into three blocks to allow for rest periods, the order of
which was again randomized between participants to eliminate any
order effects.

Procedure. The semantic priming task was presented using
experimental laboratory software E-prime (Version 1.1; 2002).
Participants were seated 60 centimetres from a computer screen,
with two fingers of their right hand resting on a SRB200 response
box (Psychology Software Tools, Pittsburgh PA). Each participant
was instructed to place one finger on a button marked “yes” and
one on a button marked “no.” The response box measured partici-
 pant reaction times (in milliseconds) to both the semantic relat-
edness and lexical decision tasks. E-prime software recorded the
accuracy and response latency of participants’ responses. Stimuli
were presented centered on the computer screen in cyan on a black
background. Text was shown in size 14 Times New Roman font
and in lower case. Priming procedures involved judgments regard-
ing semantic relatedness and lexicality. Initially, a display contain-
ing both prime words appeared. Participants had to decide whether
these words were related (semantic relatedness). The target was
then immediately displayed and participants had to decide whether
or not the target letter string spelled a real word (lexicality). Instructions were provided orally to participants, as well as being
presented on the computer screen prior to the task commencing.
Participants were instructed to respond as quickly as possible,
taking care to respond accurately.

Each trial began with an alerting signal, ‘*****’, which was
shown for 500 ms in the center of the computer screen (see Figure
1). A blank display then appeared for 1,000 ms, and was followed
by the prime display. Participants were presented with both primes
on a single display, with the homograph positioned immediately
above the associate prime, and were required to make a semantic
relatedness judgment. If no response was made after 2,000 ms, this
display disappeared and an error was recorded. Next, a blank
screen appeared for 250 ms prior to the presentation of the target.
Participants made a lexical decision on the target, with time out
occurring after 1,500 ms. An intertrial interval of 1,500 ms was
employed.

Participant reaction times, measured from the presentation of the
target stimuli to the pressing of the response box, were recorded
along with data on accuracy for both the semantic relatedness and
lexical decision tasks. A set of 16 practice trials (consisting of a
combination of all conditions) was completed before the experi-
ment, and participants were encouraged to repeat these practice
trials until they felt confident with the demands of the task.

Results

Analyses were conducted on reaction times for trials where
responses to both semantic relatedness and lexical decision tasks
were correct. Four participants were found to have no correct
responses in two or more of the experimental conditions and were
subsequently removed from further analyses. All response times
for the lexical decision task that were less than 100 ms or greater
than 1,000 ms were eliminated. Response times for the semantic
relatedness judgments that were either less than 100 ms or greater
than 1,500 ms were also eliminated from further analyses. This
procedure led to 3.25% of participants’ responses being excluded.

Mean target reaction times for each participant for each condi-
tion were then calculated, and outliers (response times greater than
two standard deviations above or below the individual partici-
 pant’s mean for that condition) were replaced by the individual
participant’s relevant upper or lower cut-off point. Outliers ac-
counted for 1.2% of all responses. Lexical decision reaction times
were then normalized by log transformation. Subsequent exami-
nation of kurtosis and skewness revealed no significant deviation
from the normal distribution after this procedure.

The Effect of Prime Context, Target Condition, and
Relatedness on Lexical Decision Reaction Time

Linear mixed model analyses were conducted on the dependent
variable of lexical decision reaction time with prime context (dom-
inant, subordinate), target condition (dominant, subordinate), and
relatedness (related, unrelated) as fixed factors and subject as a
random factor. Significant main effects were found for prime
context, $F(1, 1714) = 24.442, p < .001$; target condition, $F(1,$
$1712) = 5.049, p = .025$; and relatedness, $F(1, 1712) = 18.261,$
$p < .001$. These main effects indicated that participants responded
faster when the prime context was dominant, when the target
condition was dominant, and when the prime context and target
condition were related (see Table 2). There was also a significant
prime context x target condition effect, $F(1, 1713) = 6.783, p = .009$. Hence, when both the prime context and target
condition were either dominant or subordinate, faster reaction times to the
lexical decision task resulted. A significant three way interaction
was also observed between prime context, target condition, and
relatedness, $F(1, 1714) = 5.703, p = .017$. This interaction was
further investigated by pairwise comparisons, which were carried
out on the entire data set to identify group priming effects. Priming
effects were calculated by comparing the reaction times for unre-

