AMBIGUITY RESOLUTION OF ADULTS WITH LOW LITERACY

BY

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THESIS

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Abstract

Considerable evidence from lexical decision and speeded recognition paradigms has suggested that (a) even in sentence context, multiple meanings of ambiguous words (i.e., homographs) are activated, but quickly suppressed, and (b) college-aged readers with poorer comprehension skills and older adults take longer to suppress the inappropriate features to isolate the intended meaning. However, there has been no investigation as to whether the activation of such contextually inappropriate features influence language understanding during reading. In the present study, we investigated online processing of homographs among community-dwelling adults who were diverse in age, race, and literacy skill. Participants read 60 passages containing an ambiguous word while their eye movements were recorded. The first sentence was contextually biased toward the subordinate meaning of a homograph in which the sentence-final word was the homograph or an unambiguous control (e.g., At the beach, she played under the *palm/tree*). The following sentence contained a target word reflecting the dominant meaning of the homograph (e.g., *hand*). Fixation durations were shorter on the target when the word was ambiguous, suggesting that infelicitous activation of the homograph continued to affect comprehension. This effect was exaggerated among the oldest readers but only among those with intact literacy skills. Trial dwell time indicated that high-literacy adults were less affected by the ambiguity, but the low-literacy adults showed larger ambiguity effects that tended to get larger with age. Collectively, these results suggest that uncontrolled activation of word meanings can impact online comprehension among older adults.

To my husband, unborn daughter, parents, and sister

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Table of Contents

Chapter 1

Introduction

According to the National Assessment of Adult Literacy (2003), approximately 14% of Americans cannot perform basic literacy skills (e.g., accurately reading and summarizing a simple text, or answering simple questions about a newspaper article) to adequately perform everyday tasks involving reading. Furthermore, 43% of Americans in this study could not complete only slightly more complex literacy tasks such as summarizing a newspaper article (Baer, Kutner, & Sabitini, 2009). This is problematic not only for those individuals but also for society in general for a number of reasons. First, these Americans may be limited in their participation in aspects of society such as career choices and educational attainment, informing themselves on current affairs and politics, as well as some aspects of engaging with friends and family via social media. Furthermore, literacy development has been shown to have benefits for cognition and physical health (Baer, Kutner, & Sabitini, 2009; Stine-Morrow, Hussey, & Ng, 2015). Although there is a large literature on literacy development and the component skills required for reading, most of this research has been done with children, university or college undergraduates, and older adults rather than struggling adult readers. Unfortunately, the relatively small scientific literature investigating literacy development, skills, and processes in adults with fragile reading skills does not offer much guidance for clarifying instruction for adults. Without knowing more about the specific processes and underlying mechanisms at play in underdeveloped literacy in adulthood, literacy instruction and interventions programs for adults are based on models grounded in studies with children. Such findings might not be applicable to low-literacy adults because adults and children matched on reading level often differ in importance ways (experience, world knowledge, word recognition strategies;

Greenberg, Ehrin, & Perin, 1997). This suggests that teaching adults in the same manner as children is likely not as effective in terms of utilizing the existing skills of the student (Rayner Foorman, Perfetti, Pesetsky, & Seidenberg, 2001). Therefore, there is a great need for rigorous research on the reading processes of adults with underdeveloped literacy skills to inform instructional approaches.

More generally, there are two theoretical frameworks under which researchers have examined reading abilities: the component view (what readers have), and the process view (what readers do) (Stine-Morrow, Miller, Gagne, & Hertzog, 2008). The component view of reading, primarily focuses on skills (components) related to reading, typically measured outside the context of reading, and how variability in these individual skills impacts reading ability (which is most often operationally defined as reading comprehension a standardized assessment) (e.g., Bell & Perfetti, 1994; Mellard, Fall, & Woods, 2010). One of the most well-known component views of reading is the Simple View of Reading (Hoover & Gough, 1990). In this view, reading is depends on two major components of equal and separate importance to defining reading skill: decoding and language comprehension skills. Alternatively, the process view of reading focuses on the coordination among processing mechanisms that underpin actual reading as they comprehend text (e.g., Kintsch, 1998). Although neither of these frameworks alone is sufficient for understanding the nature of literacy development and all its complexities, together they can help researchers and educators understand individual differences in reading processes, related cognitive abilities, and reading skills that contribute to observed differences in reading.

One of the most fundamental aspects of reading is the process that affords access to word forms and meanings, known as lexical access. There is a large and well-replicated literature suggesting that the activation of word meanings in reading is dependent upon a number of

sentential and word-level features (e.g., contextual constraint, word frequency). However, there is also literature that suggests that lexical access is moderated by knowledge and skills of the reader (e.g., word knowledge, exposure to print, inhibition/suppression skill). Thus, meaning selection processes have been shown to be mediated by a complex interaction between properties of the word, the text, and the skills of the reader. Therefore, it is important to understand this relationship in the context of struggling adult readers so as to better inform instructional principles within this strikingly large population.

Chapter 2

Literature Review

It is important to understand adults with underdeveloped literacy skills in terms of what skills they have and have not acquired (the component view) as well as the differences in what less skilled readers do (the process view). Although this is a small literature, it is important to understand the similarities and differences between struggling adult readers and those who developed literacy normally (child readers and literate adults). This type of characterization is important also for understanding the significance of examining basic phenomena known to occur during reading. More specifically, this review will examine the literature regarding lexical access (a rapid process used by readers to identify words and their features) and how basic language phenomena change with literacy skill. Furthermore, the focus will pertain to lexical access under conditions of semantic ambiguity; that is, the reader's ability to select the appropriate meaning in a given context. The ability to inhibit or suppress irrelevant information is an integral part of the meaning selection process and allows the reader to the develop fluency and efficiency in the reading. However, as earlier mentioned, undeveloped literacy skill has been shown to impact the reader's ability to conduct lexical access efficiently (Swinney, 1979; Gernsbacher, Varner, & Faust, 1990, more on this to follow). Gernsbacher and colleagues argue that these readers show inefficient meaning selection processes due to less efficient suppression of irrelevant information (making it more difficult to select the appropriate meaning due to interference of inappropriate meanings). This hypothesis lays the foundation for this review and the proposed study to follow.

The review will begin by discussing the theoretical foundation for the above hypothesis regarding individual differences in lexical access and suppression skill. The emphasis will be given to early studies on lexical access that lay the foundation for the more current literature.

Then, the focus will turn to more current literature examining individual differences in semantic (meaning rather than syntactic/grammatical) ambiguity resolution. However, there are several methodological limitations in the existing literature on ambiguity resolution that will be discussed. These concerns drive the following sections which describe the methodological perspective of examining reading processes "online," specifically, measuring reading as it occurs using technology such as eye-tracking. It is important to consider this perspective in order to better understand the current direction of this literature in terms of determining the time-course of rapid processes such as lexical access and suppression skill. Finally, the review will conclude with a succinct summary of the review and discussion of the unanswered questions posed by the current literature and future directions.

The Component View of Reading

Due to the nature of the current literature on suppression skill, it is important to determine the theoretical reasons why the current state of the literature is limited. In order to do this we must first discuss the ways in which the Simple View of Reading may be insufficient for understanding the whole picture of reading. According to the Simple View of Reading, there are two component skills that underpin efficient reading: decoding and language comprehension (Hoover & Gough, 1990). Decoding skills is the ability to convert orthographic information (i.e., printed letters and words) into meaningful units. Language comprehension is comprised of all of the skills required to understand (spoken) language (e.g., semantic, syntactic, and prosodic analysis of language to create meaning). While some studies have shown that adults with underdeveloped literacy are deficient in both decoding and language comprehension (Sabatini, Sawaki, Shore, & Scarborough, 2010; Mellard et al., 2010; Ries & Castro-Caldas, 1997;

Greenberg et al., 1997), there are also studies that have shown that the relationship between general language comprehension skill and decoding may be unbalanced in illiterate adults.

