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Contextual Constraints on Phonological and Lexical Ambiguity

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Abstract

A great deal of previous eye-tracking research investigating semantic ambiguity has found support for the reordered access model, which posits that both frequency of meaning and context can affect meaning activation of homophonic homographs (e.g., DIGIT) during sentence processing, but that frequency of meaning is more influential than context (Binder & Rayner, 1998; Dopkins, Morris, & Rayner, 1992; Duffy, Morris, & Rayner, 1988; Rayner, Pacht, & Duffy, 1994; Sereno, 1995). The purpose of the present research was to investigate whether frequency of meaning and predictability of context can affect phonological ambiguity in sentence processing. Biased heterophonic homographs (e.g., SEWER) and biased homophonic homographs were presented after context that was strongly biasing, moderately biasing, or weakly biasing in relation to the subordinate meaning. Results showed that neither frequency of meaning nor predictability of context affected phonological ambiguity, but that predictability of context did eliminate the competition created by semantic ambiguity.

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Contextual Constraints on Phonological and Lexical Ambiguity

Ambiguity in the English language is pervasive, and a great deal of research has been devoted to the investigation of how such ambiguity is resolved. For example, in the sentences, "Maria was thrilled with the alterations made on her dress. The skill of the sewer was really apparent," the word SEWER is both phonologically and semantically ambiguous: multiple pronunciations (phonological representations) and meanings (semantic representations) of SEWER may be activated. Words such as SEWER are called *heterophonic homographs*. Whereas heterophonic homographs are both phonologically and semantically ambiguous, *homophonic homographs*, such as DIGIT, are semantically ambiguous. Although research investigating semantic ambiguity has been exhaustive, research investigating phonological ambiguity in sentence processing has been somewhat limited. The primary purpose of the present research was to investigate the consequences of phonological ambiguity for reading text. Specifically, this research examined whether semantic context preceding a phonologically ambiguous word can result in selective activation of only one phonological and semantic representation, or whether both phonological and semantic representations associated with heterophonic homographs are always activated.

Models of Word Recognition

Different models have been proposed to describe the process of word identification, including the dual route model (e.g., Coltheart, 1978) and the connectionist or PDP-type model (e.g., Seidenberg & McClelland, 1989). The dual route model posits that access to the meaning of words can be achieved through either an indirect, phonological route, or through a direct, orthographic route. The indirect route involves

translating the orthography, or visual characteristics of a word, into their phonological representations, and using these representations to access meaning. The direct route involves accessing meaning directly from the orthography of a word. The output of these routes compete with each other when accessing meaning, but the indirect route is generally slower than the direct route. For example, if words are very familiar (e.g., high frequency words), meanings of words will be activated more quickly via the direct route, and processing will be unaffected by the indirect route. However, if the words are unfamiliar (e.g., low frequency words), the direct route will process these words relatively slowly and it is likely that meanings will be activated simultaneously via the indirect route. In other words, readers will use their knowledge of the words' phonology to activate the words' meaning.

Although this model is accepted by a number of researchers, the connectionist model has also received considerable support. In a connectionist model, orthographic, phonological, and semantic units are connected via interlevels of hidden units. As readers become more familiar with words, the weights on connections between units are modified in order to reflect the readers' familiarity with those words. As weights on connections are modified for familiar words, identifying these words becomes a quicker and more efficient process. According to one version of connectionist model (e.g., Plaut, McClelland, Seidenberg, & Patterson, 1996; Seidenberg & McClelland, 1989) there are still two routes to meaning activation, one that begins from the orthographic units and proceeds via the phonological units, and one that proceeds directly from the orthographic units, and these two routes function in parallel.

In a different version of connectionist model (e.g., Van Orden, Pennington, & Stone, 1990), phonological units play a more central role in the activation of semantic, or meaning units. For instance, Gottlob, Goldinger, Stone, and Van Orden (1999) discussed a general resonance framework, whereby the presentation of a word or letter string (e.g., SEWER) results in activation in the orthographic units. Activation within these units then feeds forward to phonological and then to semantic units, resulting in feedback from these units to orthographic units. This process is repeated, and resonance is achieved when feedback and feedforward connections between the units are mutually reinforcing, creating a complete and coherent perceptual experience. Thus, phonological mediation plays an important role in the activation of meaning in this model. It is clear that although this resonance model differs from the dual route model and from other versions of the connectionist model in its fundamental framework, all models suggest that word identification involves three types of information: orthographic, phonological, and semantic. The present research did not address the differences between the models, but did explore the nature of phonological and semantic activation when identifying words that are presented in context.

Previous Research on Semantic Ambiguity

Given that heterophonic homographs, such as SEWER, are both phonologically and semantically ambiguous, consideration of previous research investigating semantic ambiguity is important to understand predictions about how heterophonic homographs are processed in text. As mentioned, a great deal of research has been conducted regarding semantic ambiguity. One of the fundamental goals of such research is to determine whether meaning activation of a homophonic homograph (e.g., DIGIT) is

selective, such that only one contextually appropriate meaning is activated, or whether meaning activation is exhaustive, such that all of the meanings associated with the homograph are always activated. The selective activation hypothesis stems from an interactive view of meaning activation (McClelland, 1987; Neely, 1976, 1977), which is based on the assumption that semantic processes can be influenced by top-down expectations created by context and that processing terminates once an appropriate meaning has been selected. Alternatively, the exhaustive activation hypothesis stems from a modular view of meaning activation (e.g., Fodor, 1983; Forster, 1981), which is based on the assumption that certain semantic processes are autonomous and are unaffected by extralexical information, such as sentence structure or context. According to this perspective, processing does not cease until all possible meanings of a homograph have been activated.

The selective access hypothesis has received some empirical support (Schvaneveldt, Meyer, & Becker, 1976; Swinney & Hakes, 1976; Kellas, Paul, Martin, & Simpson, 1991). For example, Schvaneveldt et al. conducted a priming task in which test sequences of three words were presented and participants were asked to make a lexical decision about each word. The first and third words were either both related to the same meaning of the homophonic homograph, which appeared as the second word (e.g., SAVE-BANK-MONEY) or they were each related to different meanings of the homophonic homograph (e.g., RIVER-BANK-MONEY). In a priming task, a stimulus that is presented as a prime is believed to activate related concepts (Collins & Loftus, 1975; Collins & Quillian, 1969). As a result, response times are typically faster for words that are related to the prime relative to words that are unrelated to the prime. In the

Schvaneveldt study, results showed that response times to the third word were significantly faster than to control words if both the first and third words were related to the same meaning of the homograph, but response times were no different than control words if the first and third words were related to different meanings of the homograph. Schvaneveldt et al. concluded that processing of the first word resulted in selective activation of a particular meaning of the homograph.

Hogaboam and Perfetti (1975) also found support for the selective access hypothesis. However, they claimed that frequency of meaning, rather than context, was the reason for selection of a particular meaning, and that an 'ordered' access model might be a more appropriate characterization of meaning resolution. They conducted a task in which participants were aurally presented with sentences containing homophonic homographs (e.g., The investor's money earned interest), and after each sentence were asked whether they thought the last word of the sentence was ambiguous. They found that participants were significantly slower to say the word was ambiguous when a sentence biased the dominant, more frequent meaning of the homograph, relative to the situation where a sentence biased the subordinate, less frequent meaning of the homograph. The authors concluded that the dominant meaning had been selectively accessed because of its relative frequency of occurrence.

In contrast to the aforementioned research, Onifer and Swinney (1981) found support for the exhaustive activation hypothesis. They used a cross-modal priming task to investigate the effects of context on biased homophonic homographs (homographs with one highly frequent or dominant meaning and one or more less frequent or subordinate meanings). Onifer and Swinney aurally presented sentences to participants that biased

either the dominant or subordinate meaning of the homographs. As participants heard a homograph in a sentence, either a word or nonword was presented on an oscilloscope and participants were asked to make a lexical decision about the word. Results showed that words related to both dominant and subordinate meanings of the homographs were responded to significantly faster than the control words, regardless of biasing context. These results support the notion that both meanings of a homophonic homograph are activated, and that the activation process is unaffected by context.

More recently, however, support has been growing for a new model: the reordered access model (Binder & Rayner, 1998; Dopkins, Morris, & Rayner, 1992; Duffy, Morris, & Rayner, 1988; Neill, Hilliard, & Cooper, 1988; Rayner, Pacht, & Duffy, 1994; Sereno, 1995; Simpson, 1981; Tabossi, 1988; Tabossi, Colombo, & Job, 1987; Tabossi & Zardon, 1993). The reordered access model is a hybrid model that combines the importance of context and frequency of meaning. However, there is a greater emphasis on frequency in this model. The model states that although all meanings are exhaustively activated, prior context increases the availability of the appropriate meaning. The predictions of this model are as follows: (1) equibiased meanings of a homophonic homograph will compete in the absence of context because they are both equally available, (2) biased meanings of a homophonic homograph will not compete in the absence of context because the frequency of the dominant meaning increases its availability, (3) biasing context preceding a homophonic homograph with equibiased meanings will result in increased availability of the appropriate meaning and hence competition between meanings will not occur, (4) preceding context that biases the dominant meaning of a biased homophonic homograph will result in increased availability of the dominant meaning and competition

will not occur, and (5) preceding context that biases the subordinate meaning of a biased homophonic homograph will result in increased availability of the subordinate meaning, resulting in competition between the dominant and subordinate meanings (this is called the subordinate bias effect).

Evidence supporting the reordered access model comes from eye-tracking research conducted by Rayner and his colleagues. Duffy et al. (1988) used an eye-tracker to monitor participants' eye movements as they read sentences containing both biased and equibiased homophonic homographs. The results supported all predictions. In the absence of context, gaze duration (which includes all fixations on a word before fixating on subsequent text) for equibiased homophonic homographs was longer than for control words, indicating that the meanings were competing with each other. In addition, gaze duration for biased homophonic homographs was similar to gaze duration for control words, indicating that the dominant meaning was more available than the subordinate meaning. When preceding context biased one meaning of the equibiased homographs, gaze duration was similar for the homographs and for the control words, suggesting that the contextually appropriate meaning was more available. Similarly, when preceding context biased the dominant meaning of a biased homograph, fixation times were similar for homographs and for control words. Finally, when the preceding context biased the subordinate meaning of a biased homograph, a subordinate bias effect was found (i.e., gaze duration was longer for homographs than for control words, indicating that the dominant and subordinate meanings were competing).

Dopkins et al. (1992) also used an eye-tracker and examined fixation times for biased homophonic homographs presented in sentences. The sentences were divided into

three conditions. In the positive condition, context preceding the homograph highlighted a semantic feature of the subordinate meaning but remained consistent with the dominant meaning. In the negative condition, context preceding the homograph was inconsistent with the dominant meaning but was not biased toward the word's subordinate meaning. In the neutral condition, context preceding the homograph did not provide evidence for either the dominant or subordinate meaning. The authors found that gaze duration for the homograph was longer in the negative condition than in the neutral condition because in the negative condition activation for the dominant meaning was dampened. As the dominant meaning was dampened, the availability of the subordinate meaning increased. Thus, all meanings were exhaustively activated, but the dominant meaning was constrained by the context, resulting in competition between the dominant and subordinate meaning. These results supported the reordered access model.

Rayner et al. (1994) noted, however, that research in this area has been inconclusive. For instance, Paul, Kellas, Martin, and Clark (1992) used a stroop priming task whereby participants read a sentence ending in a homophonic homograph and then named the color of a target word that was presented after the sentence. They found evidence of selective access in both dominant and subordinate biasing contexts. Specifically, naming of the color was significantly slower when the target was related to the contextually appropriate meaning, but not when it was related to the contextually inappropriate meaning. However, Rayner et al. pointed out that priming tasks lack ecological validity. In particular, words that participants respond to are episodically distinct from the discourse, and responses are exceedingly longer than the 100 to 200 ms needed to access meaning. In fact, many researchers have investigated the timecourse of

semantic activation and findings suggest that selection of one appropriate meaning usually occurs after 200 ms, during postlexical processing (Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982; Tanenhaus, Leiman, and Seidenberg, 1979). Thus, Paul et al.'s results may be the product of postlexical processing.

Rayner and his colleagues (Binder and Rayner, 1998; Rayner et al., 1994) sought to resolve some of the controversy and to determine whether or not meaning activation was exhaustive or selective. Rayner et al. conducted two experiments whereby participants encountered a homophonic homograph twice (along with its disambiguating information). The first experiment involved two tasks. In the first task, participants were exposed to the homograph and its disambiguating information for the first time in a list of paired associates. In the second task, participants were exposed to the homograph for the second time in a passage of text. In the second experiment participants were exposed to the homographs twice in one passage of text. The question was whether the subordinate bias effect, measured at the second exposure, would decrease or disappear as a result of the previous encounter. Both experiments showed that the subordinate bias effect could not be eliminated. These results suggest that all of the meanings were exhaustively activated because the preceding context biasing the subordinate meaning could not eliminate activation of the dominant meaning. Thus, both meanings competed and resulted in longer fixation times.

To examine this issue even further, Binder and Rayner (1998) tested the predictions of the context-sensitive (selective) model (Kellas et al., 1991; Paul et al., 1992), which posits that selective access of one meaning of a biased homophonic homograph can occur if the context preceding the homograph is strongly biasing.

Whereas the reordered access model emphasizes the influence of frequency information, the context-sensitive model emphasizes the influence of context strength. Thus, according to the context-sensitive model, a subordinate bias effect would only occur when context moderately biases the subordinate meaning, because the dominant meaning would still receive some activation and the two meanings would compete. The subordinate bias effect should be eliminated if the context biasing the subordinate meaning is strongly predictive, because only that meaning should be selected. The results did not support this model. Using an eye-tracker as well as a self-paced reading task (whereby participants advance through a passage of text presented on a computer screen by pressing a button to display the next word), Binder and Rayner found that strongly biasing context did not eliminate the subordinate bias effect. Furthermore, the subordinate bias effect was even larger when the context was strongly biasing than when the context was moderately biasing. Binder and Rayner concluded that "This pattern of results is quite consistent with the reordered access model, since the stronger context would serve to more readily boost the subordinate interpretation of the ambiguous word than would the weaker biasing context" (p. 275).