<p>| Table 2 |
| Mean Lexical Decision Reaction Times as a Function of Prime Context, Target Condition, and Relatedness |</p>
<table>
<thead>
<tr>
<th>Context</th>
<th>Dominant target</th>
<th>Subordinate target</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Related</td>
<td>Unrelated</td>
</tr>
<tr>
<td>Dominant</td>
<td>544.03</td>
<td>593.52</td>
</tr>
<tr>
<td></td>
<td>(137.34)</td>
<td>(136.95)</td>
</tr>
<tr>
<td>Subordinate</td>
<td>607.71</td>
<td>610.04</td>
</tr>
<tr>
<td></td>
<td>(137.43)</td>
<td>(131.19)</td>
</tr>
</tbody>
</table>

Note. Reaction times are recorded in milliseconds. Values in parentheses represent standard deviations.
lated and related conditions (Neely, 1991). Overall, significant group priming was found for the dominant context/dominant target condition, \( t(1718) = 5.094, p < .001 \); and for the subordinate context/subordinate target condition, \( t(1721) = 2.534, p = .011 \). No significant priming effects were found for the dominant context/subordinate target condition, \( t(1718) = 1.816, p = .069 \); or for the subordinate context/dominant target condition, \( t(1720) = 0.331, p = .740 \). In other words, significant group priming effects occurred only when the target was congruent with the preceding context.

The Effect of Working Memory on Priming

The relationship between working memory, lexical decision reaction time, and priming was examined first in a correlational analysis. Working-memory scores and priming effects for each experimental condition (dominant context/dominant target, dominant context/subordinate target, subordinate context/dominant target, and subordinate context/subordinate target) were entered as variables, and Pearson’s correlation coefficients were calculated. The positive correlation between working memory and priming effects in the dominant-context/subordinate-target condition was significant, \( r = .290, p = .037 \), as was the negative correlation between working memory and priming effects in the subordinate context/subordinate target condition, \( r = -.335, p = .020 \). These correlations indicated that as working-memory performance increased, priming for incongruent conditions decreased and priming for congruent conditions increased.

The linear mixed-model procedure was then repeated using the variables described above (dependent variable of lexical decision reaction time with prime context, target condition, and relatedness as fixed factors and subject as a random factor) with the addition of working-memory group (high or low) as a fixed factor. A significant prime context \( \times \) working-memory effect, \( F(1, 1714) = 15.375, p < .001 \); was identified (see Table 3). No significant interaction was found, however, between working memory and relatedness, \( F(1, 1712) = .087, p = .769 \).

Given the significant correlation identified between working-memory performance and priming effects and the a priori predictions made concerning different priming effects for working-memory groups, it was important to further examine the impact of working-memory function on priming effects. Accordingly, pairwise comparisons were carried out on priming effects for each group (high and low working-memory performance).

For the participants in the low working-memory group, significant priming effects were found only for conditions in which the prime context was dominant (see Figure 2). Priming effects were detected for the dominant-context/dominant-target condition, \( t(881) = 4.443, p < .001 \); and for the dominant-context/subordinate-target condition, \( t(881) = 2.234, p = .020 \). As shown in Figure 3, no significant priming occurred for the subordinate-context/dominant-target condition, \( t(882) = 0.208, p = .835 \); or for the subordinate-context/subordinate-target condition, \( t(882) = 1.216, p = .224 \).

Pairwise comparisons were then carried out for participants in the high working-memory group (see Figure 3). Significant priming effects were found for both congruent conditions (dominant-context/dominant-target and subordinate-context/subordinate-target respectively), \( t(830) = 2.791, p = .005 \); \( t(832) = 2.329, p = .020 \). However, significant priming did not occur for the incongruent conditions, dominant-context/subordinate-target, \( t(830) = .231, p = .818 \), and subordinate-context/dominant-target, \( t(830) = .341, p = .734 \). Hence, these findings mirrored the pattern of priming effects exhibited by the group as a whole. That is, participants in the high working-memory group demonstrated significant priming for congruent conditions only.

The Effect of Context on the Semantic Relatedness Judgment Task

The influence of dominance on semantic judgment speed was also investigated. In order to do so, a linear mixed-model analysis was conducted with semantic judgment reaction time as the dependent variable and working-memory group, subject, and prime context as fixed factors. Participants were found to be significantly slower when performing the semantic relatedness judgment on associates related to the subordinate meaning of the prime homograph, \( F(1, 1727) = 26.174, p < .001 \). This finding did not differ across working-memory groups.

