Baseball Fans Don't Like Lumpy Batters:

Influence of Domain Knowledge on the Access of Subordinate Meanings

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Abstract

Two experiments investigated the effects of domain knowledge on the resolution of ambiguous words with dominant meanings related to baseball. When placed in a sentence context that strongly biased toward the non-baseball meaning (positive evidence), or excluded the baseball meaning (negative evidence), baseball experts had more difficulty than non-experts resolving the ambiguity. Sentence contexts containing positive evidence supported earlier resolution than did the negative evidence condition for both experts and non-experts. These experiments extend prior findings, and can be seen as support for the reordered access model of lexical access, where both prior knowledge and discourse context influence the availability of word meanings.

Keywords: subordinate bias effect, lexical ambiguity, lexical access, domain knowledge

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The need to resolve ambiguity is a common occurrence in discourse processing. One source of ambiguity in written texts comes from the use of homographs. Previous research on lexical ambiguity resolution has demonstrated that both the relative frequency of the meanings of homographs and the discourse context can affect the speed of processing. When the context preceding a homograph is neutral, readers look longer at balanced homographs (with two meanings similar in frequency) than either control words or biased homographs (with one meaning that is substantially more frequent). When the context is consistent with one meaning of a balanced homograph, then readers fixate on homographs no longer than on control words. However, in many cases where a sentence context instantiates the subordinate meaning of a biased homograph, it still takes longer to read the homograph than a control word. This result is termed the *subordinate bias effect* (SBE, Rayner, Pacht & Duffy, 1994). When readers fixate longer on homographs or the regions following them, it is assumed that it is because multiple senses of the word are competing and the required sense has not been selectively accessed.

The SBE was first documented by Duffy, Morris, and Rayner (1988). The SBE has typically been explained in terms of the *reordered access model.* In this model, both contextual factors and word frequency jointly operate to influence lexical processing. It is assumed that in a neutral context, lexical access is determined only by word frequency, with the dominant meaning being accessed first. When a prior context supports the subordinate meaning of a homograph, this helps to activate the subordinate meaning. However, the more frequent dominant meaning will still be activated within the same time window. This results in competition for access, which induces a slow-down in reading times.

Subsequent work has provided robust evidence for the interaction of meaning frequency and biasing context during lexical processing, consistent with predictions of the reordered access model (Clifton et al. 2016). One line of studies has explored benefits from repetition of ambiguous words. Using a set of balanced homographs, Binder and Morris (1995) showed that repetition of ambiguous words within a discourse could speed access on the second occurrence. Although a similar study that embedded prior instances of biased homographs early in a discourse failed to find reductions in the SBE on the target word (Rayner, Pacht, & Duffy, 1994; Experiment 2), a more recent study found that exposure to an initial occurrence of the ambiguous word used in its subordinate sense within a few words of the target encounter could reduce the SBE (Leininger & Rayner, 2013). These results suggest that repetition may affect access, but only with immediate repetitions. Otherwise the activation of the specific subordinate meaning of the homograph may decay rapidly.

Another way researchers have tried to extend work on the SBE is by altering the semantic content of the local context. Dopkins, Morris, and Rayner (1992) manipulated the start of a sentence in two ways. A "positive evidence" condition used semantic associates of the subordinate sense of the ambiguous word, while a "negative evidence" condition excluded the dominant sense, but without strong semantic associates. For example "Although there was still a crowd on the dance floor, the ball was suddenly ended at midnight." versus "Almost as if it had never taken place,…". Both of these conditions were compared to a condition using a neutral start for the sentence, "Just as Mitchell and Marvin had expected,…". This study showed that both positive and negative evidence contexts led to faster resolution of ambiguity, as readers took less time to complete the disambiguating region than in the neutral condition. The contexts also affected reading times on the ambiguous word. Findings of longer reading times following

negative evidence than neutral, and more variability following positive evidence than neutral, were used to suggest that both evidence contexts helped to activate the subordinate meaning, and that positive evidence might even prompt selective access for some readers. However, Sheridan, Reingold, and Daneman (2009) pointed out that the neutral and positive context conditions were actually quite different in this prior study. Using a more closely matched set of sentences they were able to show the SBE on the target word when the prior context highlighted only the subordinate sense, but not when prior context supported both meanings (i.e. puns). For example, "The man with a toothache had a crown made by the best dentist in town" resulted in an SBE on the ambiguous word crown, whereas the pun "The king with a toothache had a crown…" did not. When the prior context supported both meanings, longer reading times were seen in the disambiguating region. Similarly, Rayner, Cook, Juhasz, and Frazier (2006) have now shown that the SBE can occur as early as the target word when it is immediately preceded by a single highly-constraining modifier (kitchen table vs. statistical table).