For example, Reis and Castro-Caldas (1997) conducted a study comparing literates and illiterates from a small fishing village in Southern Portugal that allowed them to control for social and cultural experiences that often covary with literacy. In this particular village, it was part of a social responsibility for the eldest children to be uneducated in order to assist their parents in keeping house and raising the younger children. Therefore, not acquiring literacy did not socially isolate the eldest children and their role was respected in their culture. This study was theoretically driven by the idea that learning to read requires learning the mappings between graphemes and phonemes, which engenders aspects of phonological analysis (the ability to segment and manipulate speech sounds and related graphemes). Thus, according to this theoretical perspective, literate and illiterate adults are qualitatively different in terms of their lexical experience. The authors tested this theory in three experiments each using a within-subjects design for condition levels. First, literates and illiterates (n = 10, 20 respectively) were presented with 24 words and 24 pseudo-words auditorily and asked to immediately repeat them back to the experimenter. Results showed that illiterates were less likely to correctly repeat pseudo-words than words while literates were not. In the second experiment, participants were presented with 20 pairs of words (10 semantically related, 10 phonologically related) and were tested for memory of the paired associates. Illiterates performed worse overall, but especially so for phonologically related word pairs compared to semantically related pairs. Literates' memory performance was the same across conditions. Finally, in the third experiment participants were given a verbal fluency task in which they were cued with a semantic or phonological category and asked to provide as many words as possible in two minutes. Results showed that illiterates

6

performed much better on the semantic category condition compared to the phonological category condition while literates did not differ across conditions. Across the three experiments, illiterates perform more poorly on tasks that require phonological awareness/analysis and conversely much better on task that utilize semantic information. Reis and Castro Caldas argue that collectively these results suggest that while illiterates rely more on sematic information in word processing due to decreased phonological awareness and decoding ability, literates are capable of processing semantic and phonological information in parallel.

More recently, Sabatini and colleagues (2010) have argued for the importance of making distinctions among decoding, language comprehension, and other skills that contribute to fluent reading, such as vocabulary and reading fluency. They did this by examining the variance accounted for in a model containing performance measures of speed/fluency, word recognition, oral language skills, and reading comprehension from adults with low-literacy. Results showed that even though the majority of variance accounting for reading comprehension was due to decoding and language comprehension skills, vocabulary and fluency/speed measures contributed a substantial amount of variance in the model as well.

Furthermore, the Simple View does not account for the way in which decoding and language comprehension might interact as comprehension unfolds (e.g., during reading). Mellard and colleagues (2010) conducted a path analysis to model the relationships that might influence one another in comprehension. Results of this study showed that are both direct and indirect effects of word recognition ability (decoding) on reading comprehension and fluency. This suggests that the Simple View of Reading is not sufficient to explain the complicated interactions that are observed empirically. Finally, the Simple View describes reading comprehension as a monolithic entity that is stable over time. However, empirical research implies that reading

requires a cascade of activation and computations that result in reading comprehension. Thus, although the Simple View of Reading may be parsimonious, it does not adequately explain the complicated nature of reading comprehension.

The Process View of Reading

According to the process view of reading (i.e., what readers do), the fundamental assumption is that written language stimulates a cascade of mental computations that are synchronized in time so as to establish the meaning of a given text. While the reader must decode each word prior to its integration in the conceptual framework of the text (i.e., this must occur linearly in time), the construction of the mental representation from the written form is not bound by these constraints (Kintsch, 1998). In this view, although processing occurs over time, the construction of the mental representation occurs incrementally such that the constraints of decoding ability and working memory, as well as features of the text itself (e.g., clause boundaries, contextual support) work together to create coherence among words and phrases. When discussing reading as a process, it is common to divide the reading process into three levels of processing (with the underlying assumption that these levels of processing interact with each other in parallel): word processing, text base processing, and situation model construction (Graesser, Millis, & Zwaan, 1997; Kintsch, 1998). Word-level processing relies upon the mental computations necessary to decode and attach meaning to the surface form of the text. Particularly, the reader must acknowledge the correspondence between the printed symbols and the word they represent, attaching meaning(s) to that word, and parsing the text into coherent segments. The textbase level depends upon the mental computations necessary to convert the parsed text into meaningful idea units, or propositions, that represent the text. Finally, at the

discouse level, the text is represented as a unit consisting of structural (e.g., narrative schema) and situational (e.g., perceptual qualities of the text) qualities (Stine-Morrow et al., 2008).

While most reserchers agree that all three levels of processing are important for comprehension, there is debate regarding the interdependence and relative timing of how these processes unfold. According to the interactive view, reading requires the interactive sychronization of the three levels of processing that occur in parallel (Kintsch, 1988; see Graesser et al., 1997 for a review). For example, under this view, discourse level context could influence activation of surface features of a word. However, a more modular view suggests that these processes do not occur in parallel, but instead occur sequentially (i.e., word level, textbase level, and then discourse level). Furthermore, according to this modular view, the word-level processing stage is the earliest on which all else depends. Therefore, according to the modular view, lexical access to word meanings is an automatic process that occurs regardless of contextual priors. Unfortunately, the debate between these views still stands because there is evidence for modular and interactive views on lexical access under different experimental conditions (Graesser et al., 1997; Swinney, 1979; Simpson & Krueger, 1991).

Regardless of the relative time course of these events, there is general agreement in the language processing literature that during the mental model construction process, fluent readers implicitly activate features of meaning and integrate them to construct a mental model of the text (Kintsch, 1988). According to the Construction-Integration model, when a reader encounters a word (e.g., BANK) a variety of conceptual nodes (e.g., river, money) and feature nodes (e.g., orthographic and phonological features of the lexical item) become promiscuously activated in the associative net (i.e., where knowledge representations are stored) through a spreading activation process. Furthermore, general knowledge (e.g., word meanings, syntax) constrains the

9

construction process such that inappropriate nodes are suppressed and only the appropriate nodes remain activated and subsequently integrated so as to create a coherent representation of the text. However, without the ability to suppress irrelevant information, the model construction process could easily become inefficient (as the model would grow exponentially with each word in the text) and inaccurate (e.g., with residual features from multiple meanings of words). Therefore, it is also very important that readers are able to inhibit inappropriate information and prune their models of irrelevant/misleading information as the model construction process unfolds in reading.

Psycholinguistic literature has provided rich evidence that strong contextual information influences lexical access (Duffy, Morris, & Rayner, 1988; Rayner & Well, 1996; Stanovich & West, 1979). For example, contextual information leads readers to predict future words likely to occur in the sentence. If a reader sees, "The dog was spinning in circles chasing its ____," most people would fill in the blank with the word "tail," suggesting that the contextual information provided in the sentence activates a set of features that represent the word meaning likely to appear in the sentence. Although there is strong evidence for contextual facilitation on lexical access of unambiguous words, the evidence for the processing of ambiguous words is not so clear. Some of the earliest evidence for the suppression of word meanings in context and features as a function of time is provided by studies examining processing of ambiguous words using a lexical decision task paradigm (Swinney, 1979; Kintsch & Mross, 1985). Lexical decision tasks require the subject to indicate whether a string of letters is a word or not by pressing a button allowing the experimenter to measure response latency (i.e., the time between stimulus onset and button press). However, there are also many studies that examine resolution of meaning online during reading (Rayner et al., 2001; Rayner & Well, 1996).