Error Analyses

As previously mentioned, trials in which incorrect responses were recorded for either the semantic relatedness judgment task or the lexical decision task were removed from analysis prior to statistical tests being performed on reaction time data. Total error data was responsible for 26.40% of all responses. The majority of these errors (20.23%) were made in the semantic-relatedness judgment task. It was observed that participants made significantly more errors when the semantic-relatedness judgment had to be made on subordinate conditions \( F(1, 2350) = 85.094, p < .001 \). Further investigation revealed, however, that the number of semantic-relatedness judgment errors did not differ across the two working-memory groups, \( F(1, 2350) = 2.387, p = .122 \). A further 6.17% of all responses were removed due to errors on the lexical decision task. Given the low percentage of errors on the lexical decision task, no further analyses were conducted on error data.

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Table 3

Mean Lexical Decision Reaction Times as a Function of Prime Context, Target Condition, Relatedness, and Working Memory (WM)

<table>
<thead>
<tr>
<th>Context</th>
<th>Dominant target</th>
<th>Subordinate target</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Related</td>
<td>Unrelated</td>
</tr>
<tr>
<td>Low WM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dominant</td>
<td>566.56</td>
<td>625.32</td>
</tr>
<tr>
<td></td>
<td>(154.80)</td>
<td>(142.38)</td>
</tr>
<tr>
<td>Subordinate</td>
<td>603.88</td>
<td>600.38</td>
</tr>
<tr>
<td></td>
<td>(149.09)</td>
<td>(123.82)</td>
</tr>
<tr>
<td>High WM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dominant</td>
<td>518.49</td>
<td>558.07</td>
</tr>
<tr>
<td></td>
<td>(109.41)</td>
<td>(121.71)</td>
</tr>
<tr>
<td>Subordinate</td>
<td>611.32</td>
<td>620.27</td>
</tr>
<tr>
<td></td>
<td>(165.69)</td>
<td>(154.11)</td>
</tr>
</tbody>
</table>

Note. Reaction times are recorded in milliseconds. Values in parentheses represent standard deviations.
Discussion

The present study employed a combined semantic-judgment and lexical decision priming paradigm to examine the impact of working memory on the inhibitory processes of lexical ambiguity resolution. The results indicated that overall, participants activated one meaning of a presented homograph while inhibiting the alternative meaning. As hypothesized, participants with high working-memory spans exhibited a pattern of priming for congruent conditions and inhibition for incongruent conditions. The performance of participants with low working-memory capacities, however, was somewhat contrary to our hypotheses. It was predicted that these participants would show priming for both congruent and incongruent conditions, due to inefficient inhibitory mechanisms. However, as the results demonstrate, this was the case only for conditions in which the context was related to the dominant meaning of the homograph.

The methodology employed in the present study was based on that of Nievas and Mari-Beffa (2002). There was, however, one crucial difference between the two studies. Nievas and Mari-Beffa's participants were divided post hoc into groups assumed to reflect strategy use: (a) slow but accurate, (b) fast but inaccurate, and (c) a medium group. Participants in the current study, on the other hand, were divided a priori into groups based on their performance on a test of working-memory span. Nievas and Mari-Beffa's analyses revealed facilitory semantic priming in congruent conditions, consistent with the overall findings of the current study. In contrast to the current study, however, negative priming was found by Nievas and Mari-Beffa when an item analysis was carried out on the data, although it should be noted that this finding was not consistent across groups or participants. The following discussion will first interpret the results with respect to inhibitory processing during lexical ambiguity resolution. Following this, aberrant findings will be discussed in the context of the center-surround model (Carr & Dagenbach, 1990; Dagenbach & Carr, 1994; Dagenbach, Carr, & Barnhardt, 1990).

The results of the present study further specify the influence of working memory on inhibitory mechanisms in lexical ambiguity resolution. As previously outlined, the exhaustive access model proposes that the nonselected meaning of a homograph becomes inhibited relative to the selected meaning (Gernsbacher & Faust 1991a, 1991b; Simpson, 1984; Simpson & Kang, 1994). Proponents of these models acknowledge that inhibitory ability varies according to the individual's cognitive capacity. Accordingly, it was hypothesized that participants with high working-memory capacities would demonstrate priming only for congruent conditions (Gunter et al., 2003). The results of the current study support this hypothesis.