A final approach that researchers have explored is whether the SBE can be altered by a more global discourse context. Several past attempts failed to find reading time differences on target homographs due to introduction of a theme or topic in an initial sentence, although some benefits have been demonstrated in reading times in post-target regions (Binder, 2003; Rayner, Pacht & Duffy, 1994). Kambe, Rayner, and Duffy (2001) were able to demonstrate that a global context instantiated in a topic sentence of a paragraph can produce the SBE on an ambiguous word presented several sentences later in the absence of local context. More recently Colbert-Getz and Cook (2013) demonstrated that the SBE could be eliminated with an elaborated, extended discourse context. In their study, prior sentences contained four associates to the subordinate meaning prior to encountering an ambiguous word such as *bank* (e.g., "Paul's

son Frank wanted to *catch a fish* for himself. Paul took him to the *local river* to get one. He wanted to make sure Frank was ready for the *mud* that was present. Paul decided to lecture Frank about being careful *around water* since he was so young. Once they got to the <u>BANK</u>, Frank ran to the shore with excitement"). Compared to an unelaborated condition, they found no processing difficulty on the target word. These results show that a strong context preceding an ambiguous word can sometimes override the SBE, consistent with the prediction that access does not necessarily need to proceed in order of the relative frequency of word meanings.

Importantly, in order to categorize which meanings are subordinate, most research in this area has generally assumed that normative data on the relative frequency of different senses of an ambiguous word are reflected in the lexicon. The question pursued in the present study is whether the possession of prior domain knowledge directly relevant to alternate meanings of words may interact with discourse context to affect the processing of homographs. In a series of experiments, we investigated the effects of domain knowledge (knowledge about the American sport of baseball) and disambiguating discourse contexts on the resolution of ambiguous words with dominant meanings related to baseball.

How prior knowledge affects processing

Prior knowledge about a topic generally proffers a strong facilitative effect on memory and comprehension for text related to that topic (Anderson, 1984; Ericsson & Kintsch, 1995; Ricks & Wiley, 2009; Spilich, Vesonder, Chiesi, & Voss, 1979). Prior knowledge has generally been thought to influence discourse processing at a situational-model or mental-model level, but not necessarily at a lexical or propositional level of processing (Fincher-Kiefer, Post, Greene & Voss, 1988). In particular, prior knowledge is thought to act as a schema that aids the integration of new information into an existing representation, or the construction of a retrieval structure for

new material. For example, if a text contains an account of a baseball game, high-knowledge individuals are able to recall the game-related actions more easily than novices because they can map the input onto existing knowledge structures (Voss, Vesonder & Spilich, 1980). Many findings have supported the idea that prior knowledge of a topic improves the integration of new information into a single coherent model of the text, thereby improving comprehension and memory for that text.

In addition to work on prior knowledge effects that are particular to some individuals due to their experience within specific domains (such as the baseball studies by Voss and his colleagues, 1980), schema-based memory effects have also been found more generally when readers are given a title for a vague or ambiguous passage to activate prior knowledge that most people possess (Bransford & Johnson, 1972; Dooling & Lachman, 1971). In the classic title experiments, knowledge of a topic like doing laundry or flying a kite allows people to understand an otherwise vague passage better, read it more quickly, and have better memory for the text. A similar line of research has provided readers with a perspective before reading which can also serve to activate schematic knowledge structures, such as being told to read the description of a house from the perspective of a homebuyer or a burglar (Anderson, Reynolds, Schallert & Goetz, 1977; Pichert & Anderson, 1977). In these studies benefits are again seen at the discourse level, as the provided schema facilitates understanding and integration of ideas, even though it does bias recall in favor of the perspective that was used.