Many studies use eye-tracking to investigate online comprehension due to the accuracy of the temporal resolution that can elucidate the underlying processes as they occur during reading (Rayner et al., 2001; Rayner & Well, 1996). As the reader's eyes move across the text, the eyes perform a series of fixations (on average 200 to 250 ms)—in which the eyes are fixed on a particular stimulus for a duration of time—and saccades (typically span eight of nine letter spaces)—short period of time where the eyes are moving from one point to another—from which the eye-tracking software can derive reading time measures for individual words (Rayner et al., 2001). While eye movements can be measured along many dimensions, there are four that are most commonly described in the literature on sentence processing: first fixation duration, gaze duration, repression path duration, and probability of regressing out. Each of these measures tend to reflect certain underlying processes occurring in time during reading that are generally agreed upon in terms of interpretation (Rayner et al., 2001). Relatively shorter fixations represent facilitated processing. First Fixation Duration is the duration of the first fixation on a particular word. First fixation duration tends to reflect low-level word processing and is sensitive to word characteristics such as word length and word frequency (Rayner et al., 2001). Gaze duration is the sum of fixations on a particular word before moving off the word to the right or left. Gaze duration tends to reflect lexical access to word meanings, and thus would be sensitive to the amount of ambiguity or the number of features activated by a particular word (Rayner et al., 2001). Regression path duration (or "go-past time") is the duration of fixations on a word and words prior to the target word before moving on to words to the right of the target word (when reading left to right). Thus regression path duration includes fixations made on words appearing before the target word during any re-reading of those previous words. Probability of regressing out is the probability that the eyes will go back to words prior to the target word. Both regression

11

path duration and probability of regressing out tend to reflect reprocessing of information in the sentence which could index processes involved in resolving ambiguity within the sentence. Each of these measures provides insight on the processes involved in ambiguity resolution during sentence comprehension.

The Critical Role of Suppression in Comprehension

In order to better understand the role of suppression in reading, researchers examine how readers deal with words that have multiple meanings. One way to do this is to examine the effects of semantic ambiguity during reading to understand the reader's process for selecting the appropriate meaning of an ambiguous word in context. Using this paradigm, Swinney (1979) conducted some of the first, and most important, studies investigating suppression mechanisms. He investigated whether contextual information in a sentence would direct lexical access such that only information appropriate in that context would become active. The experimental materials followed a 2x2 design that crossed lexical ambiguity and context to create passages of four types. Thus, the critical word was ambiguous (e.g., bug) or an unambiguous synonym (e.g., insect), and was preceded by biasing contextual information (e.g., spiders, roaches and other bugs/insects) or no biasing contextual priors. Cross-modal priming was used such that the text was presented auditorily and a lexical decision task was presented visually. Once subjects heard the critical word, a string of letters was presented for a lexical decision task, with one of three word types: contextually relevant (e.g., ANT), contextually irrelevant (e.g. SPY), and unrelated (e.g., SEW). If contextual priors constrain lexical access such that active word meanings only reflect the meanings consistent with the prior sentence context), then response latencies on the lexical decision task would show facilitation for the contextually relevant items (e.g., ANT) in the biased context condition and no facilitation for contextually irrelevant or unrelated items in

12

this condition. However, the results showed that response latencies were facilitated for both the contextually relevant and contextually irrelevant items relative to the unrelated items regardless of the context. These results suggest both meanings are active initially regardless of contextual priors. Said differently, this result suggests contextual information has no influence over lexical access to word meanings and features.

In a second experiment, Swinney (1979) introduced a third manipulation, a delay. Instead of the lexical decision task immediately following the target word, the task occurred three syllables later. In this case, there was facilitation for the contextually related items in the ambiguous condition, but not in contextually irrelevant condition. These results suggest that the irrelevant meaning of the ambiguous word was active in the immediate time window and suppressed in the delayed time window. Thus, a second phase of lexical access, slightly after initial word processing, is biased by contextual information.

Collectively, the results of the Swinney (1979) study suggest a two-stage model of lexical access, an immediate word processing phase of "promiscuous activation" and a later post-access decision process phase in which ambiguity is resolved through suppression. However, there are some limitations to this study. First, the word strings in the contextually related condition were semantically related to the target word, but this manipulation was not systematically controlled such that the items were associatively related (Kintsch & Mross, 1985). Kintsch and Mross (1985), however, were able to replicate Swinney's (1979) first experiment systematically controlling for the associative relation between the target word (i.e., word for lexical decision) and the critical ambiguous word.

Kintsch and Mross (1985), in their second experiment, were also able to replicate the Swinney (1979) experiment using an all-visual task instead of a cross-modal priming task. This

experiment was exactly the same as their first, but instead of listening to the texts, subjects read the texts word by word using the RSVP procedure (Rapid Serial Visual Presentation; i.e., experimenter-paced text presentation at 150ms per word and 40ms interstimulus interval (ISI) and the lexical decision task interrupted their reading. Finally, in their third and fourth experiments, they introduced the manipulation of a delay. In the third experiment, the texts were presented word by word, but they were self-paced such that the reader pressed a button between each word indicating that they were ready to see the next. The authors used this manipulation under the assumption that readers would schedule their own delay to allow for meaning selection before moving on to the next word. Thus, the authors expected their results to show that the inappropriate meaning of the critical word would not be activated (i.e., results should match that of Experiment 2 from Swinney (1979)). However, once again, the results of Experiment 3 matched that of their first two experiments (i.e., Swinney 1979 Experiment 1). In Experiment 4, Kintsch and Mross (1985) again used the RSVP procedure, introducing a delay similar to that of Swinney's (1979) second experiment, such that the lexical decision task occurred two words (~380ms) after the critical word. Experiment 4 of Kintsch and Mross (1985) replicated the results of Experiment 2 in Swinney (1979) such that there were no priming effects on the lexical decision task after a delay. Collectively, the results of Kintsch and Mross (1985) fully replicate the Swinney (1979) study using a more controlled stimulus set, and extend the Swinney results by replicating with an all visual display task rather than cross-modal priming.

Subsequent studies provided evidence inconsistent with the two-stage model of lexical access (Simpson, 1981; Simpson & Krueger, 1991), however. Simpson and Krueger (1991) used a 3 x 3 x 2 x 2 factorial design in which sentence type (biased toward the dominant meaning, biased toward the subordinate meaning, unbiased), ISI (immediate, 300ms delay, 700ms delay),

test word dominance (reflecting the dominant or subordinate meaning), and sentence-test word relatedness (related, unrelated). Results in this study showed that when the bias and test word dominance were consistent, lexical decisions were selectively facilitated even at the immediate ISI (a result consistent with Simpson (1981), but inconsistent with Swinney (1979) and Kintsch and Mross (1985)). Similarly, when there was no biasing context, both meanings were activated (i.e., both the dominant and subordinate meanings showed facilitation) only after several hundred milliseconds (i.e., 300ms ISI). These results stand in contrast with the results of Swinney (1979) and Kintsch and Mross (1985), and are inconsistent with the two-stage model of lexical access proposed by Swinney (1979). Therefore, these results suggest that under some circumstances of strong contextual constraint, lexical access can show immediate effects of context.