It was also predicted that participants in the high working-memory group would demonstrate inhibition for lexical items related to the nonselected meaning of the homograph. This was anticipated to be revealed in the form of negative semantic priming for incongruent conditions. However, significant negative priming effects for incongruent conditions were not demonstrated by participants in this group. It is important to consider, however, that meaning inhibition may manifest not only as negative priming, but also as a lack of any priming.

According to the exhaustive access model of lexical ambiguity, all meanings of a homograph are activated initially, irrespective of context (Simpson, 1984; Gernsbacher & Faust, 1991a, 1991b; Just & Carpenter, 1992; Nievas & Mari-Beffa, 2002). Following this initial exhaustive access phase, one meaning of the homograph is selected, and the others inhibited. As such, if no facility semantic priming occurs for a specific meaning of a homograph in a lexical decision task, inhibition is assumed to have occurred. This is because initially, lexical items related to the inappropriate meaning will have received some automatic activation (Neely, 1991). Therefore, a lack of priming may be interpreted as a sign of inhibition, albeit not as robust a sign as negative priming. As such, the results of the participants with high working memory can be explained with reference to the exhaustive access theories of lexical ambiguity processing, despite the fact that no negative priming was observed. It should be noted, however, that a lack of priming in itself cannot be interpreted as a form of inhibition.

While the results for participants with high working-memory capacity are consistent with our predictions in general, the results of the low working-memory group require further consideration.

\[ \frac{\text{Priming Effects (ms)}}{\text{Experimental Conditions}} \]

\begin{table}
\begin{tabular}{lcc}
\hline
\textbf{Experimental Condition} & \textbf{DD} & \textbf{DS} & \textbf{SD} & \textbf{SS} \\
\hline
Priming Effects (ms) & 40 & 20 & 40 & 60 \\
\hline
\end{tabular}
\end{table}

Figure 2. Low working-memory group priming effects and standard errors as a function of experimental condition. Experimental conditions are dominant context/dominant target (DD), dominant context/subordinate target (DS), subordinate context/subordinate target (SS), and subordinate context/dominant target (SD). Vertical lines depict standard errors. Priming effects = unrelated-related reaction times for each of the aforementioned conditions. *p < .05. **p < .001.

Figure 3. High working-memory group priming effects and standard errors as a function of experimental condition. Experimental conditions are dominant context/dominant target (DD), dominant context/subordinate target (DS), subordinate context/subordinate target (SS), and subordinate context/dominant target (SD). Vertical lines depict standard errors. Priming effects = unrelated-related reaction times for each of the aforementioned conditions. *p < .05.
According to inhibition models, participants with low working-memory capacity are expected to have difficulty inhibiting the nonselected meanings of a homograph effectively, resulting in multiple meanings of the homograph remaining activated (Gunter et al., 2003). With respect to the present methodology, facilitation in the form of priming effects for all related targets regardless of congruency would then be expected. Indeed, this pattern of priming effects was exhibited to a degree by participants with low working-memory capacity, but only when the context was dominant. No priming was found for conditions when the context was subordinate.

Although the observed effect of meaning dominance on participants in the low working-memory group was not predicted by inhibition models, the effect of task demands may explain these aberrant findings. When completing the experiment, participants were required to first make a semantic-relatedness judgment on a pair of primes and then quickly make a lexical decision about a target word. It is suggested, therefore, that the complexity of the semantic-relatedness judgment could potentially have affected the later lexical decision task.

It has been found that working memory underpins a range of cognitive processes (Baddeley, 1986; Rosen & Engle, 1998), and that participants with a low working-memory capacity possess a smaller resource pool to fuel these cognitive processes. Further, making a semantic-relatedness judgment on two words based on the subordinate meaning of the homograph is more difficult than making a semantic-relatedness judgment on words related by the dominant meaning. This was demonstrated in the current study by increased overall latencies and errors on judgments for subordinate relationships, as compared with judgments for dominant relationships. As such, it is possible that the demands of this task affected the ability of some participants to make lexical decisions about a related target when the preceding relatedness decision involved a subordinate relationship. In other words, participants were possibly forced to use increased cognitive resources to make the subordinate semantic-relatedness judgment. As such, it is possible that insufficient resources remained to support activation of related words in the lexical decision task when the participant had limited working-memory resources to start with. As a result, no priming was exhibited in subordinate contexts by participants in this group. Such an interpretation may also accommodate the findings of Miyake et al. (1994) that people with low working-memory capacity have difficulties keeping the subordinate meaning activated in the absence of disambiguating context.