Although most studies exploring the benefits of prior topic knowledge on text processing have found benefits at the discourse level, relatively little work has explored the effects of the possession of specific domain knowledge or expertise on basic reading processes (lexical and syntactic processing). However, several eye-tracking studies have now shown that the advantage

of a perspective or title can extend to lower levels of processing. Kaakinen and colleagues have shown that the perspective that a reader takes during the reading of texts influences early stages of word processing (Kaakinen & Hyona, 2007), with more attention allocated to perspective-relevant information than perspective-irrelevant information, as indicated by increased first pass reading times. Meanwhile, Wiley and Rayner (2000) found evidence that providing prior knowledge about the topic of a text can also influence the reading of individual words, including lexical access for ambiguous words. They found that providing titles for passages that could otherwise be interpreted in two distinct ways (e.g., baseball vs. pottery) decreased gaze durations on ambiguous words (e.g., pitcher) relative to when no title was provided. This is consistent with recent findings that sufficient activation of background knowledge related to the subordinate meaning can facilitate access (Colbert-Getz & Cook, 2013). Moreover, Rodd et al. (2016; Experiments 3, 4) recently examined the effect of expertise in the sport of rowing on lexical processing for sport-related words. Using a word association task, they found that people with long-term rowing experience were more likely to interpret ambiguous words toward their subordinate rowing-related meaning than people with no rowing experience. The purpose of the present experiments is to investigate whether the possession of domain knowledge would also affect lexical processing by altering access to non-domain relevant subordinate meanings of words.

Experiment 1

The question pursued in the present study is whether domain knowledge may interact with sentence context to affect the processing of ambiguous words. In particular, we were interested in whether the possession of extensive domain knowledge related to one meaning of an ambiguous word would affect the access of non-domain related subordinate meanings. To

investigate this question, we looked at reading times on ambiguous words with dominant meanings related to baseball. For example, consider the sentences:

Monica had a great fear of things flying around her head.

She looked for the bats that lived in the shed.

The context provided in the first sentence could allow readers to disambiguate the word *bats* in the second sentence toward the subordinate meaning. The question in this study was whether domain knowledge would interact with the previous sentence context in meaning selection. We were especially interested in whether baseball experts would experience the SBE to the same extent as novices, and whether they might resolve the subordinate meanings in a manner different than novices, since their baseball knowledge might provide additional activation for the dominant, but non-context appropriate, meanings of these ambiguous words.

Method

Participants

Thirty-two students at the University of Massachusetts either received class credit or $8 as compensation. All participants were native English speakers, with normal uncorrected vision or soft contact lenses. At the end of the session, participants filled out a 45-item baseball knowledge questionnaire (Spilich, Chiesi, Vesonder & Voss, 1979). Similar to Ricks, Turley-Ames and Wiley (2007) and Wiley (1998), readers were categorized as low knowledge if they answered fewer than 15 items correctly ($M = 4.06$, $SD = 4.25$). Participants who scored 15 or higher were categorized as high knowledge ($M = 23.62$, $SD = 8.64$).

Materials

Twelve ambiguous words with baseball-relevant dominant meanings were chosen for the experiment: *ball, bases, bats, caps, coach, count, field, game, jerseys, pitch, score* and *throw*.

Two passages were written to fit the subordinate meaning of each ambiguous word. As shown in Appendix A, the first sentence was consistent with the subordinate meaning, but provided only a weak context. The second sentence included the ambiguous word, and a disambiguating region that required that the reader take the subordinate meaning which ended the sentence. Between the target ambiguous word and the disambiguating region, there was a post-target region typically of two to three words in which spillover effects could be assessed. Due to variance in the size of these regions, reading times are analyzed adjusting for number of characters as a covariate.

Half of the target sentences were presented with the ambiguous word and half with a non-ambiguous control word, matched for fit in the sentence context, as well as length. The average probability of generating the non-baseball meaning of the ambiguous words was .10. Following Sereno, Pacht, and Rayner (1992) and Sereno, O'Donnell, and Rayner (2006), instead of closely matching the overall form of the ambiguous words with high frequency control words, we chose control words that were more closely matched in frequency to the subordinate meanings. The frequencies per million according to the Francis Kucera norms for the ambiguous words was 72.58, while the average for the control words was 14.17. Because the control words were less frequent compared to the frequencies for the overall form of the ambiguous words, this represents a conservative approach that makes it less likely that one should see longer reading times on ambiguous words simply as an artifact of using high frequency control words.

Each ambiguous word or its control was presented only once for each subject resulting in 12 target passages. The different versions of the passages were counterbalanced into four sets of materials so that words appeared in each sentence frame an equal number of times for each knowledge group. There were 48 additional filler passages of different format.