In sum, there are several studies suggesting that lexical access consists of two phases: one of initial promiscuous activation and a later phase of selective activation (Swinney, 1979; Kintsch & Mross, 1985). There are also studies that suggest that lexical access can be immediately selective (Simpson & Krueger, 1991). However, Luke & Christianson (2016) argue that very strong contextual constraints do not occur that often in real-life reading. Therefore, it appears that promiscuous activation of meanings is not only more supported by evidence in the literature but also more likely to reflect reading outside the context of experimental manipulation. However, these studies only provide evidence for this in populations of university undergraduates. It is important to understand how the processes of activation and suppression might be influenced by individual differences (e.g., reading skill).

Individual Differences in Suppression Skill

More recent literature has examined ambiguity resolution during sentence processing in different populations of adults (Gernsbacher et al., 1990; Gernsbacher & Faust, 1991; Faust,

Balota, Duckeck, Gernsbacher, & Smith, 1997; Johnson et al., 1993 cited in Balota, Cortese, & Wenke, 2001; Daneman & Carpenter, 1983). This literature, again, has primarily relied on the lexical decision task paradigm with targets at different points in the text in order to establish if reading skill or age-related change might moderate ambiguity effects, while also isolating more specifically, the time frame of suppression during reading. There are several different perspectives regarding how changes in ambiguity resolution might arise under certain conditions.

According Gernsbacher and colleagues (1990), comprehension difficulties may arise from deficits in general comprehension skill related to inefficient structure building. According to this framework, the goal of comprehension is to develop a mental structure that represents the text, and most of this is done implicitly. As features of meaning become activated (automatically), the initial activation, or first concept of meaning, forms the foundational structure of the mental model. As the reader moves through the text, the reader assesses the current structure/substructure and attaches additional features of meaning to the current structure, as long as those features are coherent with the current structure, or the reader creates a new substructure to accommodate the new information. Additionally, once certain (sub)structures are activated, they can enhance or suppress activation of other structures. By this notion, suppression of irrelevant information is simply the deactivation of substructures created that no longer contribute to a coherent mental representation of the text (Gernsbacher, 1990). However, according to Gernsbacher, less skilled comprehenders are less likely to suppress inappropriate substructures making their structures less efficient and increasing the difficulty of accessing recently comprehended text. The literature evaluating the suppression mechanisms of adults with compromised comprehension skills suggest that intact suppression skill is a marker for comprehension skill. Early evidence in support of Gernsbacher's Structure Building Framework

was provided by Gernsbacher and Faust (1990). In this experiment, subjects of varying comprehension skill (as measured by the Multimedia Comprehension Battery) were presented with a sentence ending in a homograph (e.g., SPADE) or an unambiguous control with the same meaning (e.g., SHOVEL). After viewing the sentence, subjects were presented with a word recognition task in which the task was to verify whether the word fit the meaning conveyed in the sentence. On critical trials the word was related to the dominant meaning of the homograph (e.g., ACE), and was presented either immediately following the homograph or 1000ms later. The experimenters calculated an interference score as the difference between the response latencies in the ambiguous and unambiguous conditions. Results in the immediate condition show that both skilled and less skilled comprehenders took longer to reject ACE when it was preceded by the ambiguous relative to the unambiguous word. However, results in the delayed condition show less skilled comprehenders still take longer to reject ACE when it was preceded by the ambiguous target while more skilled comprehenders no longer show response latency effects. This suggests that less skilled comprehenders maintained activation of the word ACE (i.e., did not suppress the inappropriate meaning) even after a delay. Gernsbacher argues that less skilled comprehenders' failure to inhibit the irrelevant meaning of an ambiguous word makes their structure frameworks less efficient than comprehenders that are more skilled. This makes it more difficult for less skilled comprehenders to access recently comprehended information and word meanings and makes it more difficult for them to update their structure frameworks (Gernsbacher et al., 1990). These effects have been replicated using several different designs and suggest that for less skilled comprehenders suppression of irrelevant information may not occur even 1000 milliseconds after stimulus onset (Gernsbacher, 1997).

Second, Daneman and Carpenter (1983; see also Carpenter & Daneman, 1981 for a more comprehensive overview) argue that individual differences in integration processes (including resolving ambiguity) are due to variation in working memory. According to this view, working memory consists of competing processing and storage resources of limited capacity, such that when processing resources are more taxed, storage resources are more limited (and vice versa). Daneman and Carpenter argue that poor readers have more difficulty resolving ambiguity due to their working memory resources being consumed by lower-level reading processes (e.g., orthographic decoding) that are automatized among more skilled readers. They tested this hypothesis by presenting low-, intermediate-, and high-span individuals with contextually biased passages containing an ambiguous word (or unambiguous control) followed by a disambiguating region (contextual information indicating the intended meaning of the ambiguous word) that was consistent or inconsistent with the prior context presented in the passage. Additionally, the disambiguating region was either separated from the ambiguous (or control) word by a sentence boundary or not, so as to examine how additional processing demands of integration at sentence boundaries may impact the reader's ability to integrate efficiently. Results showed that low- and intermediate-span readers had more difficulty with the sentences containing the boundary and an inconsistency suggesting that their end-of-sentence integration processes were more taxed, making ambiguity resolution more difficult. A similar result was shown in a study examining low-, intermediate-, and high-span readers in reading latencies using a moving window procedure (i.e., word-by-word reading of text on a computer screen; Miyake et al., 1994 summarized in Balota et al., 2001). Importantly, Daneman and Carpenter's model of individual differences in suppression skill would be expected for populations that experience increased limitations on working memory resources. For example, there is a large body of literature that

18

demonstrates an age-related decrease in mental mechanics such as working memory capacity (Bopp & Verhaeghen, 2005). According to Daneman and Carpenter's account of individual differences in suppression skill, older adults (with reduced working memory capacities) would pattern similarly with the poor readers. Notably, ambiguity resolution would be more difficult for this population.

Similarly, Hasher and Zacks (1988) argue that older adults are less efficient in inhibiting irrelevant information from entering working memory and are less capable of deleting that irrelevant information once it has entered working memory. Under this account, older adults have reduced language comprehension abilities due to an inhibitory deficit that reduces the functional capacity of working memory by distracting the reader from relevant information in the text. Johnson et al. (1993; summarized in Balota et al., 2001) used the Gernsbacher (1990) stimuli to compare suppression skill of younger and older adults. Results showed a similar pattern to Gernsbacher's (1990) skilled and less skilled comprehenders such that older adults showed considerable interference after a long delay compared to younger adults. Another study using Gernsbacher's (1990) materials compared healthy older adults to older adults with DAT (dementia of the Alzheimer's Type), a population known for their exaggerated inhibitory deficit. This study showed that both healthy and DAT older adults experienced ambiguity-related interference even after a delay (Faust et al., 1997), with the DAT adults showing significantly more interference than the healthy older adults. However, it is important to note that some studies do not find age differences in suppression (Balota et al., 2001). Although there are some inconsistencies in the literature, there are several studies that provide strong evidence for the inhibitory deficit hypothesis. Importantly, based on this evidence, one should expect an age-

related deficit in ambiguity resolution much like the reading skill differences expected under the Gernsbacher account.

In sum, there are several studies have provided evidence for individual differences in suppression. Based on this evidence, it is likely that less skilled comprehenders and some populations of older adults are less capable of suppressing irrelevant information in context and thus are more susceptible to interference in processing individual words.