This account is consistent, in some respects, with the center-surround theory (Carr & Dagenbach, 1990; Dagenbach & Carr, 1994; Dagenbach et al., 1990). This theory suggests that a “weak” lexical item can be facilitated while other competing related lexical items are inhibited, thus maximizing the difference in activation between the competing items. Carr and Dagenbach (1990) tested the notion of a center-surround mechanism using a range of masked priming paradigms and reported highly consistent results. Specifically, depending on task design, responses to targets preceded by masked related primes were inhibited relative to responses to unrelated primes. In situations where the participant had difficulty retrieving the prime (such as when the prime was visually degraded, or masked), semantically related items were inhibited and no priming effects were found. Carr and Dagenbach subsequently proposed a center-surround theory involving masked primes’ degraded representations being enhanced by the inhibition of any related items. No masking procedures were used on the primes in the current study. As evidenced by the present reaction-time and error data, however, the relationship between a homograph such as fence and a subordinate associate such as sword was more difficult to detect than the dominant combination fence-garden.

Thus, it is proposed that the center-surround mechanism may be triggered when strategic processing occurs, but only under certain circumstances. Specifically, strategic mechanisms may not be invoked when sufficient resources are available to complete a task without having to inhibit related items. Participants in the high working-memory group are not assumed to require such a mechanism, as they appear to have sufficient resources to correctly perform the semantic-relatedness judgment task, without having to inhibit related items. Consequently, priming effects would not be affected by the previous semantic-relatedness judgment. It has been proposed that the center-surround mechanism only occurs when a degraded representation must be bought to activation (Dagenbach & Carr, 1994). The relationship between a homograph and a dominant associate is stronger than the less frequently accessed relationship between a homograph and a subordinate associate, thus the center-surround mechanism need only be triggered by participants in the low working-memory group when the associate is related to the subordinate meaning. It is important to note, however, that this center-surround mechanism explanation is admittedly post hoc and requires further investigation.

Although this study provides clear evidence of the impact of working memory on lexical ambiguity resolution, several limitations should be acknowledged. First, the presence of a gender bias needs to be addressed. All of the current data were collected from young women, but sex differences in language processing have been identified through a range of research methodologies (Halpern, 2000; Kimura, 2004; Shaywitz et al., 1995). Accordingly, if the experimental procedures were repeated on a more representative sample, including both men and women, a wider range of working-memory abilities may also be revealed. This may result in greater differences in ambiguity processing between the groups. Second, due to resource limitations or a lack of knowledge of less frequent meanings, participants in the current study’s low working-memory group may have experienced difficulties judging relatedness for subordinate meanings (as indicated by longer reaction times) and these difficulties may have affected lexical decision-making in these conditions. Future studies could address this issue directly by including a measure of intelligence or global cognitive ability.

The current methodology may be applied to other populations to examine the influence of working memory on ambiguity processing. For instance, there is evidence that some people with dementia of the Alzheimer type experience breakdowns in their ability to store and manipulate new pieces of information (Balota, Watson, Duchek & Ferraro, 1999) and process lexical ambiguities (Balota & Duchek, 1991). Accordingly, it is possible that these differences are indicative of a working-memory deficit impacting upon the ability to successfully and efficiently inhibit unnecessary information. This paradigm could also be applied to other populations with observed deficits in working memory and lexical ambiguity processing, such as Parkinson’s disease (Copland, 2003) and schizophrenia (Titone, Levy, & Holzman, 2000).
In conclusion, working-memory capacity was found to have a significant effect on homograph meaning selection and inhibition. More specifically, the present results suggest that people with a high working-memory capacity select the meaning of a homograph congruent with the available context, while inhibiting inappropriate meanings. This ability to effectively inhibit inappropriate items is thought to occur across a range of domains, and to contribute to increased efficiency in language processing. On the other hand, people with a low working-memory capacity are unable to use the provided context to efficiently suppress the inappropriate meaning. The pattern of results displayed by the present participants in the low working-memory group lends credence to the notion that people with low working-memory capacity struggle to effectively inhibit irrelevant information and further highlights the relationship between working memory and language.

References


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