

Inhibition of Ambiguous Word Activation

In the Context of a Working Memory Task

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Abstract

The current study examines the question of whether or not all meanings of an ambiguous word are activated in the context of a working memory task, regardless of context as predicted by the exhaustive access hypothesis or if only context relevant meanings are activated. Three experiments investigated the effects of disambiguating information on the amount of activation for multiple meanings of biased homographs. Lower levels of associative priming were present for the dominant meaning of homographs in which the subordinate meaning was instantiated as compared to the dominant meaning of homographs in which no meaning is instantiated. This research supports a more interactive view of ambiguous word recognition, involving the spread of activation and inhibition of irrelevant meaning through selected attention.

Keywords: Homographs, Deactivation, Exhaustive access, Inhibition

1. Introduction

The processes involved in the resolution of the relevant meaning of ambiguous words have undergone a great deal of study. In regards to accessing the meaning of words, many researchers agree with the spread of activation theory of Collins and Loftus (1975), which states that an interconnected network contains semantic knowledge. Activation of a particular bit of semantic knowledge spreads to close neighbors within the network and hence produces associative and/or semantic priming. Disagreements about resolution of ambiguous word meanings arise when the issue of whether all meanings of an ambiguous word are activated, or if only contextually relevant meanings are activated. At issue as well is what mechanisms are involved in the selection of the relevant meaning. Activation and selection of the relevant meaning of an ambiguous word is obviously an important component of reading comprehension. An important part of meaning selection in turn must be the inhibition of the irrelevant meanings of ambiguous words. In the current investigation, inhibition is conceptualized as the automatic reduction of activation of an irrelevant or inappropriate meaning of an ambiguous word.

Several researchers have attempted not only to demonstrate the existence of inhibition of semantic meaning, but also to explain the mechanisms that control it (e.g., Gernsbacher, 1990; Simpson & Burgess, 1985; Gorfein, 2001). The use of homographs in inhibition research is common because both in and out of context at least two meanings of the homograph are available to most readers. The focus of the current investigation is whether the activation of the irrelevant meaning of an ambiguous word is inhibited after being raised?

One model of multiple meaning activation that has received support in the literature is the exhaustive access hypothesis (Simpson & Burgess, 1985; Onifer & Swinney, 1981; Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1981; Swinney, 1979; Tanenhaus, Leiman, & Seidenberg, 1979). In simple terms, according to this hypothesis, initially all meanings of an ambiguous word are activated regardless of preceding context or frequency of the meanings in the language. Later, context related to the appropriate meaning boosts its activation or inhibits the activation of the inappropriate meaning. Many of the studies which support this hypothesis have found that in lexical decision tasks words related to either meaning of the ambiguous word are responded to more quickly than unrelated words. Results of these studies provided evidence that immediately following the processing of an ambiguous word in context, multiple meanings of the ambiguous word are available to the reader.

Onifer and Swinney (1981) either presented sentences biased towards the dominant (more frequent) or subordinate (less frequent) meaning of an ambiguous word. Participants made lexical decisions for related words immediately following the sentence or 1.5 seconds later. In the immediate condition, facilitation for both dominant and subordinate meanings occurred regardless of context. However, in the delayed condition facilitation occurred only for the contextually relevant meaning. The authors interpreted this finding within the context of the exhaustive access hypothesis and argued that both meanings received initial activation.

Subsequently, context boosted activation of the relevant meaning. In question is whether inhibition occurs in this task. As Onifer and Swinney stated the simple explanation is that context facilitates the contextually relevant meaning, not that the non-relevant meaning is inhibited.

Simpson and Kang (1994) also supported the exhaustive access hypothesis, but argued that inhibition, not activation, is the cause of the facilitation of one meaning over another. They found that words related to the instantiated meaning of an ambiguous word were responded to more quickly than words inconsistent with the instantiated meaning. According to their hypothesis exhaustive activation initially occurs. Then, once context is given, the relevant meaning is selected and the activation of the irrelevant meaning is inhibited. The processing of one meaning of an ambiguous word forces the activation of the other meanings below a resting level of activation (Simpson & Adampoulos, 2001).

Evidence for an exhaustive access hypothesis is quite convincing, yet it is not clear whether multiple meanings of an ambiguous word are activated at equal speeds. There is evidence that suggests that meanings of biased ambiguous words are activated at different speeds. Simpson and Burgess (1985) found that when no context is provided the dominant meaning of an ambiguous word is available almost immediately, while the subordinate meaning is available after the elapse of time. In the same study, it was found that facilitation for the subordinate meaning declined more quickly than the facilitation for the dominant meaning.

In contrast to the above view of activation at different speeds, in the structure building framework Gernsbacher and her colleagues proposed an active mechanism that suppresses the activation of irrelevant meaning after selection of the relevant meaning (See Gernsbacher, 1990 for a review). In this view, all meanings are initially automatically activated, then irrelevant meanings are suppressed through an active control process rather than an automatic process related to activation.

Neely (1977), and Stanovich and West (1979, 1981) also described a two-process model. An initial automatic spread of activation is followed by allocation of attention resources to prime-related information. The automatic spreading activation makes available all meanings of an ambiguous word, while attention focused by the disambiguating information controls the amount of activation that is directed toward a specific memory location (or meaning).