Examining Reading "Online" using Eye-Tracking

Based on the literature on ambiguity resolution in general and those studies that suggest inefficient suppression mechanism in less skilled comprehenders and "garden-variety" poor readers, we can hypothesize that studies conducted with adults with low-literacy skills will show similar impoverished suppression skills. However, the current literature examines suppression in this population using component skill assessments and simple reaction time measures (e.g., lexical decision task, word recognition task) (Gernsbacher et al., 1990; Faust et al., 1997). In the current study, I address this limitation by using a methodological design that allows the examination of reading processes as they occur online.

There are several studies demonstrating that ambiguity influences eye-movement patterns in sentence processing (Rayner & Duffy, 1986; Duffy, Morris, & Rayner, 1988; Clifton, Ferreira, Henderson, Inhoff, Liversedge, & Reichle, 2016). In fact, a study conducted by Duffy et al. (1988) was one of the first studies to examine eye-movement patterns for sentence processing under conditions of contextual constraint and ambiguity. In this study, Duffy and colleagues monitored eye-movements while subjects read contextually biased sentences constraining to one meaning of an ambiguous (or unambiguous control) word. Furthermore, the authors carefully selected non-equibiased homographs and paired them with context such that there was always a

bias toward the less-frequent meaning. Results showed that subjects had longer gaze durations for ambiguous words compared to the unambiguous control words regardless of the biasing contextual constraint. These results suggest that both meanings of an ambiguous word are initially accessed, consistent with findings in literature previously discussed using offline measures of lexical access (Gernsbacher, 1990; Swinney, 1979).

Summary

So far, we have reviewed some of the classic theoretical and experimental literature on suppression mechanisms in undergraduates and less skilled comprehenders by examining the literature on ambiguity resolution. However, this literature lacks the connection between reading processes and components of reading. Although there are a number of studies which have examined suppression skill using a variety of methods, there are several limitations.

First, these studies typically rely on convenience samples that may or may not be representative of the population; specifically, several studies rely on undergraduates at universities or compare convenience samples of adults varying in comprehension ability (e.g., skilled and less skilled comprehenders on an Air Force base). These samples may be representative of a very select and homogeneous population whose abilities may not reflect that of the general population of English-speaking readers. Additionally, these studies often have a very limited assessment of reading skill. Notably, reading skill in these studies is usually determined using only one measure of comprehension skill (e.g., the Nelson-Denny Assessment of Reading Comprehension or the Multimedia Comprehension Battery). Although these are widely used and standardized assessment of reading comprehension, using only a single measure may not capture the wide array of skills that collectively (and independently) contribute to reading skill. Several studies have shown that although reading comprehension accounts for a

large amount of variation in reading skill, it is certainly not the sole contributor (Rayner et al., 2001; Mellard et al., 2010; Sabitini et al., 2010). Therefore, studies should use a more comprehensive assessment of reading skill (i.e., use more than one standardized assessment of reading skill) in order to properly characterize their subjects based on reading skill.

Additionally, there are currently very few studies that examine the implications of reduced suppression efficiency for comprehension during reading rather than relying on responses outside of the reading process itself (Rayner & Duffy, 1986; Duffy et al., 1988; Balota et al., 2001). Based on the current state of the literature, it is clear that future research should focus on using an approach that examines both component skills so as to characterize readers in terms of fairly well-understood constructs of reading and use that to understand how the process of reading might look different for certain types of readers. In order to do this, researchers must assess a wide variety of language skills (e.g., word decoding, vocabulary, phonological processing, and reading fluency) and use online measures of reading processes (e.g., eye-tracking) rather than relying on measures that occur outside the reading process itself (e.g., lexical decision task).

The Current Study

The current study aimed to extend the findings of Gernsbacher and colleagues (1990, 1991, 1997) by examining suppression online, using eye-tracking, with a population of community-dwelling adults of varying literacy skill and age. This study combined the component view and the process view of reading in order to examine suppression skill in a diverse population varying in age and literacy skill. More specifically, subjects in this study were given a neuropsychological battery of tests examining their component reading skills (in order to determine a composite reading grade level) and more general cognitive abilities (to be used to

help characterize the diverse sample). Additionally, this study adopted the design of the Gernsbacher et al. study (1990) but embedded the target word in the text so as to examine reading processes more naturally using online measures of sentence processing. The experimental task required subjects to read short passages and answer comprehension probes that were presented on a computer screen while their eye-movements were monitored. The text contained an ambiguous word (e.g., *palm*) embedded in a semantically biased context (e.g., At the beach she played under the *palm/tree.)* and a target word related to the inappropriate meaning of the ambiguous word positioned either early or late in the follow-up sentence (e.g., Her *hand* still got sunburnt even though she was in the shade, OR Even though she was in the shade, her *hand* still got sunburnt).

Results of this study were expected to pattern similarly to the less skilled comprehenders in the previous literature. In this study specifically, it was expected that both high and low-literacy adults would show immediate facilitation (i.e., relatively decreased reading time) on the target word (i.e., the dominant meaning of the ambiguous word presented in the second sentence, *hand*) when it was preceded by the ambiguous word (e.g., *palm*). However, participants would display no such facilitation when the target was preceded by the unambiguous control (e.g., *tree*). Furthermore, it was expected that while high-literacy adults will show no facilitation on the target word later in the sentence (i.e., long condition) when it is preceded by the ambiguous word, low-literacy adults would show facilitation. This will be taken as evidence that the inappropriate meaning of the ambiguous word was still activated later in the sentence suggesting less efficient suppression mechanisms for low-literacy adults compared to high-literacy adults.

Chapter 3

Methodology

Participants

Participants in this study were 88 adults from the Champaign-Urbana community and adult education programs such as Urbana Adult Basic Education program, and Parkland Community College. Participants were diverse in age (18-75 years), race (70.0% minority), and reading skill (3.8-12.25 Slosson Oral Reading Test grade level). Six subjects were excluded from analyses based on comprehension performance (score less than 60% correct).

For analyses, participants were divided into 6 groups based on age (young: 18-34, middle-aged: 35-47, and older: 48-75) and reading skill (high-literacy and low-literacy). Literacy level was determined by a conducting a median split on a composite reading grade level estimate derived from standardized grade level estimates based on individual subjects' scores on the Slosson Oral Reading Test and Woodcock Johnson Reading Fluency assessment (descriptions of these measures to follow). More specifically, individuals at and above the median (9.5) were coded as high-literacy adults and those below the median were coded as low-literacy adults.

Neuropsychological Battery

Psychomotor Speed. The Letter and Pattern Comparison tasks are assessments of psychomotor speed (Salthouse, 1991). The Letter Comparison task requires participants to compare strings of letters and indicate whether they are the same or different within a time limit of 30 seconds. Similarly, the Pattern Comparison task requires participants to make judgments on two abstract line drawings. For each task, participants attempt two trials, and the score corresponds to the mean number of items correct from the two trials.

Fluid and Crystallized Ability. The Wechsler Abbreviated Scale of Intelligence (WASI)

assesses fluid and crystallized intelligence (Wechsler, 1981). The assessments of fluid ability include the block design (arranging blocks to match a prompt within a particular time-limit) and the matrix reasoning (multiple choice pattern completion task), and assessments of crystallized ability probe vocabulary knowledge and the ability to articulate similarities between objects.

Word Identification. The Slosson Oral Reading Test (SORT) is a word identification task in which the subject is presented a series of twelve grade-level lists of words and the task is to pronounce the words as accurately as possible (Slosson, 1990) with no time limit. The number of correct items corresponds to a grade-level estimate of reading ability.