Apparatus

Eye movements were recorded by a Generation V Fourward Technologies Dual Purkinje Eyetracker, with a resolution of 10 min of arc. Viewing was binocular, with eye position recorded from the right eye. The eyetracking system was interfaced with a 486 computer that ran the experiment. Passages were presented in double-spaced format on a VGA monitor. The letters were in lower case except for the first letter of sentences and proper nouns. Participants were seated 62 cm from the monitor, with 4 letters subtending 1 degree of visual angle. The passages were presented with no more than 60 letter spaces per line and were 2-3 lines long.

Procedure

When the participant arrived, a bite-bar was prepared to minimize head movements and the eye tracking system was calibrated. Each participant read a series of passages on a computer screen. They were told to read for comprehension. It was stressed that they should read as normally as possible.

At the start of each trial, five boxes appeared at the top of the screen and the reader was asked to look at the left-most box. When the reader fixated on that box, a 'Get Ready' message was presented. After reading the passage, the reader pressed a button that erased the passage and the calibration screen reappeared. Simple yes-no comprehension questions were asked for filler passages at random intervals. All participants answered all questions correctly.

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Results

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Early effects of context on the processing of ambiguous words are analyzed using first pass reading times on the three regions of interest: the target region which consisted of the ambiguous or control word, the post-target region, and the disambiguating region. In addition, later effects are explored using a time-to-complete measure for the disambiguating region. This

measure included all additional time spent after completing the first pass on the disambiguating region until pressing the button to terminate the display (computed using 0 ms reading times if no extra time was spent after first pass). The measure included regressions to previous regions and returns to the disambiguating region, and was intended to reflect attempts to resolve ambiguity after the disambiguating phrase had been read (Clifton, Staub & Rayner, 2007; Dopkins, Morris & Rayner, 1992). The first pass analyses show where readers first encounter difficulty (early effects), while the time-to-complete-reading analyses show the costs of attempting to overcome this difficulty, and which readers spend more time in repairs following disambiguation (late effects).

All analyses were performed using the SPSS MIXED procedure to compute linear-mixed-effects models that included fixed effects for ambiguity and knowledge level, random intercepts for subjects and items, and number of characters as a covariate. Pairwise comparisons were computed using LSD on the Estimated Marginal Means within SPSS MIXED. Although Barr et al. (2013) recommended fitting the maximal model including random slopes for each factor, doing so created an overly-specified model that failed to converge, suggesting that the model was too complex for the data. In these cases, Bates and colleagues (2015) recommend using more parsimonious models. Effects are considered statistically significant at the 0.05 level if the absolute value of the t value is greater than 2.00 (Baayen et al. 2008). Less than 5% of the data was eliminated due to track losses or because fixations were shorter than 120 ms or greater than 800 ms.

As shown in Table 1, there was no main effect for knowledge level, and no interaction between knowledge level and ambiguity on first pass reading times in the target regions (ts < 1). However, there was a main effect for ambiguity, $\beta = 30.10$, $SE = 14.43$, $t = 2.09$. Regardless of

knowledge level, the control words were read slower than the ambiguous words. Consistent with Sereno et al. (2006), this result can be explained by the selection of very low frequency control words.

There was a significant interaction between knowledge level and ambiguity on first pass reading times in the post-target regions (β = -184.06, *SE* = 48.65, *t* = -3.78), as well as significant main effects for knowledge level (β = 186.97, *SE* = 40.52, *t* = 4.61). To follow-up the significant interaction, pairwise comparisons indicated that low knowledge participants experienced longer first pass reading times in the post-target region following ambiguous words than control words (*p* < .0001), whereas high knowledge participants did not (*p* =.33).

There was a significant interaction between knowledge level and ambiguity on first pass reading times in the disambiguating regions (β = 120.20, *SE* = 50.20, *t* = 2.39), which subsumed significant main effects for knowledge level (β = -115.73, *SE* = 49.86, *t* = -2.32) and ambiguity (β = -81.98, *SE* = 35.57, *t* = -2.31). To follow-up the significant interaction, pairwise comparisons indicated that high knowledge participants experienced longer first pass reading times in the disambiguating region when they read ambiguous words than when they read control words (*p* < .02). Low knowledge participants' reading times in the disambiguating region did not differ due to ambiguity (*p* = .28).

In addition, a significant interaction was found for time-to-complete-reading in the disambiguating region. (β = 121.89, *SE* = 48.92, *t* = 2.49), which subsumed significant main effects for knowledge level (β = -118.50, *SE* = 47.61, *t* = -2.49) and ambiguity (β = -113.55, *SE* = 34.63, *t* = -3.28). To follow-up the significant interaction, pairwise comparisons indicated that it was again the high knowledge participants who required more time to complete reading of the disambiguating region when they read ambiguous rather than control words (*p* < .001).

Completion times for low knowledge participants did not differ due to ambiguity ($p = .81$).

Because all readers experienced longer reading times later in the sentence after exposure to ambiguous words rather than control words, these results suggest that all readers tend to initially select the dominant, baseball-related meanings for the ambiguous words. However, readers with less knowledge of baseball were more likely to switch to the appropriate subordinate meaning immediately following the ambiguous word. Readers with more baseball knowledge seemed to persist in the baseball-related dominant meaning until they were forced to reconsider the subordinate meaning by the disambiguating region at the end of the second sentence.

Discussion

With a prior context that was weakly consistent with a subordinate meaning, both high and low knowledge readers experienced a SBE. This effect was demonstrated by longer reading times in the regions following target regions that contained ambiguous words as compared to control words. However, low-knowledge individuals had longer reading times on the fixations immediately following the ambiguous word (post-target region), whereas high-knowledge individuals had longer reading times in the disambiguating region. This suggests that low-baseball-knowledge individuals were able to resolve the subordinate (non-baseball) meaning faster than the high-baseball-knowledge individuals, and *before* the disambiguating phrase, suggesting that the prior context influenced (re-ordered) their access or selection of the subordinate sense of the ambiguous word. The prior context did not seem to have the same effect for the high-knowledge readers.

An interesting question left open by the results of Experiment 1 is whether readers with a great deal of prior knowledge biasing them towards the dominant meaning will always access

that meaning first, or whether a stronger context would allow for re-ordered access even for the high-knowledge participants. Experiment 2 investigated whether a stronger context would eliminate differences due to domain knowledge, and used a context manipulation rather than a non-ambiguous-control-word comparison to explore the effects on resolution in favor of a subordinate meaning.

Experiment 2

In a previous study, Dopkins, Morris and Rayner (1992) examined two different kinds of prior disambiguating contexts which they called "positive evidence" and "negative evidence" conditions, and compared them to a neutral context that did not disambiguate which meaning of an ambiguous word should be preferred. The contexts used in Experiment 1 were largely "positive evidence" contexts, that is, they were consistent with the subordinate context, and sometimes contained semantic associates of the subordinate meaning. For Experiment 2 we strengthened the positive evidence contexts, and added a negative evidence condition where the prior context was inconsistent with the dominant meaning and *excluded* the baseball-related meaning from consideration. This condition seemed especially interesting as a number of theories of ambiguity resolution have suggested that inhibition or suppression of competing meanings may be critical (Burgess & Simpson, 1988; Faust & Gernsbacher, 1996; Gernsbacher, 1997; Shivde & Anderson, 2001; Simpson & Kang, 1994; Stites & Federmeier, 2015). In order for the subordinate meaning to be considered before the dominant meaning, the dominant, baseball-related meaning may need to be inhibited or suppressed, especially among readers with domain knowledge that might further predispose them toward the dominant meaning. A prior context that excludes the dominant meaning could be one mechanism that would enable the early selection of a subordinate meaning.

Method

Participants

Thirty students at Washington State University - Vancouver either received class credit or $8 as compensation. All participants were native English speakers with normal uncorrected vision or wore soft contact lenses. As in Experiment 1, half of the readers answered fewer than 15 items correctly on the baseball knowledge questionnaire ($M = 4.75$, $SD = 2.74$) and were considered low knowledge. The other half of the scored 15 or higher ($M = 27.19$, $SD = 7.41$) and were considered as high knowledge.

Materials

The same twelve ambiguous words with baseball-relevant dominant meanings were used, except that *batter* replaced *bats* to increase the probability of fixation on the target word. Three versions of a sentence were written to fit the subordinate meaning of each ambiguous word. The first line of the sentence varied for each version of the passage, and it either provided a strong positive evidence context that was consistent with the subordinate meaning, a negative evidence context that excluded the dominant meaning, or a neutral sentence that provided no cues for disambiguation. The three versions of the first line of each sentence were matched in length and complexity. The second line of the sentence was identical for all versions of the passage and included the ambiguous word, a post-target region, and a disambiguating region that ended the sentence and required that the reader take the subordinate meaning. Due to variance in the size of these regions across target words, reading times are analyzed adjusting for number of characters as a covariate.

Each subject saw 12 passages containing ambiguous words. One-third were presented in each context. Each ambiguous word was presented only once for each subject. The ambiguous

word appeared in each context an equal number of times across subjects (and knowledge groups). The passages are included in Appendix B.

Apparatus and Procedure

The same apparatus and procedure were used as in Experiment 1.

Results

As in Experiment 1, early effects of context on the processing of ambiguous words were analyzed using first pass reading times on the three regions of interest: the target region which consisted of the ambiguous word, the post-target region, and the disambiguating region. In addition, later effects are explored using a time-to-complete measure for the disambiguating region. All analyses were performed using the SPSS MIXED procedure to compute linear-mixed-effects models that included fixed effects for ambiguity and knowledge level, random intercepts for subjects and items, and number of characters as a covariate. Less than 5% of the data was eliminated due to track losses or because fixations were shorter than 120 ms or greater than 800 ms.

As shown in Table 2, first pass reading times in the target region revealed a significant interaction between knowledge level and context ($\beta = 110.10$, $SE = 41.69$, $t = 2.64$). To follow-up the significant interaction, planned comparisons (based on prior analyses done by Dopkins, Morris, & Rayner, 1992) were performed between the neutral context and each evidence context condition separately. Longer first pass times were seen for low-knowledge readers in positive evidence contexts than neutral contexts ($\beta = 74.48$, $SE = 29.39$, $t = 2.53$). No differences were found between negative evidence and neutral contexts for low knowledge readers, and no differences were seen due to either context for high knowledge readers (ts < 1).

For the post-target region, no significant effects were found for first pass reading times

with the three-level context variable (ts < 1.41). However, planned comparisons performed between the neutral context and each evidence context condition separately showed a marginal effect for the low-knowledge readers to tend to spend longer in the post-target region following negative evidence than neutral contexts ($\beta = 131.57$, $SE = 67.32$, $t = 1.95$, $p < .053$). No differences were found between negative evidence and neutral contexts for the high-knowledge readers ($t < 1$) and no differences were found between positive evidence and neutral contexts (ts < 1).

No significant effects were found for first pass reading times in the disambiguating region using the three-level context variable (ts < 1.28). However, planned comparisons performed between the neutral condition and each evidence condition separately revealed a marginal effect for the low-knowledge readers to tend to spend less time on their first pass in the disambiguating region following positive evidence than neutral contexts ($\beta = -130.10$, $SE = 72.06$, $t = -1.80$, $p < .07$). No differences were found between positive evidence and neutral contexts for the high-knowledge readers ($t < 1$), and no differences were found between negative evidence and neutral contexts (ts < 1).

A significant effect of context was found for time-to-complete-reading in the disambiguating region ($\beta = -227.67$, $SE = 110.94$, $t = -2.05$). Planned comparisons indicated that low-knowledge readers took significantly less time to complete the disambiguating region following either positive evidence ($\beta = -305.15$, $SE = 85.57$, $t = 3.57$) or negative evidence contexts ($\beta = -257.48$, $SE = 84.87$, $t = -3.03$) than neutral contexts. Completion times for high knowledge participants were only shorter following the positive evidence context than the neutral context ($\beta = -275.81$, $SE = 131.89$, $t = -2.09$).

These results suggest that low knowledge readers were resolving the ambiguity in the

positive evidence context on or near the target region, and that both contexts allowed resolution before the neutral context condition. For high knowledge readers, only the positive evidence context led to faster processing in the disambiguating region. Long completion reading times on the disambiguating region for all but the positive evidence context suggest that high-knowledge readers were not able to resolve the subordinate meanings in the negative evidence and neutral contexts before the end of the sentence.

Discussion

In Experiment 1, high and low-baseball knowledge participants read sentences containing either ambiguous target words (with a baseball-related dominant meaning) or control target words following a context that was always consistent with the subordinate, non-baseball meaning. Low-knowledge participants, compared to high-knowledge participants, were able to resolve this ambiguity earlier. In Experiment 2, high and low knowledge participants always read sentences containing an ambiguous target word, but the preceding contexts provided positive evidence for the subordinate meaning, provided negative evidence excluding the dominant meaning, or were neutral. Low-knowledge participants were able to use the positive evidence contexts to begin resolving the ambiguity as early as the post-target region, while high-knowledge participants only demonstrated a benefit from positive evidence contexts later in the sentence.

In general these results replicate Dopkins, Morris and Rayner's (1992) finding that positive evidence contexts lead to faster resolution than do negative evidence contexts. The results suggest that the positive contexts used in the second experiment were stronger than those in the first, as at least some of the low-knowledge readers were resolving the ambiguous word toward its subordinate meaning immediately. For high-knowledge readers, neither strong

positive nor negative evidence contexts led to immediate resolution, although the strong positive context led to earlier resolution than negative or neutral contexts. While the studies differed with respect to whether effects in the disambiguating region were seen in first pass or time-to-complete reading measures, this may be in part due to the use of different baseline conditions which makes it difficult to make direct cross-experiment comparisons. In general the picture that emerges from these experiments is that readers with domain knowledge related to the dominant meaning of an ambiguous word were not able to resolve the word toward its subordinate meaning as quickly as novices.

To the extent that the negative evidence condition should have allowed for the dominant meaning to be excluded, inhibited, or suppressed, this should have facilitated the resolution of the ambiguous words towards their subordinate meaning. However, the negative evidence contexts were surprisingly only better than a neutral context for low-knowledge individuals. Although suppression or inhibition of competing meanings seems a highly plausible mechanism for how resolution might occur, the present results suggest that the activation of required meanings is more important than the inhibition of irrelevant meanings in the selection process. However, other recent studies that have tested for activation of unselected meanings have been able to provide some evidence for inhibitory mechanisms in meaning resolution using neurological measures such as the N400. For instance, Gunter, Wagner and Friederici (2003) presented high and low working-memory-span participants with sentences starting off with an ambiguous noun. The sentences cued readers to take either the dominant or subordinate meaning by a second noun. When the sentences ended in a verb that was inconsistent with the cued meaning, for high-span participants there was a large N400 in response to this final verb. The authors suggested that high-span participants had used the cue to effectively suppress the

irrelevant meaning. However, for low-span participants, when the sentence was cued toward the subordinate meaning, but ended in a verb consistent with the dominant meaning, they did not show an N400. Because the dominant meaning was still active at the final verb as indicated by the reduced N400, this suggests that low-span participants had difficulty inhibiting the dominant meaning in response to the subordinate disambiguation cue.

Similarly, in Lee and Federmeier (2012) younger and older participants were presented with sentences that syntactically cued participants toward one or another interpretation of an ambiguous word which was followed later in the sentence by a probe word that was plausible or implausible for the cued meaning. A control condition showed that younger and older adults did not differ in their N400 plausibility effect on the probe word for sentences containing unambiguous words. However, for sentences containing ambiguous words, only younger adults showed strong N400 effects on implausible probe words following syntactic cues that biased the toward the subordinate interpretation of the ambiguous words (i.e, when the probe word was consistent with the dominant meaning). Older adults had reduced N400 amplitudes. Lee and Federmeier (2011) also found a larger frontal negativity in response to the ambiguous word in younger compared to older adults, which was suggested to reflect controlled selection mechanisms. Additionally, individual differences on a verbal measure of inhibition partially mediated these age-related differences. These results suggest that older adults have impaired inhibitory control systems, but also that inhibitory control plays a role in lexical processing as older adults are less able to suppress irrelevant meanings. These other findings are more consistent with suggestions that a controlled selection mechanism that involves the inhibition or suppression of irrelevant meanings may be important for ambiguity resolution, even though the results seen in the present experiments fail to provide evidence for this account.

The main contribution of these results is to suggest that prior knowledge can factor into ambiguity resolution and delay the access or selection of subordinate meanings when the dominant meaning is also biased by the readers' prior knowledge. A complement to this result has recently been reported showing that long-term experience with subordinate meanings related to a domain can increase their accessibility (Rodd et al, 2016). These results suggest that domain knowledge and sentence context do interact as the reader attempts to access and resolve the meanings of words. Experts may have a harder time selecting a non-domain-related subordinate meaning, even when the context of a sentence strongly points them toward it. This further supports the reordered access model as an explanation of lexical ambiguity resolution, as both prior knowledge and sentence context can factor into the ordering of meanings that are selected and considered as a reader attempts to build a representation of a text.

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Author Notes

Table 1: Reading Times (in msec) on Target, Post-target and Subordinate Disambiguating

Regions in Experiment 1

	Target	Post-target	Disambiguating	
	First Pass	First Pass	First Pass	Time to Complete
Low Knowledge				
Control word	315	333	563	93
Ambiguous word	294	482	525	84
High Knowledge				
Control word	309	330	559	89
Ambiguous word	278	295	641	203

Table 2: Reading Times (in msec) on Target, Post-target and Subordinate Disambiguating

Regions in Experiment 2

	Target	Post-target	Disambiguating	
	First Pass	First Pass	First Pass	Time to Complete
Low Knowledge				
Positive Evidence	410	696	718	176
Negative Evidence	346	842	785	225
Neutral Context	335	705	854	486
High Knowledge				
Positive Evidence	375	756	918	260
Negative Evidence	383	784	851	447
Neutral Context	410	780	909	535

Appendix A

Experiment 1 Stimuli

1. Monica had a great fear of things flying around her head.

She looked for the bats(crow) *that lived in the shed*.

2. Carl's current vehicle was on its last legs.

It seemed that the old coach(sedan) *needed some new tires and brakes*.

3.   Jennifer was intrigued by the royalty at the party.

She kept track of the count(baron) *and the duchess*.

4. Sam took his job as an interior decorator very seriously.

He made sure the bases(brass) *on the lamps fit the decor*.

5. Jessica had a large collection of hand-woven blankets.

She needed just one more throw(quilt) *to keep her warm at night*.

6. Abby waited quietly for orchestra practice to begin.

She was sure the pitch(chord) *would be too high for the vocalist*.

7. Harvey turned a good profit in cream and butter this year.

He got new jerseys(holsteins) *for his farm with the extra money*.

8. Andy looked at his calendar full of fancy parties.

He hoped that the next ball(gala) *would be costume*.

9.   Unhappy as a secretary, Sally considered a programming career.

It would be hard to get into the field(firm) *without special training*.

10.   Tom had been playing cops and robbers all weekend.

His father brought some new caps(ammo) *for his toy gun*.

DOMAIN KNOWLEDGE AND AMBIGUITY RESOLUTION

11. Ken looked out the Jeep window at the elephants.

He was glad he got to see the big game(herd) *on his safari trip*.

12. Kelly called the radio station to make a request.

She really liked the score(songs) *from the Broadway musical*.

Appendix B

Experiment 2 Stimuli

1. Although there was still a crowd on the dance floor,

Almost as if it had never taken place,

Just as Mitchell and Marvin had expected,

   the <u>ball</u> *was suddenly <u>ended at midnight</u>*.

2. Having stopped to allow a rest for the horses,

Having been taken apart and cleaned,

Patrick and Michael griped loudly that

   the <u>coach</u> *was noticeably <u>squeaky when it hit the road again</u>*.

3.After John added flour and milk,

After it was thick and smooth,

While John watched from his chair,

   the <u>batter</u> *was finally <u>poured onto the griddle</u>*.

4. Because the mayor loved meeting royalty,

Because he was a famous celebrity,

After a parade and a long speech,

   the <u>count</u> *was given <u>the key to the city</u>*.

5. Although Jerry was interested in a programming career,

Although it offered high salaries and excellent benefits,

In terms of the number of hours that were needed,

   the <u>field</u> *seemed to require extensive <u>training</u>*.

6. Although the orchestra was already warming up,

Because it was so loud and unexpected,

Because they were all falling asleep,

      the <u>pitch</u> *was startling when the <u>bagpipes began</u>*.

7. Having made a good profit in cream and butter,

Because they were easy to care for and feed,

After many long years and a few hard times,

      the <u>jerseys</u> *were Harvey's favorite <u>cattle</u>*.

8. Although the new opera was very popular,

Although Harold had rehearsed it many times,

For some people, especially young students,

      the <u>score</u> *was very difficult to <u>play</u>*.

9. Although Jessica had a large collection of blankets,

Although it was old and did not match anything,

Although her grandfather complained and pleaded,

      the <u>throw</u> w*as always on the back of the <u>couch</u>*.

10. After playing cops and robbers all weekend,

After making noise with them all weekend,

Sam and Larry were very disappointed when

      the <u>caps</u> *were finally all gone from the boys' <u>guns</u>*.

11. During a safari to Africa to photograph elephants,

Because it came running towards the Jeep,

Both the photographer and Jim agreed that

  the <u>game</u> *seemed like it was about to <u>stampede</u>*.

12. While the statues were still standing after the earthquake,

Because they could not really withstand all the weight,

Because nobody had thought to repair them,

  the <u>bases</u> *were cracked and needed new <u>masonry</u>*.