Although a great deal of research has supported a reordered access model, some researchers still subscribe to the context-sensitive model. Martin, Vu, Kellas, and Metcalf (1999), for instance, found evidence that the subordinate bias effect can be eliminated in a self-paced reading task if the context is strongly biasing. Specifically, they found that there was no difference in reading times for the ambiguous word presented in the dominant-biased passage and the same word presented in the subordinate- biased passages, indicating that only one meaning was activated in either case. Yet these

findings are somewhat questionable. Binder and Rayner (1999) and Rayner, Binder, and Duffy (1999) argued that the stimuli set used by Martin et al. is problematic. For instance, many of the homophonic homographs used in Martin et al.'s study were equibiased. Furthermore, for some of the items, the context actually biased the dominant meaning of the homograph. Rayner and colleagues claimed that, for these reasons, the previous finding that strongly biasing context does not eliminate the subordinate bias effect is reliable. At present, these issues continue to be debated and the controversy remains unresolved.

Previous Research on Phonological Ambiguity

The preponderance of the semantic ambiguity research appears to support the reordered access model, indicating that frequency of meaning has the greatest impact on how meanings of semantically ambiguous words are activated during sentence processing, but that context can also influence meaning activation. An important issue, then, is whether phonological ambiguity can be affected by context. Is phonological activation exhaustive, such that all representations are initially activated? Can strongly biasing context constrain activation of phonological representations, resulting in selective access of a less frequent representation? To date, these questions have not been fully explored, although some research has been conducted that is relevant to the topic.

Previous research examining phonological processing in text has often focused on determining whether phonology plays a significant role in the activation of word meanings. At first glance, these studies appear to yield inconclusive results. For instance, Daneman and Reingold (1993) and Daneman, Reingold, and Davidson (1995) conducted eye movement monitoring studies, investigating whether participants would notice if a

homophonic heterograph (a word that shares its phonological representation with another word but has different spelling and meaning, e.g., MAID and MADE) was replaced with its mate (homophone error). Results showed that gaze durations were longer for the homophone errors than for the homophonic heterographs, and there was no significant difference in gaze duration between homophone errors and spelling control errors. The authors concluded that phonological processing does not play a significant role in activating meaning.

However, Rayner, Sereno, Lesch, and Pollatsek (1995) found positive evidence for the role of phonology in meaning activation when they tracked participants' eye movements in a 'fast priming' task created by Sereno and Rayner (1992). In this task, a random string of letters occupies the target location until the participants' eyes pass a particular boundary. Once the boundary has been passed, the letter string is replaced by a prime (which is either the homophonic heterograph mate of the target word, a word that is visually similar to the target, or an unrelated word), and then the prime is replaced by the target word. Although Rayner et al. did not find phonological priming when the prime was presented for 24 or 30 ms, they did find phonological priming when the prime was presented for 36 ms, indicating that phonological processing did influence early stages of word recognition.

Jared, Levy, and Rayner (1999) explored the inconsistency of previous findings and determined that the issue was not *whether* phonology plays a role in the activation of word meanings, but under what conditions phonology plays a role. Jared et al. examined phonological processing in two proofreading tasks (whereby participants read a story and cross out items that do not make sense) and in three eye-tracking tasks, taking into

account the predictability of the text, the frequency of the homophonic heterograph, the frequency of the homophone error, and reader skill. Results showed that phonology plays a role in the activation of word meaning when words are lower in frequency, that is, when they do not appear very often in text. These results were found for both less- and more-skilled readers (with more-skilled readers exhibiting only weak evidence for the influence of phonology). Jared et al. accounted for the inconsistent findings in the literature by determining that the stimuli used by Daneman and Reingold (1993) and Daneman et al. (1995) were of higher frequency. Thus, it seems clear that phonology does play an important role in accessing meaning for low frequency words.

Folk and Morris (1995) conducted studies that were more specific to the effects of context on phonological ambiguity. In Experiment 1, eye movements were monitored while participants read sentences containing homophonic homographs (e.g., DIGIT), heterophonic homographs (e.g., SEWER), or homophonic heterographs (e.g., MAID). Of particular relevance for the present research are the results for homophonic homographs and heterophonic homographs. In each sentence, disambiguating information biasing the subordinate meaning of the target ambiguous word appeared after the target word. Results showed that participants spent more initial time processing heterophonic homographs, but did not spend more initial time processing homophonic homographs. The authors attributed this difference to phonological competition that occurred at the early stages of word processing. In addition, participants spent more time in the disambiguating region for the homophonic homographs but did not make any regressions back to the target words. Conversely, once participants reached the disambiguating region for the heterophonic homographs, they made many regressions back to these

words. Folk and Morris explained that participants did not need to make regressions back to the homophonic homographs because both of the meanings are only associated with one phonological code. The original code that was activated remained useful when participants had to recompute the meaning designated by the disambiguating text. In contrast, participants did need to make regressions back to the heterophonic homographs because each meaning is associated with a different phonological code. Thus, when reading the disambiguating information, the original code activated was not useful in attaining the correct meaning, and participants had to regress back to these words to retrieve the appropriate phonological code.

Folk and Morris' (1995) Experiment 2 was similar to Experiment 1, except that the disambiguating information which biased the subordinate meaning *preceded* the ambiguous words. Results showed that there was a subordinate bias effect for the homophonic homographs. Participants had more difficulty processing the homophonic homographs because the preceding context boosted activation of the subordinate meaning, resulting in competition between the dominant and subordinate meaning. Initial processing difficulty for the heterophonic homographs was reduced but not eliminated, indicating that the context did not resolve the competition. In addition, participants still had difficulty maintaining the correct meaning of the heterophonic homographs because they still regressed back to these words significantly more often than to the homophonic homographs.

In Folk and Morris' (1995) Experiment 3, disambiguating information again preceded the ambiguous words, but a naming task was conducted rather than an eye-tracking task. Again, results showed that participants had initial difficulty naming the

heterophonic homographs. Folk and Morris concluded that when reading heterophonic homographs, early phonologically-driven competition between meanings makes selecting even the dominant meaning difficult. In Experiment 4, the authors examined whether participants ever overcome the difficulty and achieve the correct meaning by having participants read sentences aloud and answering comprehension questions. Results showed that participants do in fact overcome the ambiguity by the time they finish reading the sentence.

Folk and Morris (1995) suggested that when reading heterophonic homographs embedded in sentences, one orthographic representation can lead to the activation of multiple phonological codes, and readers must choose between these codes and the meanings associated with them. They asserted that competition can occur in two places. Competition can first occur during initial processing of the heterophonic homographs because the phonological codes activated are not affected by frequency. That is, both codes are activated at roughly the same time, resulting in competition. Competition may also occur later in the sentence if readers have to recompute the meaning, because phonological ambiguity makes it difficult to retrieve a previously unselected phonological interpretation.

Similarly, Gottlob et al. (1999) conducted research addressing the issue of context and phonological ambiguity. As mentioned, Gottlob et al. described a general resonance framework whereby word identification involves the activation of feedback and feedforward connections between orthographic (O), phonological (P), and semantic (S) units. These authors also proposed that inconsistency within feedback and feedforward connections can delay resonance. For example, when reading the heterophonic

homograph SEWER, activation feeds forward inconsistently from the orthographic units to the phonological units because SEWER has two phonological representations. Competition between these representations would have to be resolved before resonance can be achieved. Gottlob et al. suggested that when words are presented without context, O-P resonance will be achieved before O-S, P-S, and O-P-S resonance. When words are presented in a highly predictive context, semantic resonance may be achieved more quickly.

To test their suggestion, Gottlob, et al. (1999) included homophonic homographs and heterophonic homographs in a naming task (whereby participants name individual words that appear on a computer screen) and in two semantic classification tasks (association judgement; whereby participants decide whether a target word is related to a preceding prime word). Particularly relevant to the issue of phonological ambiguity are the reaction times to the heterophonic homographs. In the first semantic classification task, heterophonic homographs preceded the disambiguating target (e.g., BASS-GUITAR). In the second semantic classification task, heterophonic homographs followed disambiguating primes. Whereas the naming task requires O-P resonance, the semantic classification task requires O-S resonance.

In the naming task, reaction times were slower for heterophonic homographs than for control words, indicating that O-P resonance was required in this task. In the first semantic classification task (disambiguating target followed the heterophonic homograph), reaction times were slower when the disambiguating target was biased toward the subordinate meaning but not when it was biased toward the dominant meaning, indicating that the dominant meaning was automatically activated first. Gottlob

et al. noted that when the disambiguating target biases the subordinate meaning of the heterophonic homograph, participants must go back to their visual representation of the word to retrieve the other phonological code before they can access the subordinate meaning. This finding is similar to that reported by Folk and Morris (1995); when reading the disambiguating information, the original code activated was not useful in attaining the correct meaning, and participants had to regress back to the homograph to retrieve the appropriate phonological code. The results of the second semantic classification task (where the disambiguating prime preceded the heterophonic homograph) were similar to the first. Nevertheless, Gottlob et al. predicted that strong semantic constraints should eliminate the processing difficulty associated with homographs. This prediction has never been tested.

Present Research

The present research examined whether strong semantic constraints can, in fact, eliminate homograph effects when reading sentences. The sentences included heterophonic homographs and homophonic homographs. The present research consisted of three experiments. The purpose of Experiment 1 was to determine whether the typical ambiguity effects could be observed in a naming task using the words selected for this research. It is important to note that the meanings of some of the ambiguous words used in the present research did not belong to the same syntactic category. Semantically ambiguous words with meanings that belong to different syntactic categories are considered to be syntactically unambiguous. For example, REFRAIN is syntactically unambiguous because the meaning of REFRAIN that is associated with music is a noun, and the meaning of REFRAIN that is associated with holding back is a verb. Although

some research has indicated that syntactically unambiguous homophonic homographs do produce competition in the presence of context (Kinoshita, 1985; Oden & Spira, 1983; Seidenberg et al., 1982; Tanenhaus et al., 1979), Folk and Morris (2003) recently conducted an eye-tracking task and found that whereas syntactically ambiguous homographs produce competition when they appear in sentences, syntactically unambiguous homographs do not. Specifically, they found that when neutral context preceded equibiased homophonic homographs, gaze duration was longer only for syntactically ambiguous homographs relative to control words. Further, when preceding context biased the subordinate meaning of the homophonic homographs, a subordinate bias effect was only found for the syntactically ambiguous homographs. Nonetheless, the number of heterophonic homographs in the English language is limited and our primary goal was to match homophonic homographs with heterophonic homographs by frequency and length so that the effects of phonological ambiguity could be isolated by comparing the two types of words. Thus, 80% of the heterophonic homographs and 60% of the homophonic homographs used in this research were syntactically unambiguous.

Experiment 2 involved the use of an eye-tracker to measure participants' eye movements as they read phonologically and semantically ambiguous words in sentences containing context of three types: strongly biasing, moderately biasing, and weakly biasing. The context conditions differed in terms of degree of semantic bias toward the subordinate meaning of the ambiguous word. Importantly, the present research involves a stronger manipulation of semantic context than in past research. In previous research investigating the effects of context on ambiguity resolution, context strength was established by asking a group of participants to verify context bias. For example, Folk

and Morris (1995) presented participants with the ambiguous words embedded in full sentences and asked participants to provide a synonym for each ambiguous word. Thus, they were able to determine which meaning of the ambiguous word was biased by the sentences by checking that the synonyms associated with the subordinate meanings were offered as responses. In the present research, context strength was established with a cloze task. That is, participants were presented with the text preceding the ambiguous word, and they were asked to fill in the word that they thought best followed the text. This task measured the strength with which the preceding context actually predicted particular words by calculating the proportion of participants who offered the target word (or a synonym) as their cloze task response. Since this method of pilot testing has never (to my knowledge) been used before in studies on this topic, the context used in the strongly biasing context condition in this research is probably more strongly predictive of a subordinate meaning of an ambiguous word than any context used in previous research. The same stimuli used in Experiment 2 were used in Experiment 3, but a self-paced reading task was conducted to determine whether the pattern of data found in Experiment 2 was generalizable across tasks.

Pilot Study

A pilot study was conducted to determine the extent to which sentences were strongly biasing, moderately biasing, or weakly biasing in relation to the ambiguous target words. It is reported first because it was conducted prior to selection of the control words that were used in subsequent experiments. That is, control words that fit into sentences were not selected until a large number of sentences were pilot tested and the most suitable sentences were selected for each context condition.

Method

Participants. One hundred and twenty undergraduate students at the University of Calgary participated in the pilot study in exchange for bonus credit in a psychology course. All participants reported that English was their first language.

Stimuli. A set of ambiguous target words was selected prior to creating sentences to pilot test. These included heterophonic homographs (e.g., SEWER) and homophonic homographs (e.g., DIGIT). Ten heterophonic homographs and 10 homophonic homographs that were matched for frequency (Kucera & Francis, 1967) and length were selected from Twilley, Dixon, Taylor, and Clark's (1994) norms of relative frequency for 566 ambiguous words. These words were only selected if they had no more and no less than two meanings. The mean frequency for the heterophonic homographs was 36.00 and the mean frequency for the homophonic homographs was 37.70. For the heterophonic homographs, the mean relative frequency (i.e., the mean percentage of responses indicating a particular meaning was the primary meaning) of the dominant meanings was 70.29% and of the subordinate meanings was 17.43%. For the homophonic homographs, the mean relative frequency of the dominant meanings was 79.50% and of the subordinate meanings was 13.70%. The remaining percentage of responses for each word type involved unclear responses.

Six pairs of sentences were created for each ambiguous word and pilot tested for this study. Each pair of sentences was structured such that the first sentence contained the context manipulation and the second sentence contained the ambiguous target word. The second sentence was always structured so that the ambiguous target word appeared in the middle of the sentence. The ambiguous target word was presented in the middle of the

second sentence, rather than at the end of a sentence because this allowed me to separate ambiguity resolution processes from wrap up processes that typically can be observed at the end of sentences. In addition, sentences were controlled for length and syntax (to ensure that they did not contain any unusually complex clauses).

Based on my own intuitions, I constructed potential sentence pairs such that the context in two of the potential sentence pairs for each ambiguous target word contained semantic content that strongly biased the subordinate meaning of the ambiguous target word. The context in two other potential sentence pairs for each ambiguous target word contained semantic content that moderately biased the subordinate meaning of the ambiguous word. The context for the remaining two sentence pairs for each ambiguous word contained semantic content that weakly biased the subordinate meaning of the ambiguous word. In each pair, the context of the second sentence was always semantically neutral in relation to the ambiguous word.

Procedure. To pilot test the sentences, a cloze task was conducted. In a cloze task, only part of the sentence is presented to participants and participants are asked to fill in the missing word. Thus, for each pair of sentences, participants were presented with the entire first sentence but only part of the second sentence. In the second sentence, the ambiguous word and all of the words that occurred after the ambiguous word were not presented to participants. Instead, participants were asked to fill in the word that they thought best fit immediately after the last word that was presented (e.g., Maria was thrilled with the alterations made on her dress. The skill of the _____). They were told that this word would not complete the sentence. Participants were not presented with words that occurred after the ambiguous word so that the extent to which the *preceding*

context predicted the correct target word could be assessed. Six versions of the cloze task were created so that each participant only saw one sentence out of the six that were created for each ambiguous target word. Thus, each participant only saw 20 sentences.