Decoding Fluency. The Woodcock Johnson Word Attack assesses orthographic decoding ability by requiring participants to read non-words (e.g., gnobe, depnonlel) out-loud to the experimenter. The word must be pronounced fully and correctly in order to count towards their total score of correct items. The total number of correct items also corresponds to a reading grade level estimate provided in the Woodcock Johnson administration and scoring booklet.

Naming Fluency. The Rapid Automatized Naming / Rapid Alternating Stimulus task (RAN/RAS; Wolf & Denckla, 2005) requires participants to name items in sequence with speed and accuracy; there are 6 lists each containing a different set of items (objects, colors, numbers, letters, number and letters, and finally number, letters, and colors). The time it takes to name all the items corresponds to a grade-level estimate for each trial, with faster times corresponding to a higher reading level. While not a reading task, this task is highly diagnostic of reading difficulty (Norton & Wolf, 2012).

Phonological Awareness. The Woodcock Johnson (WJ: Mather & Schrank, 2001) Sound Awareness assesses the ability to manipulate speech sounds; this assessment includes subtasks that require rhyming, and deletion and substitution of sounds for words.

Reading Fluency. The WJ Reading Fluency task requires participants to read a list of sentences (e.g. *A fish lives on land*) and to determine the truthfulness for as many as possible within three minutes. The number of items correct has been normed against a grade-level estimation of reading skill.

Working Memory. Participants were given two working memory tasks: a Listening Span, and a Counting Span. In the Listening Span task participants are auditorily presented a series of true-false statements. After each statement they must indicate whether the statement was true or false while committing the final word of the statement to memory. After a series of statements (beginning with 2 statements and progressing as far as 8 statements), the participant must recall the final word in each statement in the order in which they were presented. The trial is considered fully correct if the all of the statement-final words were recalled in presentation order (1 point). Partial credit was award for responses such that if all items were recalled correctly but in transposed order or only one items was incorrectly recalled (.75 points), if more than half of the items were correctly recalled regardless of order (.50 points), or less than half of the items were correctly recalled regardless of order (.25 points). There were two trials in each level (2 trials with 2 statements, 2 trials with 3 statements, and so on) and eight levels total. The subject would move on to the next level if at least one of the two trials in that level was fully correct, otherwise, the task ended. Similarly, the Counting Span task images containing green and yellow dots located randomly across a white screen are presented to the participant. Participants are required to count the number of green dots in the image and report that number out-loud to the experimenter (in order to ensure that the subjects were counting correctly). After a series of images, the participant must recall the number of green dots in each image in the order in which they were presented. Scoring of this task was identical to the Listening span task.

Materials

      The experimental approach was adopted from Gernsbacher et al. (1990; Gernsbacher &

Faust, 1991). The materials were created in a two-by-two design with word ambiguity

(ambiguous, unambiguous) and target position (early, late) as the manipulated conditions.

Ambiguous words used in this study were chosen from homograph norms (Twilley, Dixon,

Taylor, & Clark, 1994) such that only polarized homographs were chosen for our materials.

Additionally, the dominant meaning of the ambiguous word was selected based on the same set

of homograph norms (see Appendix B for proportion meaning dominance estimates from

Twilley et al., 1994). In the current study, there were 60 experimental texts and 56 fillers. Filler

texts were materials from a study examining the contextual constraints and expectancies;

importantly, the filler sentences did not contain ambiguous words. The experimental texts began

with a sentence that was semantically biased toward the subordinate meaning of an ambiguous

word. The sentence-final word (hence referred to as T1) was either ambiguous (A) or

unambiguous (U) (e.g., At the beach, she laid under the *palm/tree*). The second sentence

contained the dominant meaning of the ambiguous word (e.g., *hand*, hence referred to as T2)

either toward the beginning of the sentence—in the early condition (E)—or toward the middle of

the sentence—in the late condition (L) (e.g., Her *hand* still got sunburnt even though she was in

the shade. OR Even though she was in the shade, her *hand* still got sunburnt.). See Table 2 for

examples. Four stimulus lists were created so that materials were counterbalanced across

condition. The target words were controlled for word length and word frequency, and sentences

were equated in grade level (no greater than 6th grade reading level). Furthermore, the conditions

were counterbalanced across each condition of each list using a Latin square balanced design method). Subjects were assigned one of the four lists no duplicate items across lists.

Analysis

Analyses of reading times for T1 began by acquiring subject means for each condition (A, U) on each dependent measure (FFD, GD, RPD, pRO). Based on previous literature, it was expected that the current study would replicate main effects of ambiguity such that control words would produce reduced reading times compared to ambiguous words but only on FFD, a measure of very early processing. To test this hypothesis, the first analysis conducted was a one-tailed t-test on FFD comparing the ambiguous condition to the control condition. Because the text was identical up to T1for early-position and late-position conditions, analyses were conducted on FFD, GD, RPD, pRO using a three-way repeated-measures Analysis of Variance (ANOVA) with ambiguity as a within-subject variable (Ambiguous, A; unambiguous, U) and two between-subjects factors, Age group (Younger, Y; Middle-aged, M; Older, O) and Literacy (High, H; Low, L). Finally, we computed proportion difference scores for the ambiguous conditions compared to the unambiguous conditions ((A – U)/U) in order to examine the ambiguity effect (controlling for individual subjects' baseline reading times) in a univariate ANOVA with between-subjects factors, Age group (Younger, Y; Middle-aged, M; Older, O) and Literacy (High, H; Low, L).

Analyses of reading times for T2 began by acquiring subject means for each condition (AL, AE, UL, UE) on each dependent measure (FFD, GD, RPD, pRO). To test whether FFDs would be faster in ambiguous condition than the control condition on T2, the first analysis conducted was a one-tailed t-test on FFD comparing the ambiguous condition to the control condition. Additionally, it was expected that the current study would produce an ambiguity by

28

position pattern similar to the Gernsbacher studies. These analyses are of most interest to the research questions at hand. Specifically, previous literature would predict significant main effects of ambiguity on T2 such that ambiguous conditions show shorter reading times because multiple meanings have been activated and thus T2 is more quickly processed than under unambiguous conditions. In addition, one should expect that the ambiguous early condition shows shorter reading times than the late condition because both meanings are activated whereas in the long condition, the inappropriate meanings are suppressed and therefore no facilitation should occur. Further analyses were conducted to test this hypothesis on FFD, GD, RPD, pRO using a four-way repeated-measures ANOVA with two within-subject variables, ambiguity (Ambiguous, A; unambiguous, U) and position (early, E; late, L), and two between-subjects factors, age group (Younger, Y; Middle-aged, M; Older, O) and literacy (High, H; Low, L). Based on previous literature one might expect that the ambiguity by position interaction would be moderated by literacy skill and/or age. More specifically, less skilled readers and older readers would be more likely to show inhibition failure (facilitation in the early and late conditions) compared to younger and more skilled readers. Finally, we computed proportion difference scores for the ambiguous conditions compared to the unambiguous conditions ((U – A)/U) in order to examine the ambiguity effect (while controlling for individual subjects' baseline reading time) in a univariate ANOVA with between-subjects factors, age group (Younger, Y; Middle-aged, M; Older, O) and literacy (High, H; Low, L). .