Based on the Simpson and Burgess (1985) findings, in the current study participants saw two ambiguous words classified as biased homographs. Sereno, Duffy and Rayner (2006; see also Rayner & Duffy, 1986) state that ambiguous words are categorized as biased or unbiased based on the frequency of the different meanings. Biased homographs are those that have an uneven distribution with one meaning having a greater frequency than alternative meanings. In the current study, contextual cues as to the relevant meaning are only provided for one of the ambiguous words and only through a related word, not a sentence which holds the cues to the context. The exhaustive access hypothesis holds that context does not affect lexical access. However, Seidenberg, et al, (1982) found that one exception occurs when one word in the

sentence strongly primes one meaning of the ambiguous word. In the current study, the word related to the ambiguous word that is provided as the contextual cue is related to the subordinate meaning of the word. The two questions most relevant to this research are: does relevant meaning of a biased ambiguous word receive more activation than the irrelevant meaning? Moreover, is the activation of the irrelevant meaning inhibited or is the activation of the irrelevant meaning simply reduced after being raised?

Woltz and Was (2006) demonstrated the content of processing in working memory tasks increased the availability of related information in long-term memory. In the current study, the measurement of increased and decreased availability was measured using a word comparison task similar to that used by Woltz and Was. The word comparisons consisted of determining whether two simultaneously presented words are related or unrelated. The two words presented in the comparisons were associated with the two specific ambiguous words previously processed in a working memory task. Differences in availability of the dominant meaning of an ambiguous word in which the subordinate meaning was instantiated occurred by comparing the response speed for word comparisons of words associated with that word to the dominant meaning of the ambiguous word in which no meaning was instantiated. In the present study, two ambiguous words and words associated with two meanings of the ambiguous words were the content processed in a simple working memory task. Word comparisons utilized words associated with both meanings of the homographs. This was the basis of the measure of meaning increased availability in the current study.

The current study hypothesizes that responses will be faster and more accurate to word comparisons of words associated with a dominate meaning of an ambiguous word that is not contextually instantiated, than to comparisons associated with the dominant meaning of an ambiguous word in which the subordinate meanings are instantiated. Results in support of this hypothesis would provide evidence that inhibition is actually the reduction of activation. The current study attempted to illustrate that the dominant meaning of an ambiguous word presented in isolation receives the strongest activation, but the level of activation is subsequently reduced following the instantiation of a subordinate meaning.

In Experiment 1, the instantiation of the subordinate meaning of the ambiguous word did not occur until after the word was processed. The hypothesized findings would support the view that when the subordinate meaning of the ambiguous word is cued after the word is processed the increased availability of the dominant meaning of the word is then lowered. This is consistent with the findings related to the exhaustive access hypothesis. When the subordinate meaning is instantiated, the activation of the dominant meaning is reduced and the subordinate meaning receives more facilitation.

2. Experiment 1

2.1 Method

2.1.1 Participants

Thirty-two undergraduate students enrolled at a large state university within the United States received course credit for their participation in the study.

2.1.2 Materials

Participant testing occurred in a well-lit room containing six IBM compatible microcomputers with 17" SVGA monitors and standard keyboards. Soundboard panels separated the microcomputers. The computer systems controlled randomization of trials, stimulus presentation, timing, and data collection using the E-prime® programming software.

Stimuli consisted of forty-eight biased homographs chosen from published norms (Gawlick-Grendell & Woltz, 1994; Nelson, McEvoy, Walling, & Wheeler, 1980; Sereno & Pacht, 1992; Twilley, Dixon, Taylor, & Clark, 1994 see Appendix A). Based on Gawlick-Grendell and Woltz (1994) norms, dominant meanings of the homographs had a probability range of 0.28 – 0.85 ($M = 0.65$, $SD = 0.14$, $Mdn = 0.66$) and subordinate meanings (meaning of the homograph with lower probabilities of that of the dominant meaning) had a probability range of 0.01 – 0.47 ($M = 0.20$, $SD = 0.11$, $Mdn = 0.19$). The mean difference between dominant and subordinate meaning probability ranges for the Gawlick-Grendell and Woltz norms was 0.45. Based on Twilley, et al, (1994) norms, dominant meanings of the homographs had a probability range of 0.28 – 0.85 ($M = 0.72$, $SD = 0.19$, $Mdn = 0.78$) and subordinate meanings (meaning of the homograph with lower probabilities of that of the dominant meaning) had a probability range of 0.01 – 0.34 ($M = 0.13$, $SD = 0.09$, $Mdn = 0.10$). The mean difference between dominant and subordinate meaning probability ranges for the Twilley, et al, (1994) norms was 0.61. In the current study, the dominant meaning of the homograph is the meaning with the greatest probability as based on the above norms.

One half of the ambiguous words were used as the focused and one half as the ignored category. Categories were counter balanced across subjects.

One word related to the subordinate meaning of each homograph was used to complete each memory list. Comparison trials consisted of words associated with the subordinate and dominant meaning of each ambiguous word, as well as neutral words for the negative match trials. The words chosen to complete the memory load and comparison trials were derived from participant responses in the norming studies described above (Gawlick-Grendell & Woltz, 1994; Nelson, et al., 1980; Sereno & Pacht, 1992; Twilley, et al., 1994)

2.2 Design and Procedure

The experimental tasks for this study were adapted from the Woltz and Was (2006) task for the activation of long-term memory nodes within a working memory task. Participants

performed the experimental task in a single 1-hour session in groups of 1-6 participants. Prior to beginning the experimental task, participants received instructions outlining both portions of the trial procedure. Subjects were not informed of the nature of the biased homographs. However, the nature of the task itself was likely to alert participants that ambiguous words were a part of the experiment. The task consisted of four basic components: (1) presentation of a four word memory load, (2) an instruction to select a subset of the memory load and reject the rest (3) recall of the selected subset, and (4) a series of word comparisons. These represent the activation or inhibition of information in long-term memory that is related to all words and their meanings from the memory load, (see Figure 1 for an example trial).

Each of the participants completed a set of 24 trials. Each trial began with the instruction to “Get ready to memorize words.” This instruction preceded an attention signal (an asterisk located in the center of the screen) lasting 750ms. The initial attention signal preceded the first word from the memory list that appeared for 1500ms. This procedure repeated until all four words in the memory list appeared. Each list consisted of two biased ambiguous words and two non-ambiguous words, one word related to the subordinate meaning of each ambiguous word. In order to avoid instantiating the meaning of the ambiguous word, one of the ambiguous words always occurred in the first position of the memory load. The remaining memory load words were selected to fill the second, third, and fourth positions so that the second ambiguous word always preceded the word related to its subordinate meaning.

Following the last word of the memory list the instruction to remember words related to the subordinate meaning of one ambiguous word appeared. This ambiguous word is then the ambiguous word of focus, while the other ambiguous word is the ignored ambiguous word. Therefore, a trial may begin as follows: arms, belt, guns, punch, Remember the words related to WEAPONS. The position of the to be remembered ambiguous word (ambiguous word of focus) was also randomized.

Next, participants are prompted to recall the first word associated with the memory instruction (What was the first word were you were to remember?). Participants reply by typing the first two letters of the word on the computer keyboard and pressing enter. The same procedure is used to recall the second word associated with the memory instruction (What was the second word you were to remember?).

Following the recall of the memory list, subjects are instructed to prepare for word comparisons by gently placing their index fingers on the “R” and “U” keys on the keyboard. Word comparisons consisted of two words presented one above the other in the center of the screen. Underneath the words to be compared were the reminders to press R if the words are related and U if the words were unrelated. Participants were instructed to respond as quickly and as accurately as possible.

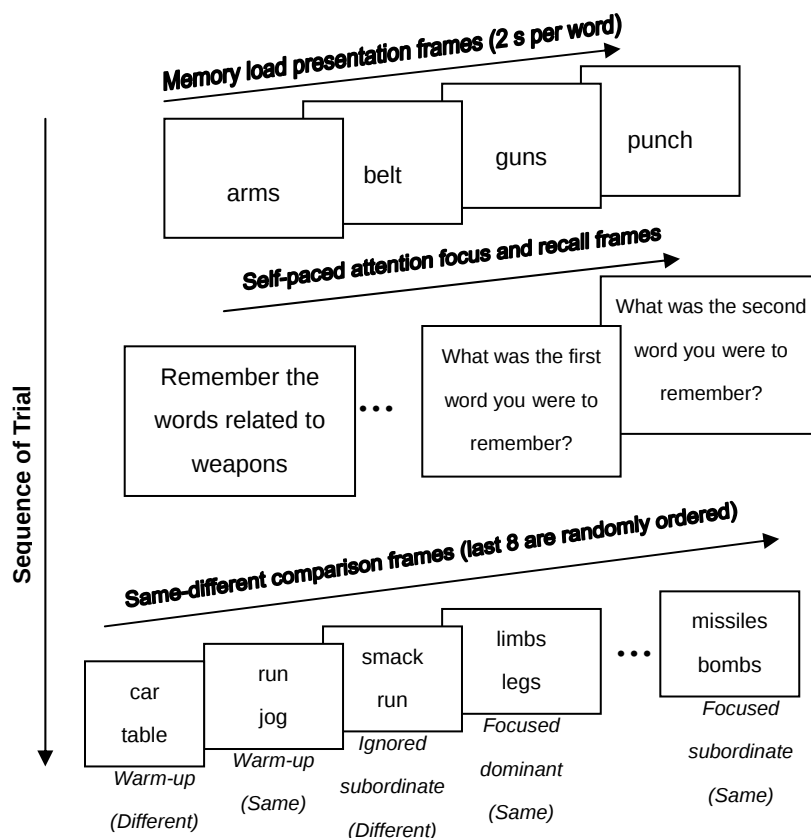


Figure 1. Example Comparison Trial

The first two comparisons were “warm-ups” which contained completely neutral stimulus (words unrelated to the memory list). The next eight random comparisons consisted of words related to both the dominant and subordinate meanings of both the ambiguous words presented in the memory load (ambiguous word of focus and the ignored ambiguous word). For each there were one “related” and one “unrelated” trial. A related trial consisted of two words related to each other. For example, a related trial linked to the dominant meaning of arms could be limbs and legs. An unrelated trial linked to the subordinate meaning of arms might be rifles and snails. Subjects responded to comparison trials by pressing R if the two words are related and U if the words are unrelated.

2.3 Results

Mean recall accuracy was lower than expected, yet high enough to assume that participants were able to distinguish the subordinate meaning of the ambiguous word of focus once given the focus instruction. Mean recall accuracy for the first word to be recalled in the memory load was $M=0.85$ ($SD=0.11$), and the second word to be recalled was $M=0.88$ ($SD=0.13$). Due to the structure of the memory load, the ambiguous word was always the first word of the associated pair and therefore the first word to be recalled in the recall portion of a trial.

Means and standard deviations of error rates and latencies for all category comparison types are presented in Table 1. Data analysis began by transforming latency and accuracy into a

speed variable. Speed was calculated, as the proportion correct divided by latency in milliseconds divided by 60,000. This measure is an index of response speed because it is the reciprocal of response latency, and it adjusts speed according to errors.

Speed is interpreted directly as number of correct responses per minute. This index has the advantage of incorporating meaningful variance of both latency and error rate, and the distribution usually approximates the normal distribution more closely than either latency or error distributions.

Table 1. Mean error rate and response latency for category comparisons by ambiguous word meaning and memory load selection.

Comparison Type	Error Rate (percentage)		Latency (ms)		Speed	
	M	SD	M	SD	M	SD
Dominant Focused	10.97	7.72	1277	432	45.58	13.99
Dominant Ignored	9.28	7.93	1223	452	49.61	18.66
Subordinate Focus	11.28	7.23	1274	434	45.29	13.37
Subordinate Ignored	10.09	6.90	1285	465	45.93	13.57

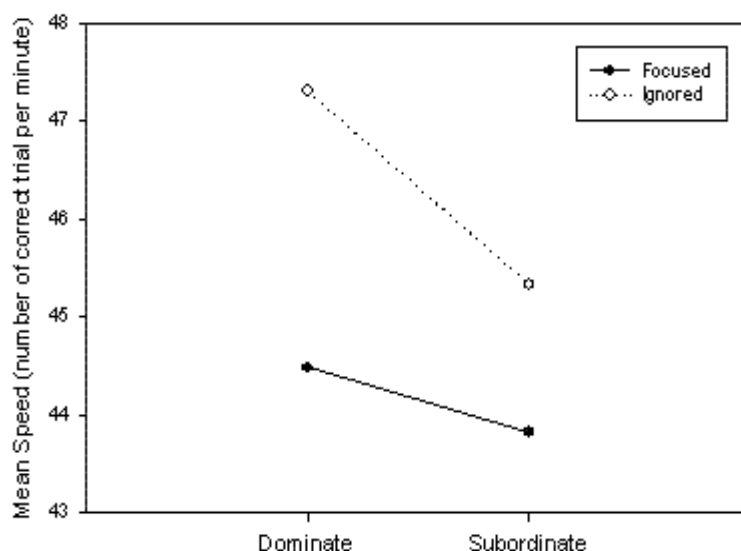


Figure 2. Mean response speed (correct responses per minute) for relatedness comparisons of Experiment 1 by ambiguous word meaning by memory load.

Figure 2 displays the facilitation of meaning for the ambiguous words in the memory load as measured by the word comparisons. The hypothesis about the facilitation of the different meanings and categories in the word comparison trials were tested using a repeated measures

ANOVA. Alpha was set at .05. In the analyses of word comparison speed, the main effect of Meaning (dominant vs. subordinate) was significant, $F(1, 31) = 4.32$, $MSe = 29.34$, $p = .046$. The main effect for Category (focus vs. ignore) was also significant, $F(1, 31) = 6.45$, $MSe = 26.89$, $p = .016$. The interaction effect was not significant, $F(1, 31) = 2.28$, $MSe = 40.08$, $p > .10$.

The core interest of this experiment was whether the dominant meaning of the ignored ambiguous word would have greater activation or facilitation than the dominant

meaning of ambiguous word of focus. The within subjects contrast revealed a significant difference between the response speed for the focused dominant and ignored dominant meanings, $F(1,31)=5.41$, $MSe= 95.47$, $p = .027$. These results indicated that participants' response to the dominant meaning of the ambiguous word of focus was significantly slower and less accurate than responses to the dominant meaning of the ignored ambiguous word.

Of secondary interest was the contrast between comparisons associated with the dominant and subordinate meaning of the ambiguous word of focus. Expected findings that the subordinate meaning of the ambiguous word of focus would receive greater activation than the dominant meaning of the same ambiguous word were not supported. The pattern occurred in the opposite direction, however it was not statistically significant ($F < 1$). Put differently, participants responded to the two meanings (subordinate and dominant) of the to be remembered ambiguous word with similar speed.

2.4 Discussion

The results supported the hypothesis that the reduction of activation, of the dominant meaning of the ambiguous word of which the subordinate meaning was instantiated (ambiguous word of focus) occurred. Simpson and Burgess (1985) reported results that confirmed that all meanings of an ambiguous word are retrieved and in the case of a biased ambiguous word, the meanings become available in the order of their frequency in the language. In the current study, the dominant meaning of the focused ambiguous word received the same number of mentions as the dominant meaning of the ignored ambiguous word, yet there was a significant difference in facilitation of the dominant meanings of these words as measured by response speed in a priming measure. One interpretation is that the presentation of the ambiguous words and related words activated all meanings, including the dominant meaning, of both ambiguous words. Then, when the subordinate meaning of the ambiguous word of focus was instantiated through context (focus instruction) a decrease in activation of the dominant meaning transpired. This interpretation is compatible with the two-process model of word recognition. Tanenhaus, et al. (1979) found that at 0 msec of stimulus onset asynchrony (SOA) both the contextually appropriate and inappropriate meanings of an ambiguous word were more readily available than the meanings of control words. However, following a 200 msec SOA, only responses to the appropriate meaning of the ambiguous word were facilitated. Tanenhaus, et al. argue that this rapid decrease in

facilitation is likely due to an active suppression of the inappropriate meaning and not a simple decay effect.

Simpson and Adamopoulos (2001) proposed an interpretation of word-priming inhibitory effects based on negative priming effects (e.g., Tipper, 1985). The first interpretation of this effect is that when two stimuli are presented and the instruction is to respond to one stimulus, while ignoring the other, the mental representation of the ignored stimuli is then inhibited. Simpson and Adamopoulos stated that some of results of their research have some similarity to the negative priming effect (e.g., Simpson and Burgess, 1985). Several competing interpretations of the negative priming effects share the view that negative priming occurs due to the processing of a stimulus on the second trial (Fox, 1995; Park & Kanwisher, 1994; Neill & Valdez, 1992). Simply stated, the second presentation of the ambiguous word paired with a different meaning than on the prime trial leads to a detection of a mismatch and therefore a negative priming effect. In the current study, the ambiguous word of issue was only seen once during the working memory processing task, and then only words associated with the subordinate and dominant meaning are used in the word comparison trials, never the ambiguous word. Therefore, the issue of negative priming as a mismatch detection is of no consequence.

One area of concern within these results is the similarity in facilitation between the focused dominant and focus subordinate comparison trials. It was expected that the focus subordinate meaning would receive more facilitation than the focus dominant meaning. A plausible explanation based on Simpson and Burgess (1985) is that the dominant meaning was initially activated then once the focus cue was given the subordinate meaning was activated as well. However, due to the lapse of time between instantiation of the subordinate meaning and the priming trials, decay of facilitation of the subordinate meaning occurred while inhibition of the dominant meaning occurred.

3. Experiment 2

The intention of Experiment two (2) was to test the hypothesis that contextual cues (focus instruction) given prior to the memory load would raise the activation of the subordinate meaning of the focused ambiguous word. However, there should be no change in the difference in response speeds between the dominant meanings of the ignored and focus ambiguous words from Experiment 1 in terms of differences in activation. If this is the case then a significant interaction effect should be present. That is, when the subordinate meaning of an ambiguous word is instantiated by presenting that meaning before the memory load, responses to comparison trials of that meaning should demonstrate greater facilitation than the dominant meaning of that ambiguous word. However, the ignored ambiguous word should demonstrate the opposite pattern of facilitation. The dominant meaning of the ignored ambiguous word should be more available than the subordinate meaning as demonstrated by greater response speeds on comparison trials. This interaction would provide further evidence for the two-process hypothesis of meaning selection. If attention is focused on specific meaning of the ambiguous word prior to the occurrence of the ambiguous word, that meaning

should receive more facilitation than alternative meanings of the word. Even if the meaning selected is the subordinate meaning. Focus of attention should direct activation to the relevant meaning of the word.

3.1 Method

3.1.1 Participants

Thirty undergraduate students enrolled at a large state university within the United States received course credit for their participation in the study. The participants in Experiment 2 did not participate in Experiments 1.

3.1.2 Materials

Participants were tested in a well-lit room containing six IBM compatible microcomputers with 17" SVGA monitors and standard keyboards. Soundboard panels separated the microcomputers. The computer systems controlled randomization of trials, stimulus presentation, timing, and data collection with the E-prime programming software. The same stimuli utilized in Experiment 1 were used in Experiment 2.

3.1.3 Experimental Task

The experimental task was identical to that used in Experiment 1 except that memory instruction came before the memory load.

3.2 Design and Procedure

Participants performed the experimental task in a single 1-hour session in groups of 1-6 participants.

3.3 Results

As in Experiment 1, participants were able to recall the specified subset of the memory load. Mean recall accuracy for the first word in the memory load to be recalled was $\bar{M}=0.85$ ($SD=0.08$), and the second word to be recalled was $\bar{M}=0.92$ ($SD=0.07$). Again, the first word in the related pair was always the ambiguous word.

Table 2 presents the means and standard deviations of error rates and latency for comparison trials of Experiment 2. As in Experiment 1, latency and accuracy were combined to create a speed variable. Repeated measures ANOVA results revealed the hypothesized interaction between Meaning (dominant, subordinate) and Category (focus, ignore), $F(1, 29) = 6.28$, $Mse=12.52$, $p = .018$ (see Figure 3). No main effects for Meaning or Category were detected. The planned comparison between the word comparisons associated with the dominant meaning of the ambiguous word of focus and the comparisons associated with the dominant meaning of the ignored ambiguous word was significant, $F(1,29) = 4.86$, $Mse=14.10$, $p = .036$.

Table 2. Mean error rate, response latency, and speed for category comparisons by ambiguous word meaning and memory load selection in Experiment 2.

Comparison Type	Error Rate (percentage)		Latency (ms)		Speed	
	M	SD	M	SD	M	SD
Dominant Focused	12.13	7.72	1293	353	44.27	10.75
Dominant Ignored	12.96	7.78	1298	344	45.79	12.20
Subordinate Focus	8.75	5.46	1277	349	46.51	12.39
Subordinate Ignored	12.11	7.13	1323	398	44.79	12.03

This repeats the findings of Experiment 1, in that when the subordinate meaning of an ambiguous word is instantiated, there is relatively less activation of the dominant meaning as compared to an ambiguous word in which neither meaning is substantiated.

Not surprisingly, the contrast between word comparison associated with the subordinate meaning of the focused ambiguous word and the dominant meaning of the same ambiguous word was significant, $F(1, 29) = 5.89$, $Mse=25.53$, $p = .022$.

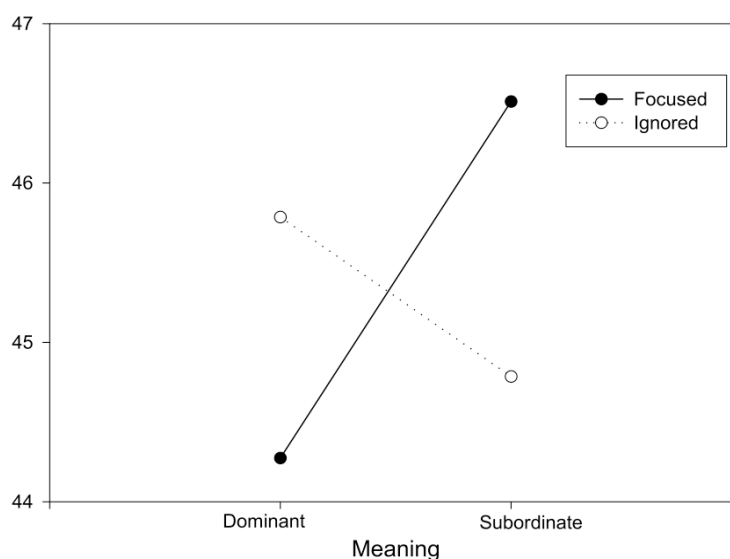


Figure 3. Mean response speed (correct responses per minute) for relatedness comparisons of Experiment 2 by ambiguous word meaning by memory load.

3.4 Discussion

In Experiment 2, the subordinate meaning of the focused ambiguous word was instantiated before the word list was presented. The results of Experiment 2 support the hypothesis that instantiating the subordinate meaning prior to the word list increases the activation of the subordinate meaning. Also as expected, the difference in response speed between the dominant meanings of the ignored and focused ambiguous word did not change. This

provides further evidence that the focus of attention may direct activation away from the dominant meaning of an ambiguous word if an alternative subordinate meaning is substantiated.

One issue not addressed in the previous two experiments is whether the activation of the dominant meaning of the focused ambiguous word returns to a baseline level. Measurement of comparison trials of neutral words provides a baseline measure to compare the dominant meaning of the focused ambiguous word.

4. Experiment 3

Experiment 3 incorporated neutral trials to determine if the activation of the dominant meaning of the ambiguous word of focus returns to a baseline of activation following the instantiation of the subordinate meaning. Measurement of baseline activation uses neutral word comparison trials to determine if activation of the focused dominant meaning returns to a starting point. If the level of activation of the dominant meaning returns to a starting point following the substantiation of the subordinate meaning than there should be no significant difference in speed in word comparison trials related to the focus dominant and neutral ambiguous words.

4.1 Method

4.1.1 Participants

Twenty-four undergraduate students enrolled at a large state university within the United States received course credit for their participation in the study. The participants in Experiment 3 did not participate in Experiments 1 or 2.

4.2 Design and Procedure

Experiment 3 was similar to the design of Experiment 1. However, in experiment 3 participants completed 16 trials instead of twenty-four. In each trial, the number of comparison trials increased from eight to twelve. In the comparison trials words related to the 48 ambiguous words were used for comparisons of words related to the ambiguous word of focus, the ignored ambiguous word, or a completely neutral trial (words related to an ambiguous word that was not presented). Therefore, one third of the 48 ambiguous words were used as the ambiguous word of focus, the ignored ambiguous word, or a neutral ambiguous word. These relationships were counter balanced across subjects. The same stimuli utilized in Experiment 1 were used in Experiment 3.

4.3 Results

Mean recall accuracy of the memory load words in this experiment was lower than the previous two. Mean recall accuracy for the first word in the memory load was $\bar{M}=0.8200$ ($SD=0.1198$), and the second word was $\bar{M}=0.7970$ ($SD=0.1456$). The mean recall accuracy in Experiment 3 is markedly lower than the two previous experiments. We are not sure why this

occurred, yet the accuracy is obviously much greater than chance and we assume that participants were able to perform the memory task.

Table 3. Mean error rate, response latency, and speed for category comparisons by ambiguous word meaning and memory load selection in Experiment 3.

Comparison Type	Error Rate (percentage)		Latency (ms)		Speed	
	M	SD	M	SD	M	SD
Dominant Focused	10.42	9.25	1407	400	41.66	12.36
Dominant Ignored	8.00	6.57	1391	460	43.81	14.02
Subordinate Focus	6.17	5.86	1355	381	45.14	11.81
Subordinate Ignored	8.37	9.02	1383	470	44.74	14.02
Unprimed (Neutral)	8.75	8.01	1379	372	41.75	12.08

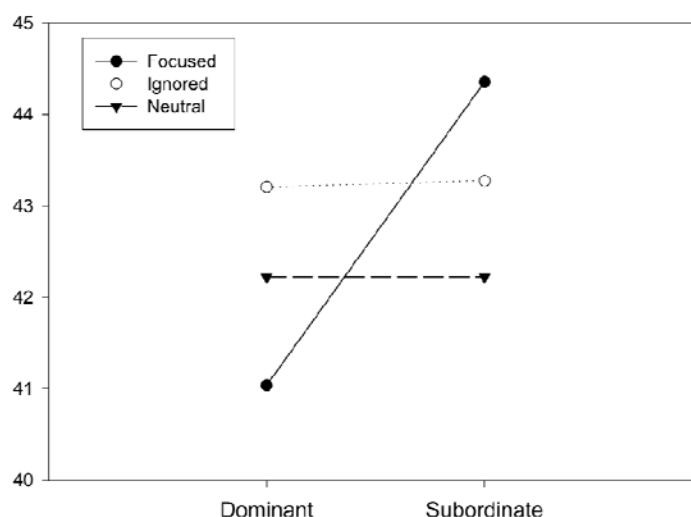


Figure 4. Mean response speed (correct responses per minute) for relatedness comparisons of Experiment 3 by category of memory load.

Table 3 presents the means and standard deviations of error rates, latency, and speed for comparison trials of Experiment 3. As in the two previous experiments, latency and accuracy were combined to create a speed variable. Figure 4 displays the means for speed for the focus subordinate, focus dominant, neutral, ignore dominant and ignore subordinate ambiguous word meanings comparison trials. Repeated measure ANOVA results revealed a main effect for Meaning (dominant, subordinate), $F(1, 23) = 4.50$, $Mse = 15.30$, $p = .045$. There was no main effect for Category (focus, ignore) ($F < 1$), and no significant interaction [$F(1, 23) = 2.02$, $Mse = 31.40$, $p = .169$].

The comparison of interest, between the focus dominant and neutral word comparison trials, was not significant ($F < 1$), which is the hypothesized outcome. This contrast indicates that responses to comparison trials associated with the dominant meaning of the focused ambiguous word are no faster than responses to comparison trials of words related to a neutral (unprimed) ambiguous word.

The contrast between the word comparisons related to the subordinate and dominant meaning of the ambiguous word of focus was significant, $F(1, 23) = 10.53$, $Mse = 25.12$, $p = .004$. Indicating, as in Experiment 2, that the subordinate meaning is more accessible following the memory load and recall, than the dominant meaning of the ambiguous word. One possible explanation for this finding is a retroactive priming effect. Early studies in retroactive priming by Kiger and Glass (1983) demonstrated that presenting primes after the target facilitated target processing with in stimulus onset asynchronies (SOA) of no more than 130. It is therefore possible that the cause of no difference between responses to word comparisons of words associated with the dominant and subordinate meaning of the ambiguous word of focus is that the selection instruction acts as a retroactive prime to the subordinate meaning.

4.4 Discussion

It is difficult to argue that the findings regarding the neutral trials and the focused dominant trials are important, because they are based on null findings. However, if there were significant priming of the focused dominant related trials as compared to the neutral trials, there would be evidence against the reduction of activation for the focused dominant trails. The results of Experiment 3 support the findings of Experiments 1 and 2.

5. General Discussion

The results of the three experiments indicated that when an ambiguous word is presented in isolation the availability of the dominant meaning of the ambiguous word is reduced by the subsequent instantiation of the subordinate meaning. The dominant meaning of the focused ambiguous word received the same number of mentions as the dominant meaning of the ignored ambiguous word, yet there was a significant difference in facilitation of the dominant meanings of these words as measured by response speed to related comparison trials. Importantly, the dominant meaning of the ambiguous word in which no meaning was instantiated showed significantly more facilitation than the dominant meaning of the focused ambiguous word. The interpretation of this study is that the presentation of the ambiguous words and associated words activated the dominant meaning of both ambiguous words then, when the subordinate meaning of the focused ambiguous word was instantiated through context a decrease in activation transpires. It is concluded that a reduction of the availability of the dominant meaning of the ambiguous word of focus occurred. However, because the availability of the dominant meaning of the ambiguous word of focus was not significantly less than that of the neutral word, it is difficult and perhaps unwarranted to argue that this reduction in activation is related to an inhibition mechanism.

The results of the three experiments can be explained within the context of multiple models of lexical ambiguity resolution. As explained in the discussion of Experiment 1, the results are consistent with an ordered access hypothesis. Simpson (1994) describes context-independent models of lexical ambiguity processing in which the meanings of an ambiguous word are activated in the order of the frequency regardless of the context in which the ambiguous word appears. Then, if the most frequent (dominant) meaning is found to be inappropriate to the context, this meaning is discarded and a second meaning is activated. This process repeats until the ambiguity is resolved. In Experiments 1 and 3 of the current study, the two ambiguous words in the memory load are initially presented without context. Then, a subordinate meaning of one of the two ambiguous words is presented via the focus instruction. The dominant meaning of the ambiguous word of which the subordinate meaning was instantiated received significantly less facilitation than the dominant meaning of the other ambiguous word in the memory load indicating that the most frequent meaning of an ambiguous word is initially activated, and less facilitation the meaning of a neutral control word, indicating that initial activation is reduced.

Exhaustive access models contend that all meanings of an ambiguous word are initially activated regardless of context then, after all meanings have been accessed, the context determines the selection of the appropriate meaning (see Simpson, 1994 for review). As is evident from the discussion of the ordered access models, the finding of the three experiments are also consistent with the exhaustive access models.

What is unclear from the current study is the exact nature of the reduction of activation of the dominant meaning of the ambiguous word of focus. A simple explanation regarding the reduced facilitation is that instantiation of the subordinate meaning of the ambiguous word focuses attention on the subordinate meaning. If activation were a limited resource, then redirecting focus from the dominant to the subordinate meaning would reduced the facilitation of the dominant meaning. An alternative interpretation is that of an active suppression mechanism. Gernsbacher (1993) described the active suppression of contextually inappropriate meanings of ambiguous words as essential to successful comprehension. This active suppression is perhaps the key to the current findings. This may be particularly relevant if the participants had become aware of the nature of the task early in the experiment. Upon encoding the focus instruction to remember the subordinate meaning of one of the ambiguous words presented in the memory load, participants may have actively suppressed the dominate meaning of that word to resting or baseline levels.

One result that created concern is the similarity in response speed between the focused dominant and focus subordinate comparison trials in Experiment 1.

Based on this finding an alternative explanation is that there is a limited amount of activation available for all of the meanings of an ambiguous word. It could be that initially the dominant meaning of the ambiguous words are activated and then the instantiation of the subordinate meaning requires the limited amount of activation to be shared among the different meanings. This interpretation would rely on the view that activation is a limited resource and this issue

was not addressed in this paper. This however, could be a topic for a great deal of discussion and research.

Presentation of the subordinate meaning of the focused ambiguous word was before the word list was presented in Experiment 2 was meant to resolve the above issue. The results of Experiment 2 did support the hypothesis that priming the subordinate meaning prior to the word list increases the activation of the subordinate meaning. Also as expected the difference in response speed between the dominant meanings of the ignored and focused ambiguous word did not change. This provided further evidence that the focus of attention directs activation to the context relevant meaning of the ambiguous word.

In Experiment 3, measurement of comparison trials of neutral words provided a baseline measure to compare the dominant meaning of the focused ambiguous word. It is difficult to argue that the findings regarding the neutral trials and the focused dominant trials are of import because they are based on null findings. However, the null findings suggest that the irrelevant meaning of the ambiguous word is reduced below the resting level of activation as Simpson and Adamopoulos (2001) suggest. The results of the final experiment did support the findings of the previous experiments and the hypothesis that more than one meaning of an ambiguous word is initially activated, and that the activation of the dominant meaning can be reduced after the presentation of context related to a subordinate meaning.

Although it is the contention of this paper that a multiple process model best describes the resolution of the meaning of ambiguous words, it in no way implies this is the case in reading ambiguous words in context. From the results obtained in this study it seems clear that when prior context does not disambiguate the relevant meaning of a ambiguous word all meanings are activated, with the dominant meaning receiving the greatest amount of facilitation. In the case when disambiguating information does proceeds the ambiguous word, attention focuses activation on the relevant meaning. In addition, when the disambiguating information follows the ambiguous word, activation is redirected by the focus of attention hence lowering the facilitation of the irrelevant meanings. It will be important to apply these findings in studies in which the context in which the ambiguous word appears is a body of text. However, understanding the underlying process as described in the current study will make it easier to assess the process of disambiguation in reading comprehension.

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Appendix

Homograph	Subordinate related word	subordinate related comparison trials		Subordinate unrelated comparison trials		Dominant related comparison trials		Dominant unrelated comparison trials	
Appendix	kidney	liver	stomach	canary	heart	addendum	supplement	addition	kite
Arms	guns	missiles	bombs	rifles	snail	limbs	legs	feet	fudge
Bar	pipe	pole	post	rod	whale	saloon	tavern	person	nightclub
Bark	branch	leaf	stem	oak	window	dog	howl	door	growl
Belt	punch	strike	slap	smack	run	buckle	strap	pants	feathers
Boil	blister	pimple	zit	bee	blemish	steam	simmer	cook	stick
Break	pause	stop	discontinue	rest	airplane	shatter	crack	fracture	hold
Calf	ankle	shin	knee	Paris	thigh	cow	bull	dolphin	steer
close	near	distant	far	narrow	Rose Bowl	slam	shut	basement	open
Corn*	shoes	socks	toe	bunion	Wendy's	peas	carrots	queen	cob
crack	cocaine	marijuana	addict	college	heroin	split	fissure	break	mower
Draw	tow	haul	drag	pull	seed	sketch	trace	lemon	etch
Fair	okay	average	good	decent	hoe	equal	honest	even	heavy
Firm	partnership	organization	business	association	soil	solid	hard	accent	stable
Fly	beetle	mosquito	gnat	elm	bee	soar	sail	airplane	Pepsi
Foot	inch	meter	liter	Chex	mile	sock	shoe	boot	salesmen
Gag	tease	jest	antic	trick	zipper	muzzle	choke	run	stifle
Game	prey	track	pursue	brunch	stalk	sport	contest	spring	competition
Grace	poise	charm	finesse	finesse	frame	blessing	benediction	prayer	tardy
Grave	critical	severe	vital	crucial	letters	tomb	cemetery	funeral	avalanche
Ground	chopped	diced	cut	cathedral	slice	earth	land	monkey	dirt
Hard	challenging	perplexing	exhausting	tough	main street	solid	rigid	stiff	wet
High	stoned	drunk	wasted	elderly	bombed	tall	lofty	scared	elevated
Jar	bump	knock	hit	bash	hungry	glass	container	cookie	hug
Just	simply	merely	solely	barely	quickly	fair	lawful	equal	red
Lead	guide	direct	ice cream	rule	copper	iron	zinc	steel	classroom
Log	diary	cane	wand	cha-cha	stick	employees	workers	group	personnel
Minute	tiny	shrink	little	micro	mildew	time	hour	second	ladder
Object	disagree	conflict	clash	symphony	argue	article	thing	entity	fertilizer
Palm	pine	oak	elm	Chrysler	birch	wrist	fingers	hand	crab
Play	drama	stage	act	musical	boat	fun	game	sports	ceiling
Plot	acre	parcel	lot	Australia	property	plan	scheme	attempt	conspiracy
Pop	rupture	explode	detonate	bang	pillow	soda	beverage	cola	glue
Range	sink	scope	reach	breadth	wedding	oven	cook	stove	bird
Rate	grade	rank	score	asses	run	speed	tempo	velocity	cradle
refuse	trash	rubbish	junk	waste	pebble	decline	reject	deny	shelves
Ruler	monarch	king	dictator	emperor	feline	inches	meters	custom	yardstick

Second	minute	month	day	hour	opaque	first	last	third	Publisher
Sharp	smart	bright	sly	able	skinny	pointed	jagged	spiky	drunk
Skip	hop	bounce	leap	cinnamon	bound	miss	omit	bypass	humor
Staff	pole	cane	wand	cha-cha	stick	employees	workers	group	personnel
Stalk	leaf	petal	stem	vine	mile	hunt	follow	boot	pursue
Stick	paste	attach	hold	glue	swim	twig	limb	branch	chalkboard
Story	floor	balcony	terrace	Barbara	hallway	legend	parable	tale	mustard
Tip	clue	hint	advice	van	pointer	summit	peak	French	top
Train	practice	drill	exercise	condition	parade	bus	subway	jump	railroad
Trim	thin	skinny	lean	submarine	slender	clip	prune	cut	house
Wind	crank	coil	wrap	blouse	twirl	air	blow	floor	Breeze

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