Results and Discussion

Pilot test cloze task responses were scored by coding the type of word that participants used to fill in the blank. Responses were considered correct if participants provided the exact target word or provided a synonym of the target word. In this way, a 'correct' response is simply an instance where the participant responded using the ambiguous word for which the sentence was written, or its synonym. Thus, the objectives were to select sentences as strongly biasing context if those sentences had high percentages of correct responses, to select sentences as moderately biasing context if those sentences had a lower percentage of correct responses, and to select sentences as weakly biasing context if those sentences had no correct responses. It is important to note that even though sentences with weakly biasing context had no correct responses, the sentences were constructed such that only the subordinate meaning of the ambiguous words made sense. Thus, the weakly biasing context was not neutral in relation to the ambiguous words.

Three sentences were selected for each ambiguous word, and these were considered strongly bias, moderately bias, or weakly bias the subordinate meaning of each ambiguous word. These sentences are presented in Appendix B. A 2 (Word Type: heterophonic homographs) by 3 (Context: strongly biasing, moderately biasing, weakly biasing) ANOVA was conducted for these 60 sentences to determine if there were significant differences in mean percentage of correct responses between the three types of

sentence pairs for each word type. Results showed that there was a significant main effect of context, $F(2, 36) = 87.56$, $MSE = 22246.25$, $p < .001$. The main effect of word type and the interaction of context and word type were not significant, all $F < 1$. Follow-up t-tests were conducted using Bonferroni correction to correct for the family-wise error rate. Results revealed that, collapsed across word type, there was a significant difference in mean percentage of correct responses between Strongly Biasing sentence pairs and Moderately Biasing sentence pairs, $t(19) = 8.78$, $SE = 5.27$, $p < .001$, such that Strongly Biasing sentence pairs had a significantly higher mean percentage of correct responses than Moderately Biasing sentence pairs (64.75% and 18.50%, respectively). Similarly, there was a significant difference between Moderately Biasing sentence pairs and Weakly Biasing sentence pairs, $t(19) = 4.62$, $SE = 4.01$, $p < .001$, such that Moderately Biasing sentence pairs had a significantly higher mean percentage of correct responses than Weakly Biasing sentence pairs (0%). Furthermore, planned comparisons revealed that there were no significant differences in percentage of correct responses between heterophonic homographs and homophonic homographs in the strongly biasing context condition (65.50% and 64.00%, respectively), in the moderately biasing context condition (19.50% and 17.50%, respectively), or in the weakly biasing context condition (0% for both), all $t < 1$. These results indicate that there are significant differences in predictability for the strongly biasing, moderately biasing, and weakly biasing contexts in the sentences chosen for Experiment 1.

Experiment 1

Experiment 1 involved a naming task to determine whether the heterophonic homographs (e.g., SEWER) used in this research actually produce the interference

typically observed for such words in naming tasks (e.g., Gottlob et al., 1999; Kawamoto & Zemblidge, 1992). Oral naming requires participants to activate the phonological representations associated with the words. Once activated, the multiple phonological representations associated with heterophonic homographs compete with each other. In order to make an oral response, this phonological competition must be resolved, resulting in longer naming latencies for heterophonic homographs relative to control words that have only one phonological representation. Establishing that the phonologically ambiguous words used in this research do produce phonological competition is necessary before assessing the effects of context on these words and proceeding to draw conclusions about processing phonological ambiguity in context.

In addition, it has often been found that in naming tasks, homophonic homographs (e.g., DIGIT) produce facilitation relative to control words (Gottlob et al., 1999; Hino & Lupker, 1996; Hino, Lupker, Sears, & Ogawa, 1998; Lichacz, Herdman, LeFevre, & Baird, 1999). In a naming task, a phonological representation needs to be completely processed in order to produce a response. The facilitory effects of semantic ambiguity are assumed to occur because some semantic processing may occur, and semantically ambiguous words would produce more semantic activation than semantically unambiguous words. The additional semantic activation for homophonic homographs can provide feedback activation to the phonological units, facilitating the process of phonological activation (e.g., Hino & Lupker, 1996). We attempted to determine whether the homophonic homographs used in this research produce this typical facilitation. Thus, the predictions were that naming latencies for heterophonic homographs would be significantly slower than naming latencies for control words, and that naming latencies

for homophonic homographs would be significantly faster than naming latencies for control words.

Method

Participants. Twenty-five undergraduate students at the University of Calgary participated in this experiment in exchange for bonus credit in a psychology course. All participants reported that they had normal or corrected vision and that English was their first language.

Stimuli. In addition to the two types of target words selected for the pilot study (heterophonic homographs and homophonic homographs), two other types of target words were selected for this task. The two other word types were unambiguous control words matched with the heterophonic homographs and unambiguous control words matched with the homophonic homographs. Ten control words were matched with the heterophonic homographs for frequency and meaning, such that each control word meaning was similar enough to the subordinate meaning of its respective heterophonic homograph so that it could replace the heterophonic homograph in each sentence context. Similarly, 10 control words were matched with the homophonic homographs for frequency and meaning, such that each control word meaning was similar to the subordinate meaning of its respective homophonic homograph. Thus, all control words could easily replace their matched ambiguous words in the sentences that were used in the pilot study. The mean frequency for the heterophonic homograph control words was 31.10 and the mean frequency for the homophonic homograph control words was 34.40. All of these target words are presented in Appendix A.

Procedure. Each trial consisted of a letter string that was presented in the center of a 17-inch Sony Trinitron monitor controlled by a Macintosh G3 and presented using PsyScope (Cohen, MacWhinney, Flatt, & Provost, 1993). The letters were approximately 0.50 cm high and at eye level for the participants. The distance between each participant and the monitor screen was approximately 40 cm. Participants were instructed to say each word as quickly and accurately as possible into a microphone attached to a PsyScope response box. The stimuli were presented in a different random order for each participant. Two lists were created so that the heterophonic homographs and the control words for homophonic homographs appeared in List 1, and the homophonic homographs and the control words for heterophonic homographs appeared in List 2. Each participant named both lists (one before a short break and one after). By using these separate lists I ensured that a control word that had a meaning matched to the subordinate meaning of an ambiguous word was never presented directly before that ambiguous word. Such an event may have resulted in priming for the ambiguous word, creating a faster response time for that word. Participants first completed 10 practice trials and were given verbal feedback if they responded incorrectly to any of the practice items. On each trial, the target was presented until the participant responded.

Results and Discussion

A trial was considered an error, and excluded from the latency analysis, if the response latency was longer than 2000 msec or shorter than 250 msec, or if participants made an incorrect response (2.5% of trials). This error rate is quite low and so error analyses were not conducted because there was not enough data. Mean response latencies are presented in Table 1. For all planned comparisons in this experiment, one-tailed tests

of significance were used. Data were analyzed with subjects ($F1$ or $t1$) and, separately, items ($F2$ or $t2$) treated as random factors.[1]

Planned comparisons were conducted using one-tailed tests of significance. Results showed that, contrary to predictions, the difference in naming latency between heterophonic homographs and control words was not statistically significant, $t1(24) = 1.10$, $SE = 8.62$, $p = .14$, $t2 < 1$. Supporting predictions, though, results revealed that the homophonic homographs were named significantly faster than control words, $t1(24) = 4.86$, $SE = 11.27$, $p < .001$, $t2(18) = 2.83$, $SE = 19.63$, $p < .01$. In fact, the advantage for homophonic homographs over control words was 55 ms, which is quite large in comparison to 10- or 25-ms effect sizes for these words reported in previous naming experiments (Gottlob et al., 1999; Hino et al., 1998; Hino & Lupker, 1996; Lichacz et al., 1999). In addition, the disadvantage for heterophonic homographs in a naming task is typically a fairly robust effect, and therefore it was rather surprising that the effect was not observed in this task.

The unexpected pattern of results prompted a closer look at the stimuli used in this experiment, and it was determined that the control words were significantly longer than the ambiguous words. This is problematic because previous research has found that word length can affect reaction time in some word recognition tasks (particularly naming tasks), such that reaction times are slower for longer words and faster for shorter words (e.g., Hudson & Bergman, 1985; Hyoenae & Olson, 1995; Lee, 1999). The naming task is a phonologically based task, and participants must settle on a phonological representation before they can accurately pronounce the word, which can take longer for longer words than for shorter words. T-tests were conducted for word sets used in the

present experiment and results showed that the heterophonic homographs (mean length = 5.50 letters) were significantly shorter than the matched control words (mean length = 7.20 letters), $t(18) = 2.23$, $SE = 0.76$, $p < .05$. Similarly, results showed that homophonic homographs (mean length = 5.50 letters) were significantly shorter than the matched control words (mean length = 7.00 letters), $t(18) = 2.13$, $SE = 0.70$, $p < .05$. These findings suggest that the phonological competition created by the heterophonic homographs and the longer reaction times associated with that competition may have been masked because the control words were processed relatively slowly due to their length. Further, the same length confound may explain the large difference in reaction times observed for the homophonic homographs and their control words. To address this hypothesis, differences in naming latencies between control words of different lengths were examined to determine if, on average, words that are longer take longer to name. A linear trend was found among the data, indicating that longer words did take longer to name. For example, control words that were 9 letters long took, on average, 654 ms to name, whereas control words that were 5 letters long took 524 ms to name, and naming latencies for words of intermediate length tended to fall between these values. These values were used to compute a length correction factor, which was applied in order to adjust response times as a function of length. Specifically, words that were 4 or 5 letters long were divided by 1, words that were 6, 7, or 8 letters long were divided by 1.06, and words that were 9, 10, or 11 letters long were divided by 1.14. The data were then reanalyzed using the naming latencies derived from these calculations.

Results supported the possibility that the lack of observable heterophonic homograph interference and the seemingly large homophonic homograph facilitation in

the initial analyses were due to differences in length between the ambiguous words and the control words. T-tests revealed that, once the data were corrected for length, there was a statistically significant difference between heterophonic homographs and control words, $t1(24) = 3.22$, $SE = 8.58$, $p < .01$, $t2(18) = 1.19$, $SE = 23.34$, $p = .13$. In addition, once the data were corrected for length, the homophonic homographs were still significantly faster than the control words, $t1(24) = 3.18$, $SE = 10.34$, $p < .01$, $t2(18) = 2.67$, $SE = 23.44$, $p < .01$, but the effect size was not nearly as large (now 33 ms). These results more closely resemble results from previous studies examining processing for these types of words (Gottlob et al., 1999; Hino et al., 1998; Hino & Lupker, 1996; Kawamoto & Zemblidge, 1992; Lichacz et al., 1999). In the following experiments, participants silently read words as they appeared on a computer screen. Processing time during silent reading can increase for longer words relative to control words. Thus, for the following two experiments, the data were examined to determine whether there were differences in the dependent variable as a function of length. If so, these differences were corrected and the data were analyzed accordingly.

Experiment 2

Experiment 2 involved eye movement monitoring. Participants were presented with heterophonic homographs (e.g., SEWER) and homophonic homographs (e.g., DIGIT), as well as their respective control words, embedded in contexts that varied in the extent to which they biased the subordinate meaning of the homographs (i.e., strongly biasing, moderately biasing, and weakly biasing). There were three primary differences between the present experiment and Folk and Morris' (1995) Experiment 2. First, the present experiment involved a stronger manipulation of context strength to determine

whether strength of context predictability could override the activation of the dominant phonological representations of heterophonic homographs. Specifically, the semantic context used in the strongly biasing context condition in the present experiment was more strongly predictive of the subordinate representation of the ambiguous words. Second, Folk and Morris used a very small set of heterophonic homographs and homophonic homographs, and each set of ambiguous words used in the present experiment was more than twice as large. Third, the key research question in the present experiment was much more specific. That is, the specific issue here is how context strength affects processing of phonological ambiguity.

Design of Study

The study was designed so that any effects of phonological and semantic competition could be distinguished from effects of semantic competition per se. Thus, the primary focus when selecting stimuli was to select homophonic homographs that were closely matched with the heterophonic homographs so that a comparison could be made between the effects generated by these types of words. The heterophonic homographs are both phonologically and semantically ambiguous and the homophonic homographs are only semantically ambiguous, so comparing the effect size (i.e., the difference between the homographs and the control words) for heterophonic homographs to the effect size for homophonic homographs in each context condition should isolate the effects of phonology and shed light on the extent to which context can affect phonological ambiguity, independent of semantic ambiguity. Homophonic homographs were matched with heterophonic homographs for frequency and length, and the effect sizes for

heterophonic homographs were compared with the effect sizes for homophonic homographs in the following two experiments.

Predictions

The predictions for the homophonic homographs in the weakly biasing and moderately biasing context conditions were based on the eye-tracking research in this area (Binder & Rayner, 1998; Dopkins et al., 1992; Duffy et al., 1988; Folk & Morris, 1995; Rayner et al., 1994). That is, it was predicted that the weakly biasing context and the moderately biasing context would boost activation for the subordinate meaning of a homograph, making this meaning more available and therefore creating competition between the dominant and subordinate meanings. Furthermore, based on Binder and Rayner's (1998) finding that strongly biasing context results in a larger subordinate bias effect, it was predicted that the subordinate bias effect would be larger in the moderately biasing context condition than in the weakly biasing context condition. That is, the moderately biasing context was more predictive of the subordinate meaning of homographs, which may lead to greater competition between the subordinate and dominant meanings in the moderately biasing context condition.

Predictions for the homophonic homographs were not as clear for the strongly biasing context condition. Predictions derived from the reordered access model of ambiguity resolution stated that a subordinate bias effect would still be observed even when the preceding context was strongly biasing because although context can influence meaning activation to some extent, frequency of meaning has more influence and the dominant meaning will always be available. In fact, according to the reordered access model, the subordinate bias effect should be largest in the strongly biasing context

condition because the subordinate meaning would be the most available in this condition, which would result in the greatest degree of competition between the dominant and subordinate meanings. However, predictions derived from the context-sensitive model of ambiguity resolution may also be relevant because it seems likely that the context used in this condition is more strongly predictive than contexts used in previous studies. Predictions based on the context-sensitive model were that the subordinate meaning of a homograph would become more available than the dominant meaning when the ambiguous word followed strongly biasing context, and that the subordinate bias effect would disappear. These predictions are based on the assumption that context can be more influential to meaning activation than can frequency of meaning.

Although Folk and Morris (1995) conducted eye-tracking experiments and found evidence of phonological competition when previous context was either neutral in relation to the subordinate meaning of a heterophonic homograph or biased toward the subordinate meaning of the homograph, Gottlob et al. (1999) predicted that the phonological competition might be reduced or even eliminated if the predictability of the context is strong enough. Accordingly, predictions derived from the context-sensitive model were that phonological competition would be observed in the weakly biasing context condition and in the moderately biasing context condition, but that this competition might disappear in the strongly biasing context condition. That is, in the weakly biasing and moderately biasing context conditions, the effect size for heterophonic homographs should be larger than the effect size for homophonic homographs (indicating that the phonological representations are competing with each other), but in the strongly biasing context condition the effect sizes for the different

words should be no different from each other (indicating that the phonological representations are not competing with each other). Such findings would extend the context-sensitive model of ambiguity resolution to phonological ambiguity, because the effects of context would be more influential than the effects of frequency of meaning. However, results showing a larger effect size for heterophonic homographs than for homophonic homographs in the strongly biasing context condition would fail to support these predictions and would indicate that the phonological competition could not be eliminated by strongly biasing context.

Predictions derived from the reordered access model for heterophonic homographs were based on the assumption that frequency of meaning is more influential than context, but that context can still affect processing. Thus, predictions were that the largest effect of phonological ambiguity would be observed in the strongly biasing context condition, and that the smallest effect of phonological ambiguity would be observed in the weakly biasing context condition. If frequency of meaning is impacting phonological competition, the smallest effect would be expected in the weakly biasing context condition because the context is less predictive than in other context conditions, and as a result, the subordinate representation should not be as available as in other conditions in which the subordinate representation is more strongly biased. However, results showing similar effect sizes for heterophonic homographs across context conditions would fail to support these predictions and would indicate that phonological competition is not affected by frequency of meaning.

Method

Participants

Forty-seven undergraduate students at the University of Calgary participated in exchange for bonus credit in a psychology course. All participants reported that they had normal or corrected vision and that English was their first language.

Stimuli

The sentences selected from the pilot study and the ambiguous words and control words used in Experiment 1 were used in this experiment. There were a total of 60 pairs of sentences, three pairs of sentences for each ambiguous target word and its respective control word. For each set of three sentence pairs, one pair strongly biased the subordinate representation of the ambiguous word, one pair moderately biased the subordinate representation of the ambiguous word, and one pair weakly biased the subordinate representation of the ambiguous word. To counterbalance sentences, six versions of the experimental materials were created so that each participant only saw one context condition for each ambiguous word. The test words and control words alternately appeared in the same sentence, so that one participant would see an ambiguous word in a sentence that included one type of context manipulation, and another participant saw a matched control word in that same sentence. Thus, each participant was presented with 20 pairs of sentences. Participants did not see both the ambiguous word and its matched control word because the control word was related to the subordinate meaning of the ambiguous word. This step was taken to avoid the situation where, if the sentence with the control word (e.g., DEXTERITY) was presented before the sentence with the ambiguous word (e.g., DIGIT), the participant would already be biased toward the

subordinate meaning of the ambiguous word, irrespective of the type of context that preceded it. For each of the six versions, two lists were created so that sentences would be pseudo-randomized for each participant. Each sentence was displayed in lower case with the first letter in each sentence displayed in upper case.

Apparatus

Participants' eye movements were recorded using a SensoMotoric Instruments Eyelink eye-tracking system. The Eyelink system has a visual resolution of less than 20 seconds of arc. The eye-tracker has a small lightweight headband with cameras that sit underneath the eyes and track the position of the pupils as they move during reading. The eye-tracker is connected to an IBM 300PL computer and a Sony Multiscan G200 monitor. The computer controls the visual display and stores the horizontal and vertical coordinates corresponding to the position of the eyes every 4 ms. Viewing is binocular and eye movements are recorded for both right and left eyes (usually only the left eye fixation data is used in the analyses). Participants sit 60 cm from the monitor.

Procedure

At the beginning of the experiment, the eye-tracker was calibrated for each participant. In the calibration phase, participants were asked to fixate on dots presented at different points on the computer screen. This calibration process took 5 to 10 minutes to complete. Participants were then asked to read pairs of sentences as they appeared on the computer screen. Participants first read sentences presented in practice trials, and then began the experimental trials. At the start of each trial, participants fixated on a point positioned in the upper half of the screen. Two sentences then appeared to them in the middle of the screen. After reading the sentences, participants were asked to look at the

bottom, right corner of the screen to indicate that they had completed reading. This process was repeated for each trial. Once all of the trials had been presented, participants were asked to respond to three comprehension questions to ensure that they were attending to the meaning of the sentences.

Results and Discussion

Responses to comprehension questions indicated that all of the participants read for comprehension. Initial processing time of the target words was measured by first fixation duration and gaze duration, and rereading of the target word was measured by mean number of regressions to the target word. First fixation duration refers to the duration of participants' initial fixations on the target word. Gaze duration refers to the total time participants fixate on the target word before moving on to the text that follows the word (i.e., fixation times for regressive eye movements were excluded from this measure). Regressions include fixations on the target word that occur after participants have fixated on text that follows the target word.

The results for first fixation duration will be reported here for the interested reader, but my conclusions will be based on the gaze duration analyses. Jared et al. (1999) stated that the first fixation duration measure may not capture the difficulty that readers can experience when reading a particular word. To illustrate, they noted that if two different words were initially fixated on for 250 ms, but only one word was fixated on a second time for 400 ms, the word that was fixated on a second time was probably more difficult to process than the word that was fixated on once, and the first fixation duration would not capture this difference. Other researchers have not reported the first

fixation duration results when they were not consistent with the gaze duration results (e.g., Folk & Morris, 1995; Folk & Morris, 2003; Rayner et al., 1994).

Fixations were included in the analyses if they occurred on the target word or one character space to the left of the target word. If there were no fixations in this region, the region was expanded to four character spaces to the left of the word, and any fixation in this region was included in the analyses. This procedure has been used by Rayner, Pollatsek, and Binder (1998) and Jared et al. (1999), who suggested that participants can perceive the target word while fixating on the end of the previous word. However, if no fixations occurred on the target word before moving beyond it, but fixations did occur on the target word after a regression was made, first fixations on the word preceding the target word were not included in the analyses. If there were no fixations either on the target or within four characters to the left of the target, the trial was not included in the analyses.

Fixation times were also examined for the first fixation following the target word and for the total fixations in the entire region following the target word. These fixations are called spillover and are believed to provide information about text-integration processes that occur as participants continue to read the sentences (Binder & Rayner, 1998; Folk & Morris, 2003; Rayner & Duffy, 1986). Fixations shorter than 100 ms and longer than 1000 ms (3% of the data) were excluded from the analyses, as it has been suggested that these fixations reflect behaviour not associated with word activation and processing (e.g., oculomotor programming, momentary track losses, blinking; Morrison, 1984). For all planned comparisons in this experiment, one-tailed tests of significance

were used. Data were analyzed with subjects ($F1$ or $t1$) and, separately, items ($F2$ or $t2$) treated as random factors.

Initial Processing of the Target Word

First fixation duration. As in Experiment 1, differences in first fixation duration for control words of different lengths were examined to determine if, on average, words that were longer resulted in longer first fixation durations. No differences were found among these data, indicating that longer words did not take longer to process initially. For example, control words that were 10 letters long had mean first fixations of 218 ms, whereas control words that were 5 letters long had mean first fixations of 227 ms. Thus, the first fixation duration data were not adjusted for word length. First fixation duration means for subjects are presented in Table 2.

A 3 (Context: strongly biasing, moderately biasing, weakly biasing) by 2 (Effect Type: heterophonic homograph, homophonic homograph) ANOVA was conducted. Results indicated that the main effect of Context was not significant, $F1 < 1$, $F2 < 1$, and the interaction of Context and Effect Type was not significant, $F1(2, 66) = 1.24$, $MSE = 6774.14$, $p = .30$, $F2(2, 18) = 1.04$, $MSE = 1519.55$, $p = .37$. The main effect of Effect Type, however, was significant, $F1(1, 33) = 7.29$, $MSE = 5983.71$, $p < .05$, $F2(1, 9) = 5.73$, $MSE = 2013.68$, $p < .05$.

Planned comparisons were conducted to further examine the data. Results revealed that heterophonic homographs were initially fixated on longer than control words in the strongly biasing context condition, $t1(43) = 1.74$, $SE = 13.42$, $p < .05$, $t2(18) = 1.91$, $SE = 10.17$, $p < .05$, however, there were no significant differences in first fixation duration between heterophonic homographs and control words in the moderately

biasing context condition, $t1(46) = 1.24$, $SE = 16.57$, $p = .11$, $t2(18) = 1.47$, $SE = 12.80$, $p = .08$, or in the weakly biasing context condition, $t1 < 1$, $t2(18) = 1.05$, $SE = 12.79$, $p = .16$. Further comparisons revealed that the difference in first fixation duration between homophonic homographs and control words in the strongly biasing context condition was significant, $t1(44) = 1.88$, $SE = 12.12$, $p < .05$, $t2(18) = 1.90$, $SE = 14.29$, $p < .05$, however, fixations were faster for homophonic homographs than for control words. There were no significant differences in first fixation duration between homophonic homographs and control words in either the moderately biasing context condition or the weakly biasing context condition, all $t1 < 1$, $t2 < 1$.

Gaze duration. Differences in gaze duration between control words of different lengths were examined to determine if, on average, words that were longer had longer gaze duration. A linear trend was found among the data, indicating that longer words were fixated on longer before reading subsequent text. For example, control words that were 9 letters long had a mean gaze duration of 508 ms, whereas control words that were 5 letters long had a mean gaze duration of 265 ms, and gaze duration for words of intermediate length tended to fall between these values. Thus, relative differences in gaze duration were computed and a length correction factor was applied, such that words that were 4 or 5 letters long were divided by 1, words that were 6, 7, or 8 letters long were divided by 1.18, and words that were 9, 10, or 11 letters long were divided by 1.93. The data were analyzed using the gaze duration data derived from these calculations, and the corrected gaze duration means for subjects are presented in Table 2.

A 3 (Context: strongly biasing, moderately biasing, weakly biasing) by 2 (Effect Type: heterophonic homograph, homophonic homograph) ANOVA was conducted, and

results indicated that the main effect of Context was not significant, $F1 < 1$, $F2 < 1$, and the interaction of Context and Effect Type was not significant, $F1 < 1$, $F2 < 1$. The main effect of Effect Type approached significance, $F1(1, 33) = 3.51$, $MSE = 24638.49$, $p = .07$, $F2(1, 19) = 6.44$, $MSE = 8211.33$, $p < .05$.

Planned comparisons were conducted to further examine the data. Results showed that gaze duration was significantly longer for heterophonic homographs than for control words in the strongly biasing context condition, $t1(44) = 2.29$, $SE = 22.21$, $p < .05$, $t2(18) = 2.70$, $SE = 19.46$, $p < .01$, the moderately biasing context condition, $t1(47) = 1.89$, $SE = 23.68$, $p < .05$, $t2(18) = 3.57$, $SE = 13.10$, $p < .01$, and the weakly biasing context condition, $t1(46) = 1.96$, $SE = 27.84$, $p < .05$, $t2(18) = 2.30$, $SE = 32.18$, $p < .05$. Further comparisons revealed that the difference in gaze duration between homophonic homographs and control words was not significant in either the strongly biasing context condition, the moderately biasing context condition, or the weakly biasing context condition, all $t1 < 1$, $t2 < 1$.

Rereading the Target Word

Regressions. Differences in mean number of regressions to control words of different lengths were examined to determine if, on average, words that were longer resulted in more regressions. No differences were found among the data, suggesting that the mean number of regressions was not greater for longer words. For example, control words that were 10 letters long had a mean number of regressions of 0.51 (the range of regressions was between 0 and 12) whereas control words that were 5 letters long had a mean number of regressions of 0.63. Thus, the regression data were not adjusted for target word length. Mean number of regressions for subjects are presented in Table 2.

A 3 (Context: strongly biasing, moderately biasing, weakly biasing) by 2 (Effect Type: heterophonic homograph, homophonic homograph) ANOVA was conducted, and results indicated that the main effect of Context was not significant, $F1 < 1$, $F2 < 1$, the main effect of Effect Type was not significant, $F1(1, 34) = 2.07$, $MSE = 7.67$, $p = .16$, $F2(1, 9) = 1.49$, $MSE = .65$, $p = .16$, and the interaction of Context and Effect Type was not significant, $F1 < 1$, $F2 < 1$.

Planned comparisons were conducted to further examine the data. Results showed that the mean number of regressions for heterophonic homographs was greater than the mean number of regressions for control words in the strongly biasing context condition, $t1(44) = 1.70$, $SE = .20$, $p < .05$, $t2(18) = 1.21$, $SE = 0.11$, $p = .12$, and in the moderately biasing context condition, $t1(47) = 1.82$, $SE = 0.26$, $p < .05$, $t2 < 1$. The difference in mean number of regressions for heterophonic homographs and control words was not significant in the weakly biasing context condition, $t1(46) = 1.05$, $SE = 0.13$, $p =.15$, $t2 < 1$. Further comparisons revealed that the difference in mean number of regressions between homophonic homographs and control words approached significance in the strongly biasing context condition, $t1(44) = 1.35$, $SE = 0.18$, $p = .09$, $t2(18) = 1.58$, $SE = 0.11$, $p = .07$, and in the moderately biasing context condition, $t1(47) = 1.57$, $SE = 0.42$, $p = .06$, $t2(18) = 1.27$, $SE = 0.20$, $p = .11$, such that the mean number of regressions was greater for control words than for homophonic homographs. The difference in mean number of regressions between homophonic homographs and control words was not significant in the weakly biasing context condition, $t1 < 1$, $t2 < 1$.

Spillover

First fixation spillover. The differences in first fixation duration did not vary as a function of word length, and it was concluded that first fixations on a word were not affected by the length of the word. Based on this conclusion, the first fixation spillover data were not adjusted for length. First fixation spillover means for subjects are presented in Table 3.

A 3 (Context: strongly biasing, moderately biasing, weakly biasing) by 2 (Effect Type: heterophonic homograph, homophonic homograph) ANOVA was conducted. Results indicated that the main effect of Context was not significant, $F1(2, 76) = 2.43$, $MSE = 10662.82$, $p = .10$, $F2\ (2, 18) = 2.93$, $MSE = 1834.30$, $p = .08$, the main effect of Effect Type was not significant, $F1(1, 38) = 1.64$, $MSE = 12136.89$, $p = .21$, $F2\ (1, 9) = 1.32$, $MSE = 2160.28$, $p = .28$, and the interaction of Context and Effect Type was not significant, $F1 < 1$, $F2 < 1$.

Planned comparisons were conducted to further examine the data. Results revealed that there were no differences in first fixation spillover between heterophonic homographs and control words in either the strongly biasing context condition or the moderately biasing context condition, all $t1 < 1$, $t2 < 1$. However, the first fixation spillover was significantly longer for heterophonic homographs than for control words in the weakly biasing context condition, $t1(45) = 1.82$, $SE = 17.96$, $p < .05$, $t2(18) = 1.55$, $SE = 19.03$, $p = .07$. Further comparisons revealed that the difference between first fixation spillover for homophonic homographs and control words was significant in the strongly biasing context condition was significant, $t1(46) = 1.64$, $SE = 15.41$, $p < .05$, $t2 < 1$, and was approaching significance in the moderately biasing context condition, $t1(46)$

= 1.27, SE = 14.50, p = .06, $t2 < 1$, however, first fixation spillover was faster for homophonic homographs than for control words. There were no significant differences in first fixation spillover between homophonic homographs and control words in the weakly biasing context condition, $t1 < 1$, $t2 < 1$.

Total fixation spillover. Differences in total fixation spillover between text regions following targets that differed in length were examined to determine if, on average, regions that were longer had longer total fixation spillover duration. A linear trend was found among the data, indicating that longer regions were fixated on longer. For example, text regions that were 30 characters had a mean spillover time of 1167 ms, whereas text regions that were 13 characters long had a mean spillover time of 891 ms, and mean spillover for text regions of intermediate length tended to fall between these values. Thus, relative differences in total fixation spillover durations were computed and a length correction factor was applied, such that text regions that were13 or 14 characters long were divided by 1, text regions that were 15, 16, 18, or 19 characters long were divided by 1.16, and text regions that were between 20 and 35 characters long were divided by 1.30. The data were reanalyzed using the total fixation spillover durations derived from these calculations, and the corrected total fixation spillover means for subjects are presented in Table 3.

A 3 (Context: strongly biasing, moderately biasing, weakly biasing) by 2 (Effect Type: heterophonic homograph, homophonic homograph) ANOVA was conducted, and results indicated that the main effect of Context was not significant, $F1 < 1$, $F2 < 1$, the main effect of Effect Type was not significant, $F1(1, 39) = 2.70$, $MSE = 140101.63$, $p = .11$, $F2(1, 9) = 2.27$, $MSE = 46631.66$, $p = .17$, and the interaction of Context and Effect

Type was not significant, $F1(2, 78) = 1.17$, $MSE = 79477.06$, $p = .32$, $F2\ (2, 18) = 1.91$, $MSE = 33839.53$, $p = .18$.

Planned comparisons were conducted to further examine the data. Results revealed that there were no differences in total fixation spillover between heterophonic homographs and control words in either the strongly biasing context condition or the moderately biasing context condition, all $t1 < 1$, $t2 < 1$. However, the total fixation spillover was significantly longer for heterophonic homographs than for control words in the weakly biasing context condition, $t1(46) = 1.89$, $SE = 64.81$, $p < .05$, $t2(18) = 1.95$, $SE = 80.02$, $p < .05$. Further comparisons revealed that the difference in total fixation spillover between homophonic homographs and control words was not significant in either the strongly biasing context condition, the moderately biasing context condition, or the weakly biasing context condition, all $t1 < 1$, $t2 < 1$.

The results for heterophonic homographs (e.g., SEWER) were similar to the results found by Folk and Morris (1995). These results did not support either the reordered access model or the context-sensitive model, but results from the homophonic homographs (e.g., DIGIT) did support the context-sensitive model. The reordered access model states that both context and frequency of meaning can influence the availability of a particular meaning, but that frequency of meaning will always have greater influence than context. Predictions derived from the reordered access model were that gaze duration would be significantly longer for ambiguous words than for control words in the weakly biasing, moderately biasing, and strongly biasing context conditions because these sentences biased the subordinate meaning of the ambiguous words, resulting in greater availability of the subordinate representation relative to the dominant

representation. Furthermore, predictions were that the competition would be greater in the moderately biasing context condition than in the weakly biasing context condition, and greater in the strongly biasing context condition than in the moderately biasing context condition. The rationale is that the dominant representation is always activated, so the greater the predictability of the context for the subordinate representation, the more likely the subordinate representation will compete with the dominant representation.

Conversely, the context-sensitive model states that both context and frequency of meaning can influence the availability of a particular meaning, but that context can have greater influence than frequency of meaning. Predictions derived from the context-sensitive model were similar to predictions derived from the reordered access model for the weakly biasing and moderately biasing context conditions. However, in the strongly biasing context condition, predictions were that gaze duration for ambiguous words would be similar to gaze duration for control words because the context was strongly predictive of the subordinate meaning of the ambiguous word, resulting in selective access of this meaning.

Results showed that gaze duration was significantly longer for heterophonic homographs than for control words in every context condition, but there were no differences in gaze duration for homophonic homographs relative to control words in any context condition. Given that semantic representations for homophonic homographs did not compete in any context condition, it can be assumed that the competition observed for heterophonic homographs is due to phonological ambiguity. The fact that gaze duration was longer for heterophonic homographs than for control words in all three context conditions indicated that, contrary to Gottlob et al.'s (1999) predictions and predictions

derived from the context-sensitive model, context could not selectively activate the subordinate representation. In addition, the effect sizes were similar in each context condition, suggesting that frequency of meaning was not influencing the activation of phonological representations (the effect size would have been relatively smaller in the weakly biasing context condition if frequency of meaning could affect phonological processing). These results indicate that neither the reordered access model nor the context-sensitive model of ambiguity resolution could be extended to account for phonological ambiguity effects in sentences.

The analyses for the mean number of regressions and spillover also indicate that phonological ambiguity is difficult to resolve. The mean number of regressions for heterophonic homographs was significantly greater for heterophonic homographs in the strongly biasing and moderately biasing context conditions, and both first fixation spillover and total fixation spillover were longer for heterophonic homographs than for control words in the weakly biasing context condition. It is likely, then, that participants are experiencing later processing difficulty for heterophonic homographs in each context condition, and that this difficulty is captured in the regression data for the weakly biasing context condition and in the spillover data for the moderately biasing and strongly biasing context conditions. These results replicate Folk and Morris' (1995) finding that participants always experienced difficulty integrating the heterophonic homographs into subsequent text. The pattern of phonological competition for gaze duration and spillover in different context conditions can be seen in Figure 1.

The lack of competition observed for the homophonic homographs in all three context conditions implies that the subordinate meaning was selectively activated in the

weakly biasing, moderately biasing, and strongly biasing context conditions. These results do not support the reordered access model, as the dominant meanings of the homophonic homographs did not appear to be available in any of the conditions. However, these results do support the context-sensitive model, as it appears that the contextually appropriate meaning was selectively activated. The results from the regression analyses and spillover analyses also support the notion of selective access. As shown in Figure 2, the spillover results mirror the results from the gaze duration analyses, such that no differences were found between first fixation spillover or total fixation spillover for homophonic homographs and control words in any context condition. The same pattern was also exhibited in the regression data. These results reveal that participants did not have difficulty during text-integration and provide additional support to the idea that the contextually inappropriate meaning was not interfering at any point during sentence processing.

Experiment 3

The purpose of Experiment 3 was to confirm that the results of Experiment 2 were generalizable across experimental tasks. This experiment involved a self-paced reading task, whereby participants read sentences that are presented to them one word at a time on a computer screen. Participants bring up each new word in the sentences by pressing a button. The stimuli in Experiment 3 were the same as in Experiment 2.

The self-paced reading task is similar to the eye-tracking task because it allows for the examination of on-line processing of ambiguous words relative to control words. However, participants are unable to regress back to previous words or to skip words as they read. As a result, this task is somewhat more difficult than the eye-tracking task

because it is less natural. Tasks that are more difficult often force participants to slow down, resulting in inflated response times and exaggerated effect sizes. Such a task may magnify any effects that are observed when ambiguous words are processed. That is, any effects captured in the eye-tracking task should be replicated in the self-paced reading task, and effects not captured in the eye-tracking task may become apparent in the self-paced reading task.

Based on the results from the eye-tracking task in Experiment 2, the predictions for this experiment were that response times for heterophonic homophones (e.g., SEWER) would be longer than response times for control words in the weakly biasing context condition, the moderately biasing context condition, and the strongly biasing context condition. However, it was unclear whether response times for homophonic homographs (e.g., DIGIT) would be similar to response times for control words, as it was uncertain whether the eye-tracking task captured the difficulty that may be associated with these words. Based on the fact that results from eye-tracking tasks in the past have revealed a subordinate bias effect (Binder & Rayner, 1998; Dopkins et al., 1992; Duffy et al., 1988; Folk & Morris, 1995; Folk & Morris, 2003; Rayner et al., 1994), it can be assumed that the eye-tracking task in Experiment 2 would be sensitive enough to detect any potential difficulty associated with the homophonic homographs. Consequently, the predictions were that no differences in response times for homophonic homographs relative to control words would be observed in the self-paced reading task.

Method

Participants

Forty-eight undergraduate students at the University of Calgary participated in this study in exchange for bonus credit in a psychology course. All participants reported that they had normal or corrected vision and that English was their first language.

Stimuli

The stimuli used in Experiment 3 were the same as in Experiment 2.

Procedure

At the beginning of the experiment, participants were informed that they would be asked three comprehension questions about the sentences in the computer task. In the self-paced reading task, participants were presented with a series of dashes in the middle of the screen. The dashes were separated by spaces, and each set of dashes corresponded to a word in a pair of sentences. Each time a participant pressed a button on a button box, the next word in the sentence appeared, and the preceding word was again replaced by a set of dashes. Once participants finished reading the last word of the second sentence in the pair of sentences, they could bring up the next trial by pressing the button again. In this way, participants could pace themselves as they read through the sentences, and participants were asked to try to read the sentences as naturally as possible. Participants began with practice trials before being presented with the experimental trials. All stimuli were presented in the centre of a 17-inch Sony Trintron monitor controlled by a Macintosh G3 and presented using PsyScope (Cohen et al., 1993). The words were approximately 0.50 cm high and at eye level for the participants. The distance between

each participant and the monitor screen was approximately 40 cm. At the end of the task, participants were asked to respond to the comprehension questions.

Results and Discussion

Responses to comprehension questions indicated that all of the participants read for comprehension. The response times to the target words and to the first, second, and last words following the targets (spillover) were analyzed. For all planned comparisons in this experiment, one-tailed tests of significance were used. Data were analyzed with subjects ($F1$ or $t1$) and, separately, items ($F2$ or $t2$) treated as random factors.

Target Words

A trial was considered an error and excluded from the latency analysis if the response latency was longer than 2000 ms or shorter than 150 ms (0.73% of the data). Differences in response times between control words of different lengths were examined to determine if, on average, control words that were longer also had slower response times. A linear trend was found among the data, indicating that longer target words were responded to more slowly. For example, control words that were 11 letters long had a mean response time of 652 ms, whereas control words that were 4 letters long had a mean response time of 463 ms, and response times for words of intermediate length tended to fall between these values. Thus, relative differences in response times were computed and a length correction factor was applied, such that words that were 4 letters long were divided by 1, words that were 5, 6, or 7 letters long were divided by 1.11, words that were 8 letters long were divided by 1.19, and words that were 9, 10, or 11 characters long were divided by 1.42. The data were analyzed using the response times derived from these calculations, and the corrected response times for subjects are presented in Table 4.

A 3 (Context: strongly biasing, moderately biasing, weakly biasing) by 2 (Effect Type: heterophonic homograph, homophonic homograph) ANOVA was conducted, and results indicated that the main effect of Context was not significant, $F1 < 1$, $F2 < 1$, the main effect of Effect Type was not significant, $F1(1, 30) = 2.12$, $MSE = 49218.22$, $p = .16$, $F2(1, 9) = 6.46$, $MSE = 18216.09$, $p < .05$, and the interaction of Context and Effect Type was not significant, $F1 < 1$, $F2 < 1$.

Planned comparisons were conducted to further examine the data. Results showed that the difference in response times between heterophonic homographs and control words was significant in the strongly biasing context condition, $t1(47) = 2.78$, $SE = 26.55$, $p < .01$, $t2(18) = 2.20$, $SE = 33.93$, $p < .05$, was approaching significance in the moderately biasing context condition, $t1(46) = 1.36$, $SE = 36.89$, $p = .09$, $t2(18) = 1.14$, $SE = 34.95$, $p = .14$, and was significant in the weakly biasing context condition, $t1(47) = 1.88$, $SE = 50.79$, $p < .05$, $t2(18) = 2.61$, $SE = 37.03$, $p < .01$, such that response times were longer for the heterophonic homographs than for control words. Further comparisons revealed that the difference in response times between homophonic homographs and control words was not significant in either the strongly biasing context condition, the moderately biasing context condition, or the weakly biasing context condition, all $t1 < 1$, $t2 < 1$.

Spillover

First word spillover. A trial was considered an error and excluded from the latency analysis if the response latency was longer than 2000 ms or shorter than 150 ms (0.04% of the data). Differences in first word spillover response times between words of different lengths were examined to determine if, on average, words that were longer

resulted in longer response times. No differences were found among the data, indicating that longer words did not take longer to process initially. For example, words that were 8 letters long had a mean response time of 512 ms, whereas control words that were 2 letters long had a mean response time of 484 ms. Thus, the first word spillover data were not adjusted for word length. Response times for subjects are presented in Table 5.

A 3 (Context: strongly biasing, moderately biasing, weakly biasing) by 2 (Effect Type: heterophonic homograph, homophonic homograph) ANOVA was conducted, and results indicated that the main effect of Context was not significant, $F1 < 1$, $F2 < 1$, and the interaction of Context and Effect Type was not significant, $F1 < 1$, $F2(2, 18) = 1.07$, $MSE = 13853.91$, $p = .36$. The main effect of Effect Type, however, was significant, $F1(1, 31) = 6.75$, $MSE = 46787.29$, $p < .05$, $F2(1, 9) = 2.50$, $MSE = 43495.78$, $p = .15$.

Planned comparisons were conducted to further examine the data. Results showed that the difference in response times between the first word following the heterophonic homographs and the first word following control words was approaching significance in the strongly biasing context condition, $t1(46) = 1.37$, $SE = 42.52$, $p = .09$, $t2(18) = 1.22$, $MSE = 33.91$, p = .12, was significant in the moderately biasing context condition, $t1(46) = 1.97$, $SE = 35.51$, $p < .05$, $t2(18) = 1.58$, $SE = 56.99$, $p = .07$, and was significant in the weakly biasing context condition, $t1(47) = 2.65$, $SE = 42.14$, $p < .01$, $t2(18) = 1.97$, $SE = 60.77$, $p < .05$, such that response times were longer for the first word following heterophonic homographs than for the first word following control words. Further comparisons revealed that the difference in response times between the first word following homophonic homographs and the first word following the control words was

not significant in either the strongly biasing context condition, the moderately biasing context condition, or the weakly biasing context condition, all $t1 < 1$, $t2 < 1$.

Second word spillover. A trial was considered an error and excluded from the latency analysis if the response latency was longer than 2000 ms or shorter than 150 ms (0.04% of the data). Differences in second word spillover response times between words of different lengths were examined to determine if, on average, words that were longer resulted in longer response times. No differences were found among the data, indicating that longer words did not take longer to process initially. For example, words that were 8 letters long had a mean response time of 460 ms, whereas control words that were 3 letters long had a mean response time of 451 ms. Thus, the second word spillover data were not adjusted for word length. Spillover response times for subjects are presented in Table 5.

A 3 (Context: strongly biasing, moderately biasing, weakly biasing) by 2 (Effect Type: heterophonic homograph, homophonic homograph) ANOVA was conducted, and results indicated that the main effect of Context was not significant, $F < 1$, $F2 < 1$, the main effect of Effect Type was not significant, $F1(1, 31) = 2.37$, $MSE = 16883.11$, $p = .13$, $F2(1, 9) = 1.62$, MSE = 12549.49, $p = .24$, and the interaction of Context and Effect Type was not significant, $F1 < 1$, $F2 < 1$.

Planned comparisons were conducted to further examine the data. Results showed that the difference in response times between the second word following the heterophonic homographs and the second word following control words not significant in either the strongly biasing context condition, $t1 < 1$, $t2 < 1$, or in the moderately biasing context condition, $t1(46) = 1.14$, $SE = 32.84$, $p = .13$, $t2(18) = 1.47$, $SE = 27.70$, $p = .08$.

However, the difference was significant in the weakly biasing context condition, $t1(47) = 1.98$, $SE = 26.85$, $p < .05$, $t2(18) = 1.51$, $SE = 45.74$, $p = .08$, such that response times were longer for the second word following heterophonic homographs than for the second word following control words. Further comparisons revealed that the difference in response times between the second word following homophonic homographs and the second word following the control words was not significant in the strongly biasing context condition, $t1 < 1$, $t2 < 1$, was approaching significance in the moderately biasing context condition, $t1(47) = 1.26$, $SE = 14.20$, $p = .06$, $t2 < 1$, (such that response times were longer for control words), and was not significant in the weakly biasing context condition, $t1 < 1$, $t2 < 1$.

Last word spillover. For the last word in the second sentence there was a large range in response times (174 ms to 7320 ms). Rather than try to impose RT cutoff values, I included all of these data in the analyses. Differences in last word spillover response times between words of different lengths were examined to determine if, on average, words that were longer resulted in longer response times. No differences were found among the data, indicating that longer words did not take longer to process initially. For example, words that were 11 letters long had a mean response time of 820 ms, whereas control words that were 2 letters long had a mean response time of 898 ms. Thus, the last word spillover data were not adjusted for word length. Spillover response times for subjects are presented in Table 5.

A 3 (Context: strongly biasing, moderately biasing, weakly biasing) by 2 (Effect Type: heterophonic homograph, homophonic homograph) ANOVA was conducted, and results indicated that the main effect of Context approached significance, $F1(2, 62) =$

2.69, $MSE = 1295835.39$, $p = .08$, $F2(2, 18) = 1.01$, $MSE = 229383.95$, $p = .39$. However, the main effect of Effect Type and the interaction of Context and Effect Type were not significant, all $F1 < 1$, $F2 < 1$.

Planned comparisons were conducted to further examine the data. Results showed that the difference in response times between the last word following the heterophonic homographs and the last word following control words not significant in either the strongly biasing context condition, $t1 < 1$, $t2 < 1$, or in the moderately biasing context condition, $t1 < 1$, $t2 < 1$. However, the difference was significant in the weakly biasing context condition, $t1(47) = 2.35$, $SE = 197.53$, $p < .05$, $t2(18) = 1.62$, $SE = 203.09$, $p = .06$, such that response times were longer for the last word following heterophonic homographs than for the last word following control words. Further comparisons revealed that the difference in response times between the last word following homophonic homographs and the last word following the control words was not significant in the strongly biasing context condition or in the moderately biasing context condition, all $t1 < 1$, $t2 < 1$. However, the difference was approaching significance in the weakly biasing context condition, $t1(31)= 1.26$, $SE = 14.20$, $p = .06$, $t2 < 1$, such response times for the last word following homophonic homographs were somewhat longer than the last word following control words.

The results of Experiment 3 were similar to the results of Experiment 2, indicating that the results of Experiment 2 were replicated across tasks. The response times for heterophonic homographs (e.g., SEWER) were significantly longer than response times for control words in the strongly biasing context condition and in the weakly biasing biasing context condition, and this difference was approaching significance in the

moderately biasing context condition. These results again replicated Folk and Morris' (1995) results, supporting the notion that context did not appear to eliminate the initial competition created by phonological ambiguity. In addition, the effect size for heterophonic homographs was not the smallest in the weakly biasing context condition, suggesting that the reordered access model cannot account for phonological ambiguity, because frequency of meaning was not affecting phonological competition. However, the spillover data suggest that context may affect the speed with which the phonological competition can be resolved. Competition was observed when reading the first word following the target in all three context conditions (although the difference between heterophonic homographs and control words only approached significance in the strongly biasing context condition). When reading the second and last words following the target, however, competition was only observed in the weakly biasing condition. These results provide partial support for the idea that context can mediate phonological competition to some extent, because the greatest amount of spillover was observed in the weakly biasing context condition and the least amount of spillover was observed in the strongly biasing context condition. This pattern is similar to the pattern found for spillover in Experiment 2, but regression analyses in Experiment 2 revealed that the mean number of regressions was significantly greater in the moderately biasing and strongly biasing context conditions, suggesting that integration difficulty was still experienced in these conditions. As mentioned earlier, the self-paced reading task is less natural than the eye-tracking task, and tasks that are more difficult often result in exaggerated effects. Thus, any influence that context may have on integration processing for heterophonic homographs appears to minimal, and may only occur when the task is relatively difficult and

participants are compelled to slow down. The pattern of phonological competition for target response times and spillover in different context conditions can be seen in Figure 3.

The results for the homophonic homographs (e.g., DIGIT) in Experiment 3 were identical to the results for these homographs in Experiment 2. As shown in Figure 4, no differences in response times or in spillover were exhibited for these words relative to control words in any of the context conditions, suggesting that the subordinate meaning was selectively activated in the weakly biasing, moderately biasing, and strongly biasing context conditions. These results support the context-sensitive model of ambiguity resolution.

General Discussion

Three experiments were conducted to examine the effects of context and frequency on phonological ambiguity resolution. In Experiment 1, a naming task was conducted to determine whether the heterophonic homographs (e.g., SEWER) used in subsequent experiments produced the interference typical of these words in a naming task, and to determine whether the biased homophonic homographs (e.g., DIGIT) used in subsequent experiments produced the facilitation typical of these words in a naming task. After adjusting the data to account for differences in word length, the analyses revealed that the heterophonic homographs did take longer to name than control words, and that homophonic homographs were named faster than control words.

In Experiment 2, an eye-tracker was used to monitor participants' eye movements while they read heterophonic homographs and homophonic homographs that appeared after semantic context that was either strongly predictive, moderately predictive, or weakly predictive in relation to the subordinate meaning of the target homograph. After

the data were adjusted to account for length, it was found that results for the heterophonic homographs were similar to Folk and Morris' (1995) results, such that both representations associated with the heterophonic homographs competed with each other in all context conditions. In addition, this competition could still be observed as participants read text that appeared after the ambiguous words, suggesting that participants were having difficulty integrating the phonologically ambiguous words with the text. The competition was not attenuated by context or frequency in this experiment, suggesting that neither the reordered access model nor the context-sensitive model of ambiguity resolution could be extended to characterize effects of phonological ambiguity.

The results from Experiment 2 also revealed that the representations associated with the homophonic homographs did not compete in the strongly biasing, the moderately biasing, or the weakly biasing context condition. Further, no competition was observed during processing of subsequent text, suggesting that participants did not experience difficulty integrating the homophonic homographs with the text. These results support a context-sensitive model of ambiguity resolution, which states that context can impact the activation of semantically ambiguous words such that only one meaning of a homophonic homograph is selectively activated, even if the meaning is less frequent.

In Experiment 3, a self-paced reading task was conducted to determine whether the results from the eye-tracking task used in Experiment 2 were generalizable across tasks, and to determine whether additional effects could be observed in a task that is more difficult and therefore more likely to result in exaggerated effects of ambiguity. The response data were once again adjusted to account for length, and were very similar to the results of Experiment 2. Competition was observed for the heterophonic homographs in

all context conditions (although differences only approached significance in the moderately biasing context condition). However, competition observed during integrative processing appeared to be mediated somewhat by context, such that integrative difficulty was greatest in the weakly biasing context condition and least in the strongly biasing context condition. An effect of context on integrative processing was not observed in Experiment 2, so any effect of context observed in Experiment 3 was probably due to the fact that the self-paced reading task used in Experiment 3 was more difficult, causing participants to slow down and resulting in exaggerated effects. Thus, based on the combined results of Experiments 2 and 3, it can be concluded that the effect of context on text integration for heterophonic homographs is minimal. No competition was observed for the homophonic homographs in any context condition, either during initial processing or during later, more integrative processing, which lends further support to the context-sensitive model.

Thus, the results of Experiments 2 and 3 provide convincing evidence that phonological ambiguity effects are pervasive and are, for the most part, unaffected by either context or frequency. Such evidence provides additional support for the notion that phonology is routinely activated during visual word recognition (Jared et al., 1999). The results of the present research are consistent with each of the word recognition models described above. For instance, the data are consistent with the dual route model because most of the words used in the present experiments were low frequency words, and it has been suggested that the indirect route, which involves the translation of orthography into phonology, is typically used to process low frequency words (Coltheart, 1978). The data are also consistent with the Seidenberg and McClelland's (1989) PDP-type model and

Gottlob et al.'s (1999) general resonance framework. The PDP-type model entails activation of orthographic, phonological, and semantic information in parallel, and the general resonance framework involves feedback and feedforward activation of orthography, phonology, and semantic information. Thus, these models imply that the activation of phonological information is an integral part of semantic processing, and such activation can result in phonological competition (and therefore longer reaction times) when words have multiple phonological representations. Thus, all three models of word recognition could account for the present results.

The results of the present research do not provide information about the timecourse of phonological activation relative to semantic activation. It is possible that phonological information is activated prior to the activation of semantic activation, and that phonological competition commences before semantic access. However, it is also possible that phonological activation occurs after meaning activation, and that competition between phonological representations occurs during postlexical processing. That is, it is possible that multiple semantic representations are exhaustively activated before phonological activation, and that the activation of semantic representations leads to the activation (and therefore competition) of multiple phonological representations. This possibility depends on the assumption that multiple semantic respresentations could be activated but not necessarily compete, because participants did not spend a longer amount of time processing homophonic homographs relative to control words in the present study. A third possible characterization of the semantic and phonological activation process is that these types of information are activated in parallel, and that while context constrains semantic activation (resulting in activation of only the context-

appropriate meaning in the present study) it does not constrain phonological activation in a similar way. Since my results do not allow me to adjudicate among these possibilities, the important finding here is that phonological information *is* activated during silent reading, and that the phonological competition created by heterophonic homographs appears to be more difficult to resolve than the semantic competition that can be created by homophonic homographs.

It should be mentioned that a more thorough investigation of whether the reordered access model can be extended to account for phonological competition would have entailed the inclusion of a neutral context condition. The reordered access model states that in the absence of biasing context, the dominant meaning of a biased ambiguous word would always be more available and no competition would arise between representations. However, the present results suggest that the subordinate representation of a heterophonic homograph does not differ in availability depending on the nature of the preceding context. Rather, the present results suggest that the subordinate representation is equally available when the preceding context is weakly biasing, moderately biasing, or strongly biasing. Thus, predictions based on the present research would be that phonological competition would still be observed when the context preceding heterophonic homographs is neutral.

One model that seems able to account for the present results is Seidenberg and McClelland's (1989) connectionist model of lexical processing (see Figure 5). In this model, each oval represents sets of units that are connected via hidden units. The sets of units include orthographic, phonological, semantic, and, importantly, context units. Whereas orthographic, phonological, and semantic units can influence each other

directly, context units can only influence or be influenced by orthographic and phonological units indirectly. Such a model can account for the present results because according to this framework, context would be much more likely to influence semantic competition created by homophonic homographs than phonological competition created by heterophonic homographs. That is, when preceding context biases the subordinate representation of a biased homophonic homograph, such as DIGIT, the influence of context on meaning activation is relatively direct, and selective activation of the contextually appropriate meaning can occur. However, when preceding context biases the subordinate representation of a biased heterophonic homograph, such as SEWER, the influence of context on phonological activation is not direct, resulting in competition between the two phonological representations.

It could be argued that the activation of multiple phonological representations of heterophonic homographs can result in the activation of both semantic representations via the connections between phonology and semantics in the Seidenberg and McClelland (1989) model, creating semantic competition. In this way, the phonological ambiguity effects would be largely due to semantic, and not phonological, competition. It is, however, unlikely that the competition observed for the heterophonic homographs in the present research is due to semantic competition, because no semantic competition was observed for the homophonic homographs. That is, if semantic competition could occur for heterophonic homographs in the presence of biasing context, it would have been observed for the homophonic homographs as well.

Although the results for the homophonic homographs in Experiments 2 and 3 support the context-sensitive model, it is somewhat surprising that a subordinate bias

effect was not observed for the homophonic homographs in the weakly biasing and moderately biasing context conditions. The subordinate bias effect has been a rather consistent finding in the eye-tracking investigations of semantic ambiguity (Binder & Rayner, 1998; Dopkins et al., 1992; Duffy et al., 1988; Folk & Morris, 1995; Folk & Morris, 2003; Rayner et al., 1994). Although the context-sensitive model has also received some support (e.g., Kellas et al., 1991; Paul et al., 1992), the investigations providing evidence for this position have been criticized for problems in methodology. While my results could be taken as evidence for the notion of selective access, there are also three possible reasons why a subordinate bias effect may not have been observed in these experiments.

The first reason is the possibility that the semantic context in the present study was not predictive of the subordinate meaning, and that the dominant meaning was always selected without interference. However, the results from the pilot study imply that this is not the case. There was a significant difference in predictability between the strongly biasing, moderately biasing, and weakly biasing context conditions, and participants made a correct response when asked to fill in the blank (which took the place of the target word) in the strongly biasing context condition 64.75% of the time.

A second reason may be that the differing lengths between the ambiguous words and the control words was too great a confound; this may have introduced error variability and diminished the sensitivity of the task to detect ambiguity effects. It was very difficult to select control stimuli for this experiment, and I made a decision to emphasize frequency matching over length matching. Although the differences in length have been controlled to some degree by the corrections applied in the analyses, it is

difficult to know the true impact that this confound had on the results and whether the adjustment of the data dealt with it adequately. Although it would be difficult, future research should examine phonological ambiguity and context predictability using control words that are matched for both length and frequency. Nevertheless, the results obtained after the data had been adjusted for length were more similar to results in previous naming tasks (Gottlob et al., 1999; Hino et al., 1998; Hino & Lupker, 1996; Kawamoto & Zemblidge, 1992; Lichacz et al., 1999), so it seems reasonable to assume that the adjustments made to the data successfully reduced the effect of length.

The third reason is that, because of the constraints created in matching homophonic homographs to a limited selection of heterophonic homographs (there are a very small number of these words in English), some of the homophonic homographs used in the present research were syntactically unambiguous (i.e., their meanings crossed syntactic categories; e.g., REFRAIN). As mentioned previously, Folk and Morris (2003) found that the pattern of data for syntactically unambiguous words was not similar to the pattern of data for the syntactically ambiguous words. Folk and Morris reported that biased homophonic homographs that were syntactically unambiguous did not produce a subordinate bias effect when the preceding context biased the subordinate meaning, and equibiased homophonic homographs that were syntactically unambiguous did not exhibit competition when the preceding context was weakly biasing. Given these findings, it may be possible that the six syntactically unambiguous homophonic homographs in the present set of stimuli skewed the results so that no effect was observed.

To investigate this hypothesis, the means for the syntactically ambiguous homophonic homographs were compared to the means for the syntactically unambiguous

homophonic homographs. An evaluation of these means revealed that, in the eye-tracking data in Experiment 2, the means did not differ for targets that were syntactically ambiguous or unambiguous. However, in Experiment 3, the means revealed that a potential difference may exist between the syntactically ambiguous and unambiguous words in the moderately biasing context condition. Numerically, response times for the syntactically ambiguous homophonic homographs appeared to be slower (493 ms) relative to control words (447 ms) in the moderately biasing context condition. T-tests were conducted to examine the difference, and results revealed that there were no significant differences between syntactically ambiguous homophonic homographs and control words in any context condition. It is difficult to determine what the data would look like if more syntactically ambiguous words had been used. It is important to point out, though, that there also appeared to be a reverse effect in the strongly biasing context condition for this subset of words, indicating that even if there was a subordinate bias effect, it was eliminated in the presence of semantic context that was highly predictive of the subordinate meaning. These tentative results still provide evidence in favour of the context-sensitive model of ambiguity resolution.

It should also be mentioned that any impact that syntactic ambiguity was having on this data would simply provide more support to the argument that the initial competition created by phonological ambiguity when reading heterophonic homographs cannot be attenuated by context. Eighty percent of the heterophonic homographs used in the present research were syntactically unambiguous. Thus, the effects of syntax may resolve competition created by these semantically ambiguous words, but phonological ambiguity certainly does not appear to be resolved by this factor. Although future

research on this issue would be helpful, the present research provides convincing evidence that the effects of syntax cannot eliminate such conflict.

In spite of some limitations of this research, the results from the present experiments provide compelling evidence that phonological ambiguity encountered during silent reading cannot be easily resolved. Contextual constraints cannot eliminate the initial interference created by the competing representations, and frequency of meaning also has little effect. To date, none of the extant models of semantic ambiguity resolution can be extended to account for phonological ambiguity resolution, as it appears that the nature of phonological ambiguity is much different than the nature of semantic ambiguity.

Endnote

[1]Although we will report the results of these items analyses for the interested reader, we will not be basing our conclusions on them. That is, the stimuli used in these experiments were selected specifically because they met multiple criteria. Further, in the case of homographs, the stimuli selected virtually exhausted the pool of suitable English homographs. Thus, treating items as a random factor violates the basic assumptions underlying the ANOVA model (see Wike & Church, 1976).

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Table 1

Experiment 1: Mean Naming Latencies as a Function of Word Type

	Heterophonic Homographs[a]		Homophonic Homographs[b]	
Word	BA	AA	BA	AA
Target	567 (81.55)	551 (79.57)	506 (65.40)	494 (63.77)
Control	557 (81.35)	524 (75.90)	560 (90.68)	527 (84.79)
Effect Size	+10	+27*	-54*	-33*

Note. BA = before adjustments were made to the data to account for length effects; AA = after adjustments were made to account for length effects; standard deviations are in parentheses.

[a]SEWER. [b]DIGIT.

* $p < .05$

Table 2

Experiment 2: Mean First Fixation Duration, Mean Corrected Gaze Duration, and Mean Number of Regressions as a Function of Word Type and Context Condition

	Strongly Biasing			Moderately Biasing			Weakly biasing		
Stimulus Type	FFD	GD	REG	FFD	GD	REG	FFD	GD	REG
Heterophonic Homograph[a]	245	281	0.60	258	286	1.36	242	336	1.49
	(75.04)	(120.38)	(2.25)	(104.78)	(144.57)	(5.02)	(67.62)	(166.05)	(5.08)
Heterophonic Homograph	221	230	0.27	237	242	0.89	232	282	1.35
Control[b]	(55.79)	(75.52)	(1.06)	(60.03)	(81.56)	(3.45)	(67.39)	(137.08)	(5.12)
Homophonic Homograph[c]	205	242	0.32	232	270	0.52	243	295	1.24
	(56.39)	(86.98)	(1.24)	(70.78)	(95.35)	(1.85)	(99.70)	(124.93)	(4.50)
Homophonic Homograph	228	247	0.57	240	277	1.19	240	296	1.21
Control[d]	(82.06)	(104.23)	(2.19)	(52.70)	(107.34)	(4.40)	(52.87)	(77.63)	(4.15)

Note. FFD = first fixation duration; GD = gaze duration after correcting for length; REG = mean number of regressions (the range of regressions was between 0 and 12); standard deviations are in parentheses.

[a]SEWER. [b]TAILOR. [c]DIGIT. [d]DEXTERITY.

Table 3

Experiment 2: Mean First Fixation Spillover and Mean Corrected Total Fixation Spillover as a Function of Word Type and Context Condition

	Strongly Biasing		Moderately Biasing		Weakly biasing	
Stimulus Type	FFS	TFS	FFS	TFS	FFS	TFS
Heterophonic Homograph[a]	200	899	217	865	244	1034
	(61.65)	(385.23)	(72.34)	(218.05)	(93.37)	(398.88)
Heterophonic Homograph Control[b]	211	861	224	835	211	911
	(86.65)	(358.13)	(100.48)	(272.11)	(69.47)	(382.40)
Homophonic Homograph[c]	218	806	199	900	227	847
	(63.78)	(318.96)	(54.46)	(383.34)	(62.73)	(329.30)
Homophonic Homograph Control[d]	243	808	217	897	224	871
	(98.24)	(294.83)	(83.55)	(269.37)	(80.48)	(430.29)

Note. FFS = first fixation spillover; TFS = total fixation spillover after correcting for length; standard deviations are in parenteses.

[a]SEWER. [b]TAILOR. [c]DIGIT. [d]DEXTERITY.

Table 4

Experiment 3: Mean Corrected Target Word Response Times as a Function of Word Type and Context Condition

Stimulus Type	Strongly Biasing	Moderately Biasing	Weakly biasing
Heterophonic Homograph[a]	509 (249.38)	504 (287.00)	565 (337.56)
Heterophonic Homograph Control[b]	436 (155.24)	454 (210.07)	470 (209.68)
Homophonic Homograph[c]	490 (206.90)	479 (204.48)	478 (233.29)
Homophonic Homograph Control[d]	486 (231.92)	473 (204.68)	465 (208.37)

Note. Standard deviations are in parentheses.

[a]SEWER. [b]TAILOR. [c]DIGIT. [d]DEXTERITY.

Table 5

Experiment 3: Mean First Word Spillover, Mean Second Word Spillover, and Mean Last Word Spillover as a Function of Word Type and Context Condition

	Strongly Biasing			Moderately Biasing			Weakly biasing		
Stimulus Type	FS	SS	LS	FS	SS	LS	FS	SS	LS
Heterophonic	539	478	1082	552	499	1113	632	506	1805
Homograph[a]	(222.13)	(159.99)	(880.96)	(242.25)	(231.68)	(821.92)	(296.97)	(145.31)	(1408.2
Heterophonic	481	457	1072	482	461	1091	520	453	1342
Homograph Control[b]	(243.03)	(150.36)	(1070.63)	(173.86)	(149.92)	(828.78)	(203.68)	(169.64)	(1117.7
Homophonic	459	430	987	477	446	1180	461	485	1513
Homograph[c]	(165.30)	(124.89)	(1014.45)	(223.07)	(138.76)	(918.33)	(212.76)	(163.13)	(916.18
Homophonic	440	428	972	448	428	1160	454	460	1220
Homograph Control[d]	(140.67)	(122.99)	(765.35)	(140.02)	(109.09)	(1032.52)	(155.09)	(146.22)	(901.40

Note. FS = first word spillover; SS = second word spillover; LS = last word spillover; standard deviations are in parentheses.

[a]SEWER. [b]TAILOR. [c]DIGIT. [d]DEXTERITY.

Figure Caption

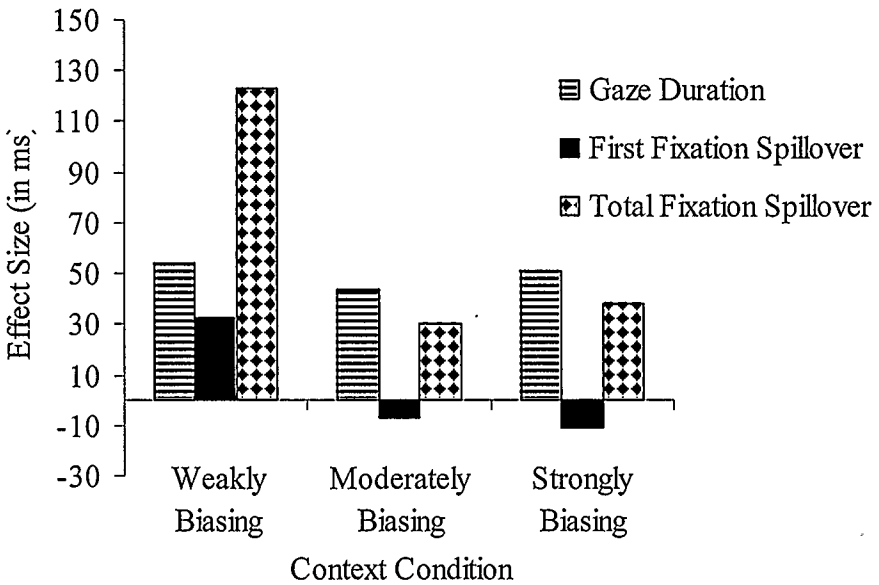
Figure 1. Mean Effect Sizes for Gaze Duration, First Fixation Spillover, and Total Fixation Spillover for Heterophonic Homographs as a Function of Context Condition in Experiment 2.

Figure 2. Mean Effect Sizes for Gaze Duration, First Fixation Spillover, and Total Fixation Spillover for Homophonic Homographs as a Function of Context Condition in Experiment 2.

Figure 3. Mean Effect Size for Targets, First Word Spillover, Second Word Spillover, and Last Word Spillover for Heterophonic Homographs as a Function of Context Condition in Experiment 3.

Figure4. Mean Effect Size for Targets, First Word Spillover, Second Word Spillover, and Last Word Spillover for Homophonic Homographs as a Function of Context Condition in Experiment 3.

Figure 5. Seidenberg and McClelland's (1989) Connectionist Model for Lexical Processing.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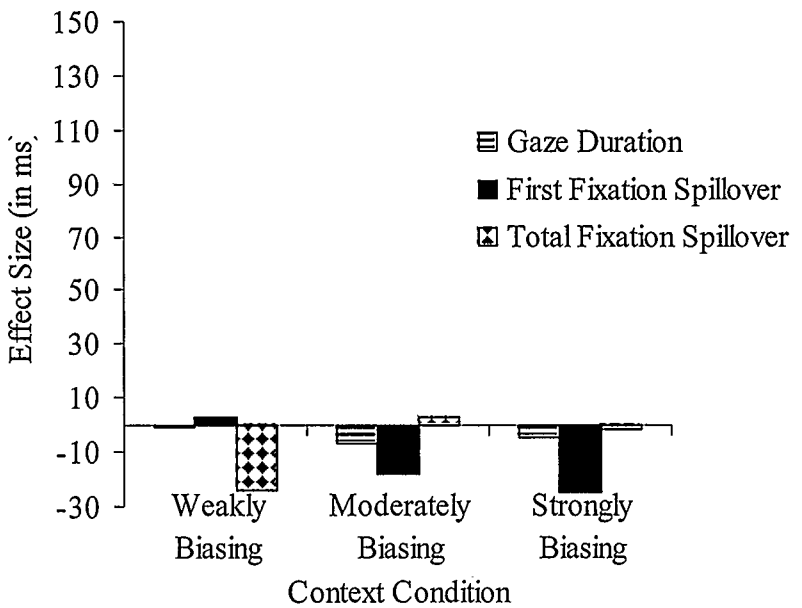
110
90
70
50
30
10
-10
-30
Effect Size (in ms)
Gaze Duration
First Fixation Spillover
Total Fixation Spillover
Weakly Biasing
Moderately Biasing
Strongly Biasing
Context Condition