In addition, there were two measures that were the same across T1 and T2, comprehension accuracy and Trial Dwell Time (the total amount of time spent on a given trial). Analyses of these two variables began with acquiring subject means for each condition (AL, AE, UL, UE), and then conducting a four-way repeated measures ANOVA with two within-subjects

variables, ambiguity (Ambiguous, A; unambiguous, U) and position (early, E; late, L), and two between-subjects variables, age group (Younger, Y; Middle-aged, M; Older, O) and literacy (High, H; Low, L).

Procedure

The entire session lasted approximately two and a half hours. First, participants provided information about background and health and were then administered the Neuropsychological battery, which typically took less than an hour and a half. Afterwards, they completed the reading task, requiring another hour.

Participants read the sentences while their eye movements were monitored using an Eye-Link 1000 Plus remote system (SR Research Eye-Link 1000). The desktop mounted eye-tracker sampled at a rate of 1000 Hz with accuracy within 0.05 degree of visual angle. Sentences were presented in white 20-point Courier New font on a black background on a 17-inch Dell monitor set to 1,024 X 768 resolution, and a refresh rate of 85 Hz. Participants were seated approximately 70 cm from the monitor such that three letters subtended less than 1 degree of visual angle. Most sentences did not fit on one line, but target words were never located at the end or beginning of a line so as to control for line-change disruption in reading time data. Participants placed their heads in a chinrest in order to minimize head movements. The experimenter then aligned and calibrated the tracker to one of the subject's eyes (starting with the right eye and moving to left eye if necessary; of the 82 participants used in analyses, 3 people had their left tracked). When the eye being tracked was properly calibrated, the participant could initiate each trial by pressing a button on a game console. In addition, a fixation correction was presented between each trial to verify that the tracker remained properly calibrated. In cases where the calibration was lost, the tracker was completely recalibrated before proceeding.

Chapter 4

Results

Comprehension

Overall, comprehension was good ($M = 0.77$, $SD = 0.09$), which suggested that the sentences were within the reading level of our sample. In general, comprehension was better among those with higher literacy skill, $F(1, 76) = 12.64$, $p < 0.001$; $M = 0.73$ $SD = 0.01$; $M = 0.80$ $SD = 0.01$. However, comprehension accuracy did not differ among age groups, $F < 1$. The effects of ambiguity and position alone were non-significant, $F's < 1$, but there was a significant interaction between ambiguity and position condition, $F(1, 76) = 17.18$, $p < 0.001$. As shown in Figure 1, at the early position, comprehension was better for the ambiguous condition compared to the unambiguous, yet at the late position, it was worse. Additionally, there was a significant interaction between ambiguity and age group, $F(1, 76) = 6.07$, $p < 0.01$, shown in Figure 2, such that there was no difference between ambiguous and unambiguous sentences for young or older adults, $t(27) = 1.04$, $p = 0.31$ and $t(27) = 1.43$, $p = 0.17$ respectively, but for middle-aged adults, performance in the unambiguous condition was better than in the ambiguous condition, $t(25) = 2.81$, $p < 0.01$.

Eye-Tracking Measures

Because reading time measures tend to be positively skewed, FFD, GD, RPD, and TDT were analyzed after they had been log transformed. In fact, the results from the analyses of raw reading times and log-transformed reading times largely did not differ, although analyses with log-transformed times generally showed slightly larger F-values. The analyses reported are for log-transformed values. In addition, fixation durations were trimmed based on the following criteria: (1) two fixations with durations less than 80ms and within a half a degree of visual angle

were combined, and (2) fixations shorter than 80ms (with no close neighboring fixations) and longer than 1000ms were excluded from analyses. Second, GDs longer than 3000ms and RPDs longer than 5000ms were excluded from analyses. In total, less than 1% of the data were excluded from analysis.

Target 1. As earlier mentioned, we tested the a priori hypothesis that the ambiguous word would take longer to initially process relative to the control by conducting a one-tailed t-test of the ambiguity effect on FFD. In fact, this prediction was confirmed (245 and 239, for A and U, respectively), $t(1, 81) = 1.76$, $p < 0.05$.

Next, we report the Age x Literacy x Ambiguity ANOVAs on FFD, GD, RPD, and pRO. In general, the high-literacy readers showed faster reading times compared to low-literacy readers. This effect was significant for FFD (225 vs. 260ms), $F(1, 76) = 15.86$, $p < 0.001$; GD (300 vs. 379ms), $F(1, 76) = 24.35$, $p < 0.001$; RPD (597 vs. 801ms), $F(1, 76) = 21.59$, $p < 0.001$. However, there was no difference between high- and low-literacy readers in probability of regressing out, $F < 1$. Although there were no main effects of age for FFD, GD, or RPD, F's < 2, there was a significant main effect of age for pRO such that the probability of regressions tended to decrease with age (0.41, 0.35, and 0.30, for Y, M, and O, respectively), $F(2, 76) = 3.54$, $p < 0.05$. However, pairwise comparisons revealed that the young were significantly more likely to regress than older adults ($p < 0.05$), but there were no differences between middle-aged and older adults or young and middle-aged adults.

There were significant age by literacy interactions for FFD, $F(2, 76) = 4.04$, $p < 0.05$, and GD, $F(2, 76) = 3.48$, $p < 0.05$. As shown in Figure 3, this interaction was such that there were large difference in reading times between the high- and low-literacy adults for the younger and older groups, but not in the middle-aged group (Y, $F(1, 27) = 11.13$, $p < 0.01$; MA, $F(1, 28) =$

.13, $p = 0.72$; O, $F(1, 27) = 29.90$, $p < 0.001$; Y, $F(1, 27) = 21.73$, $p < 0.001$; MA, $F(1, 28) = 2.50$, $p = 0.12$; O, $F(1, 27) = 9.83$, $p < 0.01$; for FFD and GD respectively).

In the three-way ANOVA on FFD, which did not capitalize on the sensitivity of the a priori test, the main effect of ambiguity only reached a marginal level of significance, $F(1, 76) = 3.26$, $p = 0.08$; this was also true for the univariate ANOVA of the proportion ambiguity effect, which showed that the grand mean was significantly different from zero, on FFD, $F(1,76) = 5.00$, $p < 0.05$. The ambiguity main effect was not significant for any other timing measure, F's < 2. However, as demonstrated by the univariate ANOVA on pRO, $F(1,76) = 4.01$, $p < 0.05$, the proportion ambiguity effect was significantly larger than zero suggesting that in general, readers were more likely to regress out of an ambiguous target than an unambiguous one. Although there was no significant main effect of ambiguity for GD, there was a significant ambiguity by age interaction, $F(2, 76) = 3.35$, $p < 0.05$. As shown in Figure 4 the young and older adults show a numerical trend toward the ambiguity effect in the expected direction (i.e., A > U; $t(27) = 1.87$, $p = 0.07$ and $t(27) = 1.21$, $p = 0.24$), yet the middle-aged adults show a numerical trend toward the ambiguity effect in the opposite direction (i.e., A < U; $t(25) = 1.55$, $p = 0.13$). Finally, there was a significant ambiguity by literacy interaction for pRO, $F(1, 76) = 4.30$, $p < 0.05$. As shown in Figure 5, the low-literacy group tended to be more likely to regress from the ambiguous word compared to the unambiguous word, $t(37) = 1.91$, $p = 0.06$, while the high-literacy group showed no difference, $t(43) = -1.36$, $p = 0.18$.

Target 2. The one-tailed t-test of the ambiguity effect at T2 on FFD was significant (246 and 255ms, for A and U, respectively), $t(81) = 2.47$, $p < 0.05$, showing that the inappropriate meaning of the ambiguous word was activated in the second sentence.

Next we report the analyses from the Age x Literacy x Ambiguity x Position ANOVA on

FFD, GD, RPD, and pRO. Consistent with the analyses from T1, high-literacy readers generally showed reduced reading times compared to low-literacy readers. This effect was significant for FFD (231 and 272ms), F(1, 76) = 20.50, $p < 0.001$; GD (293 and 375ms), $F(1, 76) = 26.63$, $p < 0.001$; RPD (463 and 654ms), $F(1, 76) = 29.42$, $p < 0.001$; and pRO (0.22 and 0.30, $F(1, 76) = 8.17$, $p < 0.01$. The main effect of age did not reach significance for any of the four eye-tracking measures, F's < 2. However, there was a significant interaction between age and literacy for GD that patterned similarly to those on T1, $F(2, 76) = 3.57$, $p < 0.05$. As shown in Figure 6, it was the young, $F(1, 27) = 8.90$, $p < 0.01$, and older adults, $F(1, 27) = 13.98$, $p < 0.001$, who showed significant effects of literacy skill, while the middle-aged adults did not, $F(1, 28) = 1.34$, $p = 0.26$.

There was a significant main effect of position on all eye-tracking measures, though these trended in opposite directions. Early-pass measures showed facilitated processing on targets in the later sentence position compared to the early sentence position for FFD (247 vs. 254ms), $F(1, 76) = 3.90$, $p < 0.05$, and GD (320 vs. 343ms), $F(1, 76) = 12.75$, $p < 0.01$, but later-pass measures showed that readers spent more time in reprocessing when targets were in the later position: they were more likely to regress out of the word when it was in the later sentence position than in the early sentence position (0.30 vs. 0.22), $F(1, 76) = 51.77$, $p < 0.001$, and showed longer RPDs (569 vs. 533ms), $F(1, 76) = 3.83$, $p < 0.05$.

As expected from the a priori test, FFD showed a significant main effect of ambiguity, $F(1, 76) = 10.50$, $p < 0.01$ (which was also demonstrated in the univariate ANOVA testing the effects of age and literacy for the proportion ambiguity effect, $F(1,76) = 6.29$, $p < 0.01$). However, this effect was not significant for GD, RPD, or pRO, F's < 2.

As shown in Figure 7 there was a significant three-way interaction between age, literacy, and ambiguity on FFD, $F(2, 76) = 4.09, p < 0.05$, such that the ambiguity effect was not observed among the low-literacy adults regardless of age (t's < 1), but it was the only the high-literacy older adults who showed a significant ambiguity effect, $t(12) = 2.96, p < 0.01$. This interaction was also supported by the univariate ANOVA analyses of the proportion ambiguity effect, $F(2,76) = 3.23, p < 0.05$.

Total Processing Time. Here we report the Age x Literacy x Ambiguity x position ANOVA for TDT. Again, there was a main effect of literacy skill such that high-literacy adults spent less time reading than low-literacy adults (6837 vs. 10134ms), $F(1, 76) = 35.44, p < 0.001$. Consistent with the analyses on other reading time measures, there was no main effect of age, $F(1, 76) = 0.82, p = 0.92$.

Although the ambiguity effect reached only marginal levels of significance in the expected direction (8398 vs. 8250ms, A and U respectively), $F(2,76) = 2.96, p = 0.09$, the univariate ANOVA analyses showed that there was a significant proportion ambiguity effect, $F(1,76) = 4.10, p < 0.05$. In addition, there was a marginally significant four-way interaction among ambiguity, position, age, and literacy, $F(2,76) = 2.63, p = 0.08$ (this was the only case where the interaction was more reliable in the raw reading time analyses, $F(2,76) = 3.89, p < 0.05$. In order to better understand this interaction, we conducted t-tests to determine which differences (i.e., A – U) were significantly different from zero. Results from these t-tests suggest that only the middle-aged low-literacy adults in the early condition showed significant difference between the ambiguous and unambiguous conditions, $t(14) = 2.23, p < 0.05$, all other t-tests were non-significant (t's < 1). However, as shown in Figure 8 (where the bars represent the proportion –ambiguity effect), while the high-literacy adults showed smaller and more consistent ambiguity

effects, the low-literacy adults showed sporadic and larger numerical trends toward ambiguity

effects.

Chapter 5

Discussion

The effects of ambiguity resolution in offline measures of reading (e.g., lexical decision task) are robust and have been demonstrated across a variety of populations, the literature examining ambiguity resolution in a natural reading situation (e.g., eye-tracking) is underrepresented in the literature. Furthermore, the studies investigating individual differences in ambiguity resolution fall short in properly characterizing their sample as skilled and less skilled readers by using only one measure. Thus, it is hard to determine from the existing literature how ambiguity resolution influences what readers do and how different readers might act differently under conditions of ambiguity.

Importantly, we were able to replicate previous findings that ambiguous words take longer to process than unambiguous words (Rayner & Duffy, 1986; Duffy et al., 1988; Clifton et al., 2016). This finding provides support for Swinney's (1979) concept of promiscuous activation. Importantly, this effect was not moderated by age or literacy skill, suggesting that this promiscuous activation occurs naturally during reading regardless of individual differences in age or literacy. Furthermore, this promiscuous activation persisted into the next sentence causing a robust facilitation effect for the target word when it was preceded by the related ambiguous word relative to the control. Although this was expected for the early condition (where there was only one word between the ambiguous word and the target word), this effect was not moderated by sentence position of the related word. More specifically, activation of the inappropriate meaning of the ambiguous word was apparent regardless of sentence position (as shown in Figure 9). This finding stands in contrast with previous literature examining suppression offline (e.g., Swinney, 1979; Gernsbacher et al., 1990, Gernsbacher et al., 1991; Gernsbacher, 1997).

This suggests that not only does the word become active, but it remains active into the next sentence during natural reading. Furthermore, this suggests that a reduced ability to inhibit inappropriate meanings may not have such negative implications for reading as previous literature might suggest.

According to the literature on individual differences in suppression skill, one would expect the ambiguity effects to be moderated by literacy skill. Although in general low-literacy readers take longer to process words than high-literacy readers, with the exception of pRO on T1, there were no effects that were moderated by literacy skill alone. However, there were several instances where the ambiguity effects were moderated by age and literacy skill (as shown by the 3-way interaction on T2 FFD, and the four-way on TDT). Although there is not a clear reason for the observed variability in these effects, Perfetti's Lexical Quality hypothesis argues that lexical confusion might contribute to individual differences in suppression ability. According to this view, comprehension difficulties arise from the reduced ability to access the lexical representations of word meanings and word forms (Perfetti, 2007). More specifically, less skilled readers have less specific (i.e., orthographic and phonological features are not as well specified for a given word) and less flexible (e.g., semantic information is too rigid and underspecified) word representations. In other words, the lexical representation of the word is less likely to be activated by variable semantic information (i.e., the "definition" must match very closely in order for the representation to be activated via semantics) and less likely to be uniquely activated by the surface features of the word. According to this view, when a less fluent reader encounters an ambiguous word, there are a multitude of lexical representations being activated due to the surface features of the word and the potential for the correct meaning to be activated. In short, when a less skilled reader encounters a homograph, the appropriate and less

appropriate meanings and forms can become confusable due to "lower quality" lexical representations making lexical access relatively inefficient as compared to more fluent readers (Perfetti, Yang, & Schmalhofer, 2008). Furthermore, a reader with less ability to conduct the necessary processes required to activate the correct meaning (e.g., less skilled comprehenