5-2-2021

Discovering the wire: Dominance effects in the processing of polysemes in sentences

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Honors Thesis

Submitted to:

Psychology Department

University of Richmond

Richmond, VA

May 2, 2021

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Abstract

Previous research examining the processing of polysemous words presented in neutral sentence contexts has revealed conflicting results. Two different models attempt to explain these divergent patterns. The first predicts that the subordinate sense of an ambiguous word is more difficult to retrieve and process while the second predicts no differences in processing difficulty between the subordinate and dominant senses of ambiguous words. The current study tested the different predictions of these models by presenting sentences with polysemes in a neutral context. Critically, the sense relatedness of the polysemes and the sentence structure were held constant, while the sense frequency of the polysemes were carefully measured using corpus data. Reading time data suggest there was greater processing difficulty for the subordinate sense completions than the dominant sense completion. The magnitude of this dominance effect was not moderated by the strength of the dominant sense compared to the subordinate sense. Overall, the results suggest that readers initially retrieve the dominant sense of a polyseme leading to a processing cost when the sentence then resolves toward the subordinate sense.

Many of the words comprehenders encounter in everyday conversation and reading are ambiguous. A large body of literature has examined different types of lexically ambiguous words. A distinction is drawn between homonyms, words with two or more unrelated meanings, and polysemes, words with multiple related senses. For example, the homonym *bank* may refer to a financial institution or the side of a river. The polysemous word *wire* may refer to a thin metal filament or a listening device. The examination of lexically ambiguous words has produced two broad questions: how are ambiguous words, and their different senses, stored within the mental lexicon and how are these words processed. These questions have produced different models for understanding the representation and processing of ambiguous words that each seek to understand the role of contextual constraints, sense frequency, and sense relatedness.

Separate Representation Model

According to the Separate Representation Model (Langacker, 1987), each sense of an ambiguous word is stored separately in the mental lexicon. In the absence of contextual constraints, this model predicts robust dominance effects such that the comprehender will access the more frequent, or dominant, sense of the word initially. Most researchers agree that the different, and unrelated, meanings of homonyms are stored separately in accordance with this model. Klein and Murphy (2001) conducted a series of experiments using sensicality judgment tasks to provide evidence that the different senses of polysemes are represented separately in the lexicon. Polysemous words were matched with two different modifiers that evoked either the dominant (e.g., shredded paper) or subordinate sense (e.g., liberal paper). Participants were primed with a phrase that was either consistent (e.g., daily paper) or inconsistent (e.g., wrapping paper) with a target phrase (e.g., liberal paper). They found that participants were significantly more accurate and had shorter RTs for consistent trials than inconsistent trials. This provides evidence that priming one sense of a polyseme provided no processing advantage for retrieving the other sense as would be expected if the senses were stored together. Instead, Klein and Murphy (2001) argue their pattern of results suggests that the facilitation provided in the consistent conditions demonstrates that the senses are stored separately.

To further examine the representations of polysemous words, Klein and Murphy (2002) utilized a forced-choice sorting task to explore how participants categorized the different senses of polysemous words. Participants were given a target phrase that contained a polyseme (e.g., wrapping paper) and two potential choice phrases. One potential choice used the polyseme in a different sense (e.g., liberal paper) and the other choice was thematically linked to the target word (e.g., smooth cloth). Participants were instructed to select the choice that best created a category with the target phrase. They found that participants chose the polysemous option only 20% of the time. In a follow up experiment, Klein and Murphy (2002) replicated the previous experiment utilizing homonyms as well as polysemes. For polyseme trials, participants chose the polyseme option 14.1% of the time compared to 6.6% for homonym trials. These results suggest that polysemes and homonyms pattern together. Further, they argue that these results provide additional evidence that the senses of ambiguous words are stored separately.

While the majority of evidence for the Separate Sense Model examined polysemes on their own or modified by a single word, Foraker and Murphy (2012) examined the effect of context on the processing of polysemes within sentences. They constructed sentences containing polysemes in which the preceding context was either consistent, inconsistent, or neutral with regard to the sense completion of the polysemous word. Of particular importance to the Separate

Sense Model is the neutral context condition (see Example 1, below for the neutral context conditions).

(1a) They discussed the cotton after the fabric ripped a second time.

(1b) They discussed the cotton after the crop failed a second time.

If the different senses of polysemes are stored separately, then the dominant sense of an ambiguous word should be accessed more quickly than the subordinate sense in a neutral context. In three different reading experiments, Foraker and Murphy (2012) found dominance effects in the neutral condition such that the dominant sense (1a) was processed more quickly than the subordinate sense (1b). They also investigated whether the sense frequency of the polyseme modulated the magnitude of the dominance effect. They found evidence that as the frequency of the dominant sense increased so did the magnitude of the dominance effect for that polyseme. Taken together, Foraker and Murphy (2012) argue for a Separate Sense Model for the representation of polysemes and against a Same Representation Model.

Same Representation Models

The Single-Entry Model (Nunberg, 1979), on the other hand, attempts to take sense similarity into account. It argues that, when words have highly related senses (i.e., polysemes), those senses are stored together within the lexicon under a single orthographic form. Specifically, the senses of the ambiguous word are underspecified within the lexicon and the distinct sense is derived during processing. As such, this model predicts no effect of sense frequency on processing as the comprehender will delay accessing a specific sense until they encounter contextual constraints that supports the retrieval of a specific sense. Within the framework of the Single-Entry Model, Frisson (2009, 2015) has argued for a Same Representation Model in which the different senses of an ambiguous word are underspecified.

That is, upon encountering an ambiguous word, comprehenders initially activate a semantically underspecified meaning rather than activating a more specific sense. Comprehenders might eventually “hone in” on the intended meaning, but the sense frequency of the senses plays no role at the access stage.

Frazier and Rayner (1990) conducted an eyetracking while reading study in which the ambiguity of the target word was manipulated using polysemes, homonyms, and unambiguous control words (see Example 2, below for the polyseme and unambiguous conditions).

(2a) Unfortunately the newspaper was destroyed, lying in the rain.

(2b) Unfortunately the newspaper was destroyed, managing advertising so poorly.

(2c) Apparently the treasure was lost because the pirates sank the ship.

The sense frequency of the ambiguous word was manipulated to resolve either to its dominant or subordinate sense. They found no significant differences between polysemes (Sentences (2a) and (2b) and unambiguous control words (2c) as function of whether the sentence completed to the dominant or subordinate sense. For homonyms, however, sentences that resolved toward the dominant sense were processed more quickly than sentences that resolved toward the subordinate sense. The absence of a dominance effect for polysemes as compared to homonyms provides evidence for a Same Representation Model for polysemes in which comprehenders can delay accessing a specific sense of an ambiguous word until they encounter a supportive context.

Frisson (2015) utilized eyetracking while reading to test the different predictions of the Separate Representations Model and the underspecification account. Using the same polysemes as Klein and Murphy (2001) he presented sentences containing a polyseme that disambiguated toward either the dominant or subordinate sense of the word. The underspecification account predicts no difference in processing times between dominant and subordinate sense completions as readers will initially access an underspecified meaning rather a specific sense. The Separate Representation Model, on the other hand, predicts robust dominance effects such that the dominant sense completions should be accessed and read more quickly than the subordinate sense. He found no significant differences in processing times between the dominant and subordinate sense completions lending support the underspecification account. As such, there is evidence, from multiple paradigms, that supports both models of polyseme representation. To understand the discrepancies in the literature, some researchers have suggested that the specific features of the polysemous senses may affect whether those senses are stored separately or together. Those studying the retrieval and processing of polysemes have turned towards the differences in relative sense relatedness and sense frequency across polysemes.

Shared Features Model

The final model discussed here has attempted to explain the divergent results found in the literature. The Shared Features Model (Brocher, Foraker, & Koenig, 2016; Brocher, Koenig, & Mauner, 2018) argues that the representations of different senses of an ambiguous word are overlapping. The semantic features of the senses and the sense frequency information is divided between shared and unshared features. Initially, only the semantic features shared between the different senses are activated, and the comprehender can delay committing to a particular sense. Eventually, the unshared semantic features of the senses, including sense frequency information, are activated as well. After the unshared features have been activated, this model predicts between-sense competition as the interpretation of the sentence progresses. The differences between ambiguous words with related senses compared to less semantically related senses as well as the impact of sense frequency on polyseme access and retrieval are highly important.

Sense Relatedness

The different senses of polysemous words are more closely related than the different meanings of homonyms. This can explain the differences in polysemes and homonyms that some researchers have found. Within the polyseme literature, however, polysemes can further be distinguished from each as either regular or irregular. The senses of a regular polyseme tend to be more related as the relationship between them is formed via a productive rule. For example, “chicken” can refer to either the animal or the meat that comes from the animal. The senses of irregular polysemes, on the other hand, tend to be less related as the relationships between them are less predictable and are not derivable via a productive rule. For example, “wire” can refer to a thin metal filament or a listening device (Eddington & Tokowicz, 2015). If the senses of a polyseme are closely related (i.e., regular polysemes), then one might expect those senses to share a representation. Similarly, if the senses of a polyseme are not very closely related (i.e., irregular polysemes), then one might expect those senses to be represented separately within the lexicon.

Previous studies within the literature used a mixture of regular and irregular polysemes (Klein & Murphy, 2001, 2002; Foraker & Murphy, 2012; Frazier and Rayner, 1990; Frisson, 2015), but Klepousniotou, Titone, and Romero (2008) presented evidence that sense relatedness has an effect on the retrieval and processing of polysemes. They divided ambiguous words into three groups based on the amount of semantic overlap between the senses: low, moderate, or high overlap. Participants completed sensicality judgments on target word pairs containing a polyseme and a modifier that was biased toward either the dominant or subordinate sense completion of the polyseme. They found different effects of dominance for high overlap words as compared to low and moderate overlaps words. These results suggests that irregular polysemes pattern more closely with homonyms than they do with regular polysemes. It then follows that the senses of regular polysemes, due to their closely related meanings, may be represented together in the lexicon while the senses of irregular polysemes, which are less related, may be represented in separate entries.

Rabagliati and Snedeker (2013) used a picture naming production task to further differentiate between regular and irregular polysemes. Using regular and irregular polysemes, as well as homonyms, they constructed sets of images containing two different senses of an ambiguous word and two unrelated filler images. Participants were instructed to name the images in the order that they saw them. Because two of the images in the set shared the same name (e.g., chicken meat vs the live animal chicken), Rabagliati and Snedeker (2013) were interested in whether or not the participants would explicitly disambiguate the different senses. As such, the proportion of trials in which participants did not avoid ambiguity was measured. They found that participants were more likely to disambiguate regular polysemes than irregular polysemes or homonyms. The failure to recognize and avoid the ambiguity in the case of irregular polysemes suggests that those senses are stored separately within the lexicon. Comparatively, the participants' success in avoiding ambiguity for regular polysemes suggests those senses are represented in the same entry. Because previous studies did not differentiate between regular and irregular polysemes, this might explain the inconsistencies within the literature regarding polyseme representation.

Sense Frequency

The different senses of an ambiguous word often differ in terms of relative frequency. Within the homonym literature, there is evidence that sense frequency can modulate the magnitude of the dominance effects. That is, the more frequent a dominant meaning is relative to the less frequent, subordinate meaning, the greater the magnitude of the dominance effect. Thus, if the sense frequency of polysemes is not carefully controlled, it might explain the presence or absence of dominance effects. Much of the literature previously relied on polysemes with relative sense frequencies all across the board. In arguing for their Shared Features Model, Brocher et al. (2016) investigated the relationship between sense frequency and polysemy processing in sentence reading. Looking specifically at biased homonyms and polysemes, or ambiguous words with a much more frequent dominant sense compared to a much less frequent subordinate sense, they manipulated the location of a disambiguating context (See Example 3, below).

(3a) Because the wire was well hidden, the skilled spy of the agency remained undetected.

(3b) Michael didn't like the bank in the suburbs, because the fishing was not very good.

When context disambiguated toward the subordinate sense of a word, participants were significantly slower for homonyms (3b) than polysemes (3a). They argue that the absence of this dominance effect for biased polysemes, as compared to homonyms, suggests that readers were successfully able to delay committing to a specific sense for polysemes but not for homonyms. These results seem at odds with those of Foraker and Murphy (2012) who presented evidence that the more biased the polyseme's senses were, the stronger the dominance effect was for that polyseme.

Building off their prior studies, Brocher et al. (2018) examined the difference in processing between biased and balanced polysemes and homonyms in an eyetracking while reading experiment. Their critical comparisons were between the biased polysemes and homonyms and between the balanced polysemes and homonyms (see Example 4, below).

(4a) When Mr. Jordan discovered the wire in the lamp, the FBI aborted the top secret mission.

(4b) Marlene looked out for a cone on her way home, since a big pothole had been marked there yesterday.

(4c) Ken decided on the bank near the clubhouse, since the other beaches were too crowded for swimming.

(4d) Something seemed to be wrong with the calf that day, because the animal did not drink nor eat.

In accordance with their Shared Features Model, which predicts between sense competition, they found evidence that balanced words, both polysemes (4b) and homonyms (4d), took longer to process than biased words ((4a) and (4c)). Additionally, the cost of reanalysis for selecting the unintended sense was greater for balanced homonyms than for balanced polysemes. Brocher et al. (2018) suggest this can be explained by differing representations of homonyms as compared to polysemes. Though they classified irregular polysemes as either categorically balanced or biased, Brocher et al. (2016, 2018) calculated dominance scores on a continuum. Participants were presented with the polysemes and told to write down five different things about each word. Those responses were then coded as belonging to either the dominant sense, subordinate sense, or a different or noncomphrensible meaning of the polyseme. Dominance scores were thus calculated relative to the subordinate sense of the word. This subjective method of measuring sense frequency does not capture the wide array of dominance across the continuum.

Sentence Structure

Additionally, previous studies investigating polysemy used a variety of different sentence structures. Both within specific studies and across the literature, the wide array of structures used might explain some of the divergent patterns of results. Evidence from the broader sentence processing literature in both eyetracking studies and error detection paradigms has demonstrated the importance of sentence structure. Specifically, different processing patterns have been observed depending on the location of the target word (i.e., in a focused position compared to a subordinate clause or other adjunct phrases) (Baker & Wagner, 1987; Lowder & Gordon, 2012, 2013). Accordingly, the items constructed for the current study always positioned the polyseme as the object of the verb, thereby controlling for any effects of sentence structure.

Current Study

The purpose of the current study was to address the inconsistencies in experimental design to reconcile the divergent findings across the polyseme literature. The foundational studies within the polyseme literature used polysemes whose different senses encompassed a wide range of semantic relatedness and relative frequency. More recent studies have demonstrated that these factors can affect retrieval and processing times (Klepousniotou et al., 2008; Rabagliati & Snedeker, 2013; Brocher et al., 2016, 2018). To specifically address the differing predictions of the Separate Representation Model and the Same Sense Representation Model, it is critical to carefully control for and measure sense relatedness and frequency. By only using irregular polysemes (from Brocher et al. 2016, 2018) to hold sense relatedness constant, and conducting a corpus search to classify polysemes across a continuum of dominance scores, this study allows us to test the predictions of the different models of polyseme representation. Will there be evidence of a dominance effect when polysemes are presented in an initially neutral context? I predicted, in line with the Separate Representation Model, that the dominant sense of polysemes would be processed more quickly than the subordinate sense. Further, I expected that this dominance effect would be moderated by the dominance score of the polyseme such that the greater the dominance score of the polyseme, the greater the magnitude of the dominance effect.

Method

Participants

Forty-eight students at the University of Richmond participated in this experiment for course credit. All participants reported normal or corrected-to-normal vision. The data from eight participants were excluded, two because English was not their first language and six for poor calibration. The data from 40 participants were included in the analysis.

Materials

One hundred twenty-four sentences were used. From Brocher et al. (2016, 2018), 40 irregular polysemes were used to construct forty sets of experimental items. Of the remaining 84 sentences, 44 were unrelated fillers and 40 were from an unrelated experiment. The experimental items were counterbalanced across four different lists such that each participant saw an equal number of each condition. In all experimental items, the polyseme, or unambiguous control word, was presented in a neutral context in a focused position in the first clause before a noun disambiguated it toward either the dominant or subordinate sense in the second clause (see Example 5, below, see Appendix B for full set of materials).

(5a) James discovered the **wire**, so he called the skilled policeman to ensure he was at the right location.

(5b) James discovered the **bomb**, so he called the skilled policeman to ensure he was at the right location.

(5c) James discovered the **wire**, so he called the skilled electrician to ensure he was at the right location.

(5d) James discovered the **cable**, so he called the skilled electrician to ensure he was at the right location.

These sentences were constructed so that upon encountering the polyseme in (5a) and (5c), the sentence could resolve toward either the dominant or subordinate sense. In the second clause, a noun was used to disambiguate the polyseme toward a particular sense. For (5a), *policeman* resolves the sentence toward the more subordinate sense of *wire* whereas in (5c), *electrician* disambiguates the sentence toward the more dominant sense of the word.

Using the English Lexicon Project, the polysemes, the unambiguous control words, and the disambiguating words found in the corpus were matched in length and frequency (Brysbaert & New, 2009). There were no significant differences in length between the polyseme (mean number of letters= 5.18) and the control word in the dominant condition (mean number of letters= 5.53), $t(78) = -1.01$, $p > .05$. Similarly, there were no significant differences in log frequency between the polyseme (M=3.17) and the control word in the dominant condition (M=2.93), $t(78) = 1.63$, $p > .05$. There were no significant differences in length between the polyseme (mean number of letters= 5.18) and the control word in the subordinate condition (mean number of letters= 5.68), $t(78) = -1.32$, $p > .05$, nor were there differences between the polyseme (M=3.17) and subordinate-control word (M=2.94) in log frequency, $t(78) = 1.53$, $p > .05$. For the disambiguating words, there were no differences in length between the dominant condition (mean number of letters= 7.60) and the subordinate condition (mean number of letters= 7.63), $t(78) = .044$, $p > .05$. There were also no significant differences in log frequency between the dominant condition (M=2.56) and the subordinate condition (M =2.67), $t(72) = .714$, $p > .05$.

Dominance ratings

The Corpus of Contemporary American English (COCA) was randomly sampled for 50 instances for each polyseme (Davies, 2008). The different senses of the each polyseme were identified using the Merriam Webster Online Dictionary (Merriam-Webster, n.d.). Using the criteria described by Rabagliati and Snedeker (2013), the senses of irregular polysemous words had to be listed under the same entry in the dictionary. For some items, only the two target senses appeared in the corpus entries. For other items, there were several different senses found in the corpus entries. Two different raters coded each use from the corpus corresponding to a specific sense of the polyseme. Agreement was at 85%. All disagreements were resolved by discussion.

For each polyseme, the most frequent meaning was chosen as the dominant interpretation. The subordinate interpretation was chosen from the remaining senses. A dominance score was calculated as the ratio of dominant uses over the total number of entries (M= 0.64, range= 0.96-0.22). This method of calculating dominance scores captures a wide range of sense frequency as compared to Brocher et al. (2016, 2018). By understanding sense frequency across a continuum from highly biased to more balanced, we can better discern the role it plays on the retrieval and processing of polysemous words.

Pretesting to confirm sense completion

Forty participants were recruited using Amazon’s Mechanical Turk. Individuals were eligible to participate if they reported that they were 18 years of age or older, indicated that English was their native language, their IP address registered as being in the United States, and they had amassed an approval rate of 95% of greater for 50 or more previous tasks. Participants were paid US$4 for completing the task. To ensure that the experimental items were being interpreted as disambiguating toward the appropriate sense, participants were presented with a two-alternative forced-choice for each item. The items were counterbalanced across two lists so that participants saw an equal number of dominant and subordinate sense completions. For example, participants first read *James discovered the wire, so he called the skilled [policeman / electrician] to ensure he was at the right location.* Half saw *policeman* in the sentence, and half saw *electrician.* They were then asked: "What does 'wire' mean here? A listening device OR thin metal filament." Participants were significantly more likely to correctly select the dominant sense completion (M=0.73, SD= .15) than incorrectly select the subordinate sense completion (M=.28, SD= .15), $t(39)$= -9.78, $p < .01$. Similarly, participants were significantly more likely to correctly select the subordinate sense completion (M=0.68, SD= .15) than incorrectly select the dominant sense completion (M=0.32, SD= .15), $t(39)$= 7.70, $p < .01$.

Procedure

Participants' eye movements were recorded with an EyeLink 1000 Plus eyetracker (SR Research) at a sampling rate of 1,000 Hz. A chinrest and headrest were used to minimize head movement. Participants were instructed to read at a natural pace. At the start of each trial, a fixation point was presented near the left edge of the monitor, marking the location where the first word of the sentence would appear. When the participant's gaze was steady on this point, the experimenter presented the sentence. After reading the sentence, the participant pressed a button, which caused the sentence to disappear and a true-false comprehension question to appear in its place. Participants pressed one button to answer "true," and another button to answer "false." Mean comprehension question accuracy was 90%. There was no significant difference in the accuracy between conditions. After the participant answered the comprehension question, the fixation point for the next trial appeared. Participants were first presented with four of the filler sentences. After this warm-up block, the remaining 120 sentences were presented randomly.

Analysis

Data analysis focused on five standard eye-movement measures. *Gaze duration* is the sum of all fixations that occur in a region before exiting that region to the right or left. *Regression-path duration* (also called *go-past time*) is the sum of all fixations in a region, as well as regressive fixations to earlier parts of the sentence before progressing past the region's right boundary. Thus, regression path duration measures both early reading and some rereading. *Regressions out* is the proportion of trials in which a participant made a regression out of the target region to an earlier part of the sentence. *Second-pass time* is the time spent rereading a region after the eyes have exited the right boundary of this region. Unlike the other measures, second-pass time includes zeroes (i.e., trials when the reader did not reread this region). *Total time* is the sum of all fixations in a region and reflects a comprehensive integration of the information that was read. We report reading times for one region of interest. The Disambiguating region consisted of a noun in the second clause of the sentence ("policeman" in (5a) and (5b) and "electrician" in (5c) and (5d)). This region consisted of a single word in all but seven items, where it was two words.

An automatic procedure in the EyeLink software combined fixations that were shorter than 80ms and that were within one character of another fixation into a single fixation. Additional fixations shorter than 80ms and longer than 800ms were eliminated. In addition, means and standard deviations were computed separately for each condition, region of interest, and dependent measure. Reading times that were greater than three standard deviations from the condition mean were eliminated.

Results

Eyetracking measures

Mean reading times for the four conditions are presented in Table 1. Eye-tracking data for each measure were subjected to a 2 (polyseme/control) x 2 (dominant/subordinate) analyses of variance (ANOVAs) treating participants as a random variable. For *Gaze duration*, there were no significant effects at the disambiguating region. For *Regressions out*, there was a marginally significant main effect of sense, $F(1,39)= 3.51$, $p=.069$, such that participants were more likely to make regressions out of the disambiguating region in subordinate sentences than dominant sentences (see Figure 1 in Appendix A). In *Regression-path duration*, the main effect of sense was fully significant, $F(1,39)= 6.92$, $p= .012$, with longer reading times for subordinate sentences than dominant sentences (see Figure 2 in Appendix A). For *Second-pass time,* there was a fully significant main effect of sense, $F(1,39)= 4.68$, $p=.037$, with longer reading times for subordinate sentences than dominant sentences (see Figure 3 in Appendix A). Finally, for *Total time,* there was a fully significant main effect of sense, $F(1,39)=4.79$, $p=.035$ (see Figure 4 in Appendix A). Across all eyetracking measures, there were no significant main effects of ambiguity, nor significant sense-by-ambiguity interactions.

Correlations

To test whether the strength of the dominance effects was moderated by relative sense frequency, a difference score was calculated by subtracting mean reading times for subordinate sentences from mean reading times for dominant sentences for each of the reading time measures. These difference scores captured the dominance effects found in the reading experiment. A correlation was performed using the difference scores and the different reading time measures. The correlations between all eyetracking measures and the dominance effect were non-significant (see Table 2).

Discussion

Using the same irregular polysemes as Brocher et al. (2016, 2018), we tested the differing predictions of the Separate Representation Model and the Same Representation Model. In all the reading time measures that we analyzed, except for Gaze duration, we found a significant main effect of sense. Reading times on the disambiguating word were longer for sentences that resolved toward the subordinate sense of the polyseme than sentences that resolved toward the dominant sense. The presence of this dominance effect, especially in later eyetracking measures, provides evidence for a Separate Representation Model of polyseme retrieval and processing. We found no evidence that readers delayed committing to a particular sense of the polyseme as argued by Frisson's (2009, 2015) underspecification account. Instead, our results suggest that when readers encountered the polyseme in a neutral context, they retrieved the dominant sense initially. This resulted in a processing cost when the sentence later resolved toward the subordinate meaning of the polyseme, leading to longer reading times. This finding replicates the patterns found in Foraker and Murphy's (2012) reading experiments.

These main effects of sense were not qualified by a significant interaction. The absence of an interaction was surprising. Because the unambiguous control words were matched in length and frequency to the polysemes, one would expect no reading time differences to emerge between the dominant and subordinate control conditions. We expected that the dominance effect would be driven primarily by the differences between the ambiguous sentences. There are two possible explanations. First, although the disambiguating words were matched in length, we could not find frequency information for several very infrequent words. It is possible that the disambiguating words in both the control subordinate and polyseme subordinate conditions were less frequent than in the dominant conditions. Second, although the control words were selected to be unambiguous, it is possible that the subordinate control words caused processing difficulties similar to the polyseme in the subordinate condition. Additionally, like Foraker and Murphy (2012) found, we predicted that the magnitude of the dominance effect would be modulated by the relative sense frequency of the polysemes such that the higher the dominance score, the greater the magnitude of the effect. None of the reading time measures we analyzed were significantly correlated with dominance scores. Instead, our results were similar to the findings of Brocher et al. (2016) who also found that the magnitude of the dominance score did not depend on the relative sense frequency of the polysemes. These results were unexpected, and a possible explanation relates to the corpus search. Although the corpus search was a more objective method of measuring sense frequency information, the data may not be an accurate reflection of the sense frequency information represented in the mental lexicon. For example, consider the corpus data for the polysemous word *cardinal*, which can mean either a red bird or a Catholic official. One's intuitive sense might assume that the bird sense of cardinal is much more dominant, but the corpus data revealed the Catholic official sense was more dominant, with a dominance score of .96. For comparison, in Brocher et al. (2018) the bird sense of cardinal was dominant with a score of .64. Although this is the most extreme example, the corpus search did produce some dominance scores that seemed at odds with intuition. If this corpus search data does not reflect the sense frequency information in the mental lexicon, this might explain the non-significant correlations between dominance scores and reading measures.

This study provides evidence for a Separate Representation Model of irregular polyseme processing. By only using irregular polysemes, we were able to reconcile some differences between previous studies. As suggested by Klepousniotou et al. (2008) and Rabagliati and Snedeker (2013), the senses of irregular polysemes might be sufficiently different enough from each other that they each have their own separate entry in the lexicon. The robust dominance effects we found for irregular polysemes supports this view. Additionally, unlike previous studies examining polysemes, we carefully constructed our experimental items to ensure that any effects found could not be contributed to variation in sentence structure. The robust dominance effects found suggests that our manipulation of sense completion was successful. Further evidence of this was provided by our pretest. By and large, as participants encountered the polyseme in a neutral context, the disambiguating word sufficiently biased the comprehenders' interpretation of the polyseme toward a particular sense.

Although this study attempted to clarify some inconsistencies across the literature, future studies are needed to fully understand the retrieval and processing of polysemes in sentences. To tease apart the relationship between sense frequency and reading time patterns, a future study could explore different methods of capturing sense frequency information. Both Foraker and Murphy (2012) and Brocher and colleagues (2016, 2018) calculated dominance scores using subjective responses from participants. Despite their methodological similarities, they found differing patterns. This question requires further consideration. Additionally, while this study provides clarity on the retrieval of irregular polysemes, a future study could include a direct comparison of irregular polysemes, regular polysemes, and homonyms in order to get a clearer understanding of how exactly these ambiguous words are similar or dissimilar from each other.

Overall, this study tested the predictions of two different models for polyseme processing while paying careful attention to sense relatedness, sense frequency, and sentence structure. We found evidence that the different senses of irregular polysemes are represented separately in the mind. Because of this, comprehenders are quicker to retrieve the more dominant sense relative to the more subordinate sense of the polyseme. This provides evidence for a Separate Representation Model of polyseme processing.

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Appendix A: Tables and Figures

	Polyseme-Sub	Polyseme-Dom	Control-Sub	Control-Dom
Gaze Duration	297.61	300.52	304.51	291.95
Regressions Out	.27	.22	.24	.22
Regression-Path Duration	518.62	445.00	456.37	414.53
Second-Pass Time	183.00	152.18	167.97	151.53
Total Time	553.16	496.33	524.38	487.38

Table 1. Mean reading times for each condition for all eyetracking measures, reported in milliseconds.

	Gaze Duration	Regressions Out	Regression-Path Duration	Second-Pass Time	Total Time
Pearson Correlation	.124	-.225	-.183	.068	.009
***p*-value**	.445	.162	.257	.679	.954
N	40	40	40	40	40

Table 2. Non-significant correlations between reading time measures and the calculated dominance effect.

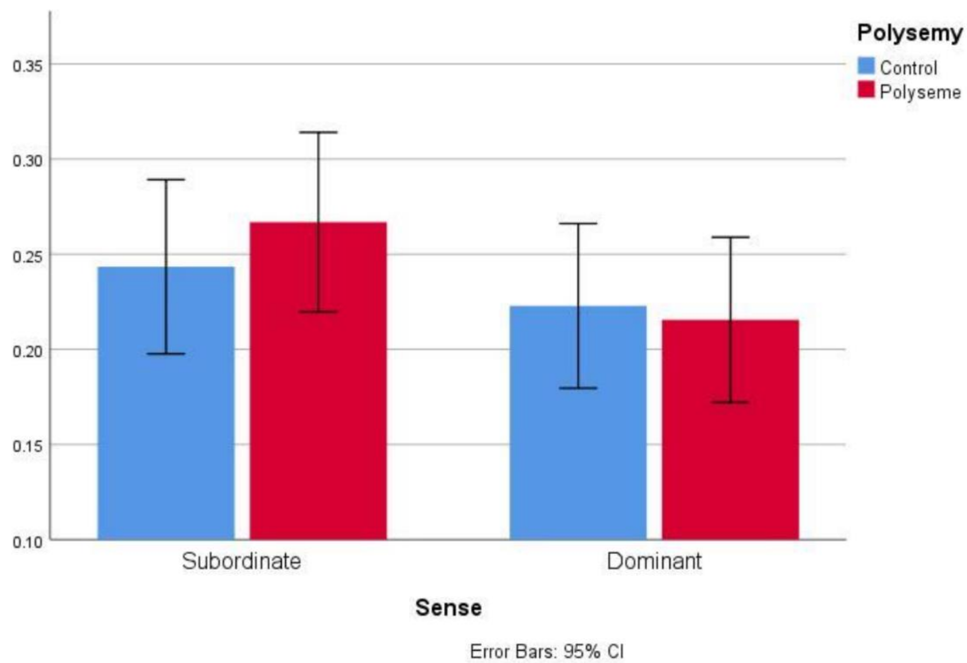

Figure 1. Regressions Out

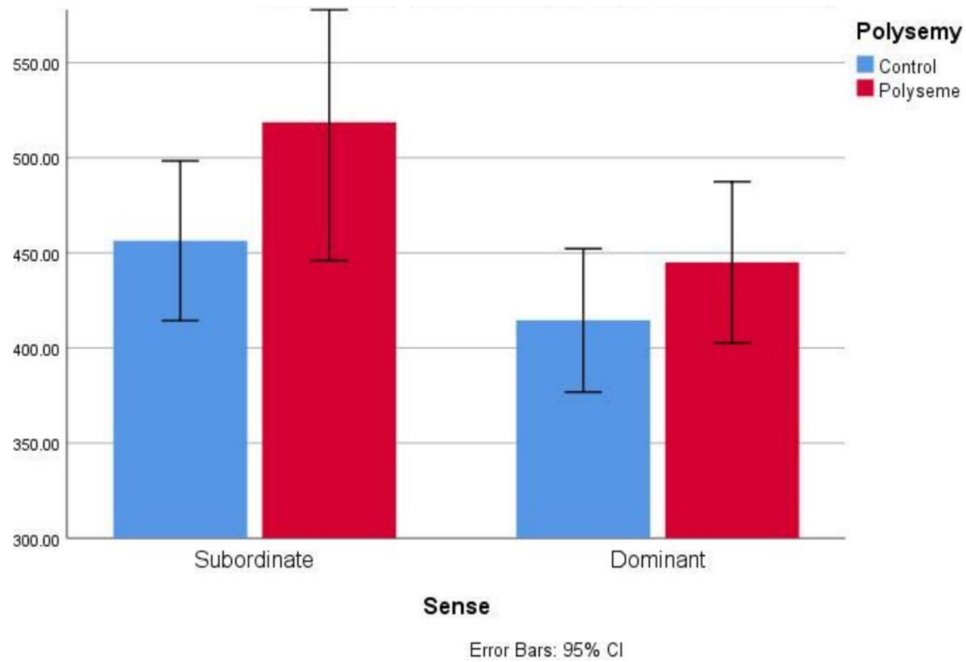

Figure 2. Regression-path Duration

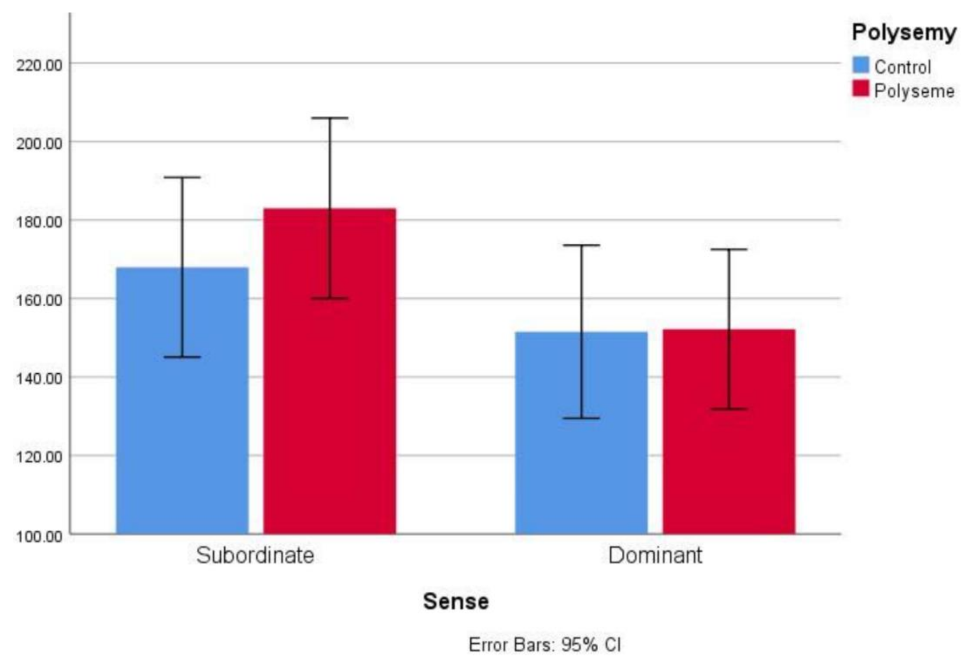

Figure 3. Second-pass Time

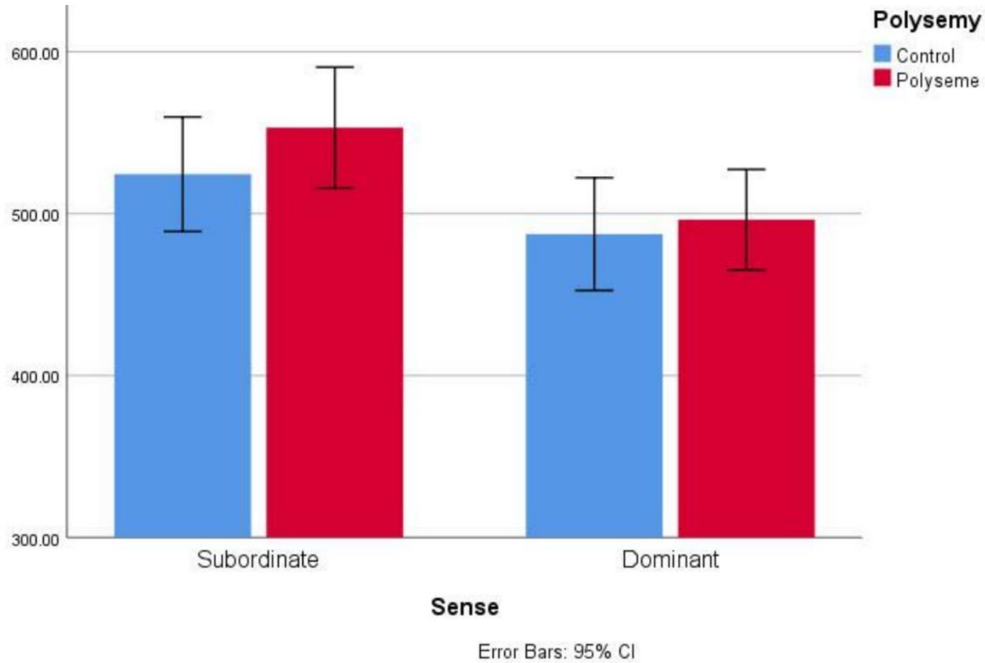

Figure 4. Total Time

Appendix B: Experimental Items

1a. James discovered the **wire (bomb)**, so he called the policeman to ensure he was at the right location.

1b. James discovered the **wire (cable)**, so he called the electrician to ensure he was at the right location.

2a. Kelly signed the **article (law)**, and she hoped the old constitution would be changed prior to November.

2b. Kelly signed the **article (journal)**, and she hoped the old publication would be changed prior to November.

3a. Frank bought a **belt (screw)**, and he asked the young mechanic for a receipt for the purchase.

3b. Frank bought a **belt (shirt)**, and he asked the young stylist for a receipt for the purchase.

4a. Marcus recognized the **character (honesty)**, so he told the talented therapist why it was important to him.

4b. Marcus recognized the **character (story)**, so he told the talented author why it was important to him.

5a. Robert admired the **clean (sober)** woman, but he confronted the trusted rehab director about her on Sunday.

5b. Robert admired the **clean (neat)** woman, but he confronted the trusted housekeeper about her on Sunday.

6a. John remembered the **cold (mean)** woman, and he heard her constant gossiping across the room.

6b. John remembered the **cold (chilly)** woman, and he heard her constant shivering across the room.

7a. Hannah wanted the **diamonds (cards)**, so she accompanied the experienced gambler sitting at the table to the door.

7b. Hannah wanted the **diamonds (gems)**, so she accompanied the experienced jeweler sitting at the table to the door.

8a. Will despised the **film (coating)**, so he contacted the renowned maid to have it removed.

8b. Will despised the **film (movie)**, so he contacted the renowned director to have it removed.

9a. Julie monitored her **hand (gambling)**, and she asked the tired card dealer about it on Friday night.

9b. Julie monitored her **hand (arm)**, and she asked the tired nurse about it on Friday night.

10a. Tonya needed the **hunt (food)**, so she warned the foolish fisherman about the danger in the morning.

10b. Tonya needed the **hunt (quest)**, so she warned the foolish wizard about the danger in the morning.

11a. Susan noticed the **letter (comma)**, and she showed the young calligrapher exactly where she wanted everything.

11b. Susan noticed the **letter (envelope)**, and she showed the young secretary exactly where she wanted everything.

12a. Oliver approached the **load (task)**, and he stacked the empty forms on the shelf when he was finished.

12b. Oliver approached the **load (shipment)**, and he stacked the empty boxes on the shelf when he was finished.

13a. Nora fixed the **loop (code)**, and she left the computer in the living room when she was ready for lunch.

13b. Nora fixed the **loop (shoelace)**, and she left the boot in the living room when she was ready for lunch.

14a. Jennifer disturbed the **nest (loft)**, and she worried the naïve architect with concerns about the structure's stability.

14b. Jennifer disturbed the **nest (burrow)**, and she worried the naïve zoo keeper with concerns about the structure's stability.

15a. Megan disliked the **notes (tunes)**, but she decided the friendly musician was not at fault.

15b. Megan disliked the **notes (packages)**, but she decided the friendly mailman was not at fault.

16a. Talia checked the **oil (easel)**, and she encouraged the eager painter to take pride in the finished product.

16b. Talia checked the **oil (car)**, and she encouraged the eager engineer to take pride in the finished product.

17a. Madelyn watched the **play (performance)**, and she complimented the exciting actor in the evening after being introduced.

17b. Madelyn watched the **play (game)**, and she complimented the exciting athlete in the evening after being introduced.

18a. Malcolm observed the **scene (painting)**, and he interviewed the revered artist about the inspiration behind it.

18b. Malcolm observed the **scene (script)**, and he interviewed the revered playwright about the inspiration behind it.

19a. John appreciated the **service (sermon)**, and he considered the gifted minister a very close friend.

19b. John appreciated the **service (agency),** and he considered the gifted technician a very close friend.

20a. Claire loathed the **shade (color)**, but she defended the bright color she was accustomed to in Florida.

20b. Claire loathed the **shade (shadow)**, but she defended the bright sunlight she was accustomed to in Florida.

21a. Katie tasted the **sour (nasty)** food, and she hoped it was not spoiled because she spent a lot of money on it.

21b. Katie tasted the **sour (acidic)** food, and she hoped it was not bitter because she spent a lot of money on it.

22a. Tyler examined the **table (report)**, and he invited the reliable accountant to explain the process behind the project.

22b. Tyler examined the **table (stool)**, and he invited the reliable carpenter to explain the process behind the project.

23a. Ben chose the **vessel (container)**, and he welcomed the energetic mover to his property before the storm began.

23b. Ben chose the **vessel (ship)**, and he welcomed the energetic captain to his property before the storm began.

24a. Amy described the **basin (bucket)**, and she acquired a new sponge from the store based on her description.

24b. Amy described the **basin (valley)**, and she acquired a new hiking staff from the store based on her description.

25a. Dylan acknowledged the **cardinal (bird)**, and he greeted the quiet biologist who was standing nearby.

25b. Dylan acknowledged the **cardinal (nun)**, and he greeted the quiet monk who was standing nearby.

26a. Monica avoided the **cone (flower)**, and she scolded the weary botanist for not paying attention on Monday.

26b. Monica avoided the **cone (crosswalk)**, and she scolded the weary pedestrian for not paying attention on Monday.

27a. David recalled the **cross (dog)**, and he knew the charitable breeder who spent years thinking about it.

27b. David recalled the **cross (church)**, and he knew the charitable priest who spent years thinking about it.

28a. Mason prioritized the **date (meeting)**, and he held the important woman close to his heart all the time.

28b. Mason prioritized the **date (month)**, and he held the important schedule close to his heart all the time.

29a. Leah welcomed the **fortune (destiny)**, and she judged the smiling palm reader to be good at her job after the meeting.

29b. Leah welcomed the **fortune (wealth),** and she judged the smiling banker to be good at her job after the meeting,

30a. Maria dropped the **glass (cup)**, and she cleaned the strewn juice that was all over the floor in her house.

30b. Maria dropped the **glass (mirror)**, and she cleaned the strewn shards that were all over the floor in her house.

31a. Liam pondered the **green (caddy)**, and he resented the other golfer for making the job look easy.

31ab. Liam pondered the **green (salad)**, and he resented the other waiter for making the job look easy.

32a. Sophia identified the **hall (theatre)**, and she passed the nice usher who showed her where her parents were waiting.

32b. Sophia identified the **hall (corridor)**, and she passed the nice butler who showed her where her parents were waiting.

33a. Gwen browsed the **oranges (purples)**, and she forgot the name of the exotic color that her brother liked the most.

33b. Gwen browsed the **oranges (apples)**, and she forgot the name of the exotic fruit that her brother liked the most.

34a. Jane took the **paper (homework)**, but she defended the constant plagiarizing because she believed it was not her fault.

34b. Jane took the **paper (wrapper)**, but she defended the constant littering because she believed it was not her faut.

35a. Charlie examined the **sign (display)**, and he thanked the honest clerk for helping him the previous week.

35b. Charlie examined the **sign (hint)**, and he thanked the honest psychic for helping him the previous week.

36a. Ryan treasured the **program (system)**, and he expected the unfamiliar <u>laptop</u> to ask him for identification.

36b. Ryan treasured the **program (college)**, and he expected the unfamiliar <u>administrator</u> to ask him for identification,

37a. Travis prepared a **provision (supply)**, but he understood the position of the local <u>homeless shelter</u> who disagreed with him.

37b. Travis prepared a **provision (law)**, but he understood the position of the local <u>city council</u> who disagreed with him.

38a. Nolan heard the **shower (rain)**, so he asked his favorite <u>weatherman</u> if he knew about this.

38b. Nolan heard the **shower (bath)**, so he asked his favorite <u>roommate</u> it he knew about this.

39a. Patrick moved a **step (stride)**, and he left the only <u>car</u> behind in his hurry to get away last night.

39b. Patrick moved a **step (phase)**, and he left the only <u>plan</u> behind in his hurry to get away last night.

40a. Allison purchased the **tin (jar)**, and she finished her current <u>container</u> so she needed to replace it.

40b. Allison purchased the **tin (foil)**, and she finished her current <u>roll</u> so she needed to replace it.