150
130
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70
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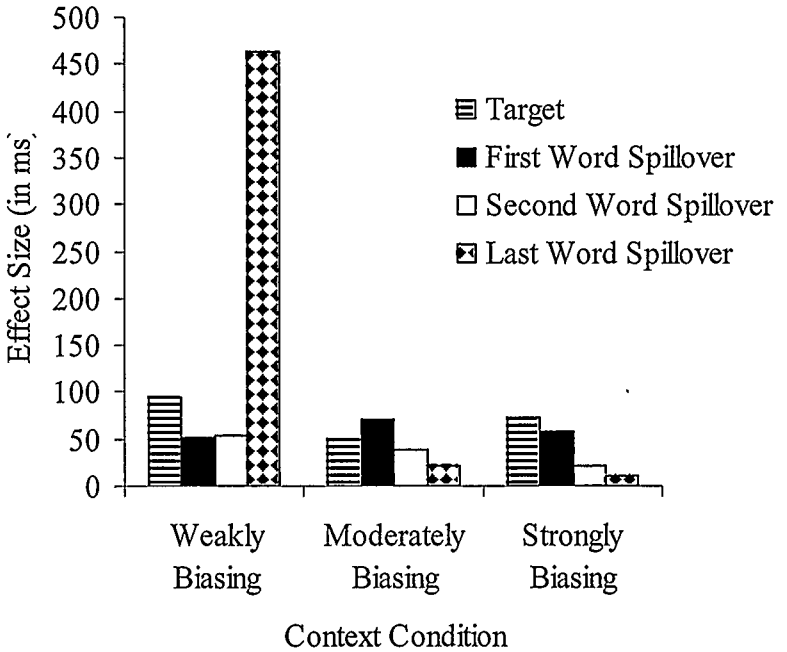
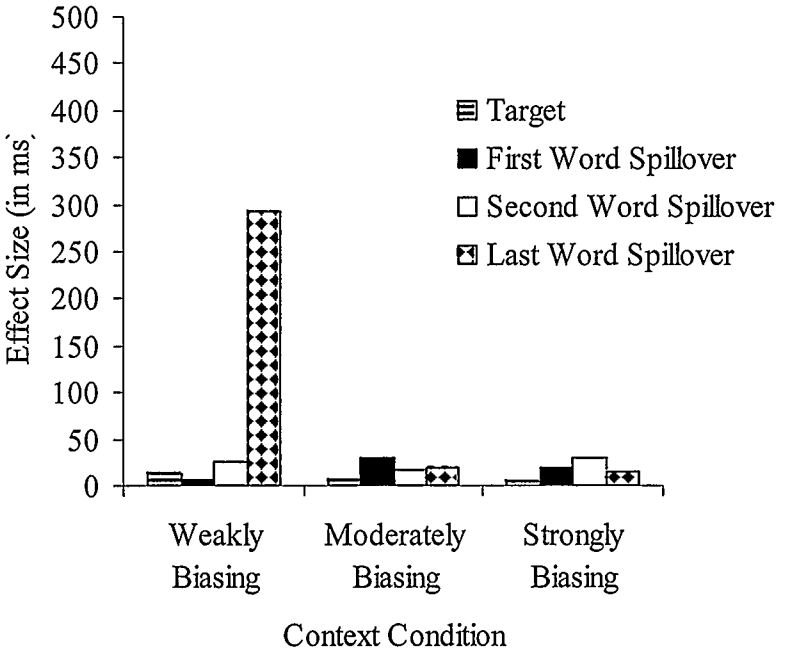
-10
-30
Effect Size (in ms)
Gaze Duration
First Fixation Spillover
Total Fixation Spillover
Weakly Biasing
Moderately Biasing
Strongly Biasing
Context Condition


500
450
400
350
300
250
200
150
100
50
0
Effect Size (in ms)
Target
First Word Spillover
Second Word Spillover
Last Word Spillover
Weakly Biasing
Moderately Biasing
Strongly Biasing
Context Condition


500
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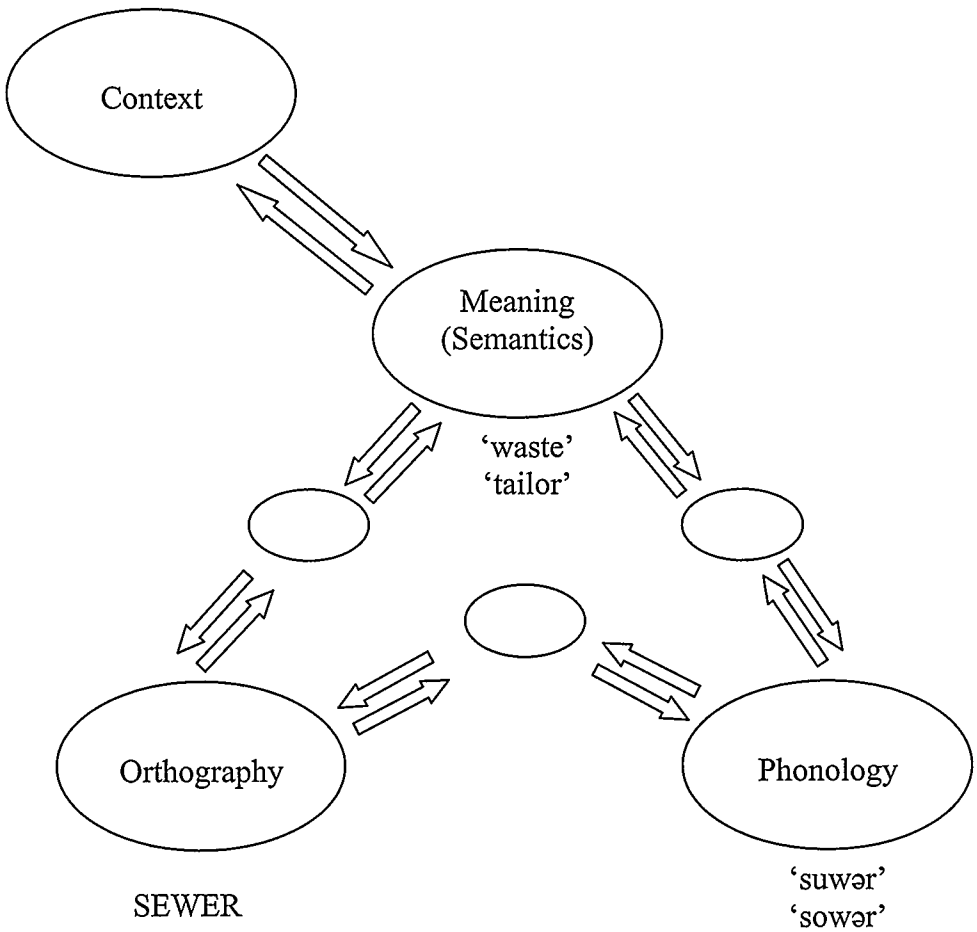
Effect Size (in ms)
Target
First Word Spillover
Second Word Spillover
Last Word Spillover
Weakly Biasing
Moderately Biasing
Strongly Biasing
Context Condition


Context
Meaning
(Semantics)
'waste'
'tailor'
Orthography
Phonology
SEWER
'suwər'
'sowər'

Appendix A

Word Stimuli

Heterophonic Homographs	Control Words	Homophonic Homographs	Control Words
dove	sprang	duck	sidestep
invalid	outpatient	deposit	fossil
minute	tiny	novel	unique
moped	scooter	staple	regularity
refuse	garbage	refrain	rhyme
sewer	tailor	ruler	dictator
wound	adjusted	toast	blessing
live	continue	land	turn
object	fight	express	reveal
console	contraption	digit	dexterity

Appendix B

Sentences for Heterophonic Homographs and Control Words

1. DOVE/SPRANG
STRONGLY BIASING: Jonathan climbed to the highest board at the pool. After he _____ he smiled with satisfaction.
MODERATELY BIASING: Jonathan saw the woman drowning in the lake. After he _____ he saw nothing.
WEAKLY BIASING: It was a beautiful day in the middle of July. After Jonathan _____ he smiled with satisfaction.

2. INVALID/OUTPATIENT
STRONGLY BIASING: My grandfather became ill and could not care for himself. He was an _____ and was very unhappy.
MODERATELY BIASING: My baby brother could not take care of himself. He was an _____ and was very unhappy.
WEAKLY BIASING: The man went to the store and bought a paper. He was an _____ and was very unhappy.

3. MINUTE/TINY
STRONGLY BIASING: Sheila changed her hair color from brown to black. The difference was _____ and her friend was happy.
MODERATELY BIASING: John was a spy who used a very small camera. The camera was _____ in comparison to others.
WEAKLY BIASING: John bought a sandwich to eat for his lunch. The sandwich was _____ in comparison to others.

4. MOPED/SCOOTER
STRONGLY BIASING: Brandon couldn't buy a motorcycle so he bought something similar. He bought a _____ and was very pleased.
MODERATELY BIASING: Brandon needed an efficient way to get around Atlantic City. He bought a _____ and was very pleased.
WEAKLY BIASING: It was a hot day and Brandon enjoyed the sunshine. He bought a _____ and was very pleased.

5. OBJECT/FIGHT
STRONGLY BIASING: The lawyer was annoyed when the defense attorney badgered his witness. He decided to _____ and was satisfied.
MODERATELY BIASING: Diane went to her boss and asked for new supplies. He decided to _____ and she was not satisfied.
WEAKLY BIASING: Doug went to the store to buy chocolate. His girlfriend decided to _____ and was satisfied.

6. REFUSE/GARBAGE
STRONGLY BIASING: The dumpster was beginning to emit a pungent smell. A large amount of _____ had piled up.
MODERATELY BIASING: George took off the wrapping to see his prize. He left the _____ and then walked away.
WEAKLY BIASING: George was really dreading getting home from vacation. He had so much _____ in his apartment.

7. SEWER/TAILOR
STRONGLY BIASING: Maria was thrilled with the alterations made on her dress. The skill of the _____ was really apparent.
MODERATELY BIASING: Maria got her skirt caught and it ripped. Her father was a _____ and Maria felt relieved.
WEAKLY BIASING: Maria went for dinner with her friend after work. The diligent _____ knew she had earned it.

8. WOUND/ADJUSTED
STRONGLY BIASING: The music box eventually stopped playing its beautiful song. It needed to be _____ and dusted soon.
MODERATELY BIAISNG: The old clock hanging in the hallway stopped working. It needed to be _____ and dusted soon.
WEAKLY BIASING: The woman looked confused when she saw the item. It needed to be _____ and dusted soon.

9. LIVE/CONTINUE
STRONGLY BIASING: The man tried to commit suicide with a knife. He didn't want to _____ anymore and was unhappy.
MODERATELY BIASING: Diane's boyfriend continued to abuse her in their apartment. She could not _____ with him much longer.
WEAKLY BIASING: Bill went camping and taught his children how to fish. He didn't want to _____ anymore and was unhappy.

10. CONSOLE/CONTRAPTION
STRONGLY BIASING: The airplane pilot realized that the switches were not working. He pounded the _____ with his fist.
MODERATELY BIASING: The man grew angry while driving behind a drunk driver. He punched the _____ because he was frustrated.
WEAKLY BIASING: The man knocked when he arrived at the right house. He did not know the _____ had been delivered.

<u>Sentences for Homophonic Homographs and Control Words</u>

1. DUCK/SIDESTEP
STRONGLY BIASING: The tall man often hit his head on the hanging sign. He learned to _____ when he encountered the sign.

MODERATELY BIASING: The woman walking in the forest noticed the long branches. She had to _____ to avoid a collision.
WEAKLY BIASING: The boy felt content as he walked along the path. He had to _____ to avoid a collision.

2. DEPOSIT/FOSSIL
STRONGLY BIASING: The museum exhibit contained dinosaur bones embedded in layers of rock. The most common _____ was from the mesozoic era.
MODERATELY BIASING: The geologist examined the layers of rock in the mountains. He found a _____ that was very interesting.
WEAKLY BIASING: The woman went for a walk after finishing her lunch. She saw a _____ that had formed.

3. NOVEL/UNIQUE
STRONGLY BIASING: The researcher realized something that had never been thought of before. His idea was very _____ and he was rewarded.
MODERATELY BIASING: Sandra was surprised by the reaction to her comment in class. Her idea was _____ and she was happy.
WEAKLY BIASING: The man drove downtown while he listened to the news. The situation seemed _____ to him and he chuckled.

4. STAPLE/REGULARITY
STRONGLY BIASING: Meat was the main component in all of Brad's meals. Meat was a _____ of Brad's diet.
MODERATELY BIASING: Bob sat down in the cafeteria to eat lunch. Meat was a _____ in Bob's diet.
WEAKLY BIASING: Bob went to the mall to purchase a new television. Meat was a _____ in Bob's diet.

5. REFRAIN/RHYME:
STRONGLY BIASING: Carl knew the words for the recurring part of the song. He felt that the _____ was his favorite part.
MODERATELY BIASING: The woman was humming on the way to work. She felt that the _____ was her favorite part.
WEAKLY BIASING: The girl was excited to go to her Aunt's house. She had memorized the _____ and she was happy.

6. RULER/DICTATOR
STRONGLY BIASING: The king was a mean man who treated his people poorly. He was a horrible _____ and people were unhappy.
MODERATELY BIASING: George knew people were unhappy and something had to change. He was a _____ with issues on his mind.
WEAKLY BIASING: Calvin felt his life on the earth was not very significant. He was a _____ with issues on his mind.

7. TOAST/BLESSING
STRONGLY BIASING: It was time for speeches at the reception after the wedding. The best man gave a _____ and everyone clapped.
MODERATELY BIASING: Brian thought about how much he loved his wife. He gave a _____ and everyone clapped.
WEAKLY BIASING: Brian smiled to himself as he drank his coffee. The man gave a _____ and everyone clapped.

8. LAND/LEAVE
STRONGLY BIASING: The pilot flew into the storm and felt the danger. He tried to _____ as soon as possible.
MODERATELY BIASING: The skier began the jump without very much control. She did not _____ properly and people were concerned.
WEAKLY BIASING: Sherrie felt relieved that she was able to calm herself down. She tried to _____ as soon as possible.

9. EXPRESS/REVEAL
STRONGLY BIASING: The psychologist tried to increase communication between the husband and wife. The man needed to _____ his ideas more often.
MODERATELY BIASING: Melissa tried to find her boyfriend in the crowd of people. She needed to _____ her ideas more often.
WEAKLY BIASING: Jim went to a picnic down by the pond. He needed to _____ his ideas more often.

10. DIGIT/DEXTERITY
STRONGLY BIASING: The pianist tried to learn to play again but his finger would not respond. He felt that his _____ was no longer useful.
MODERATELY BIASING: Brenda practiced all day and all night on the piano. She felt that her _____ was no longer useful.
WEAKLY BIASING: Brenda looked at the painting and heard the man laughing. She felt that her _____ was no longer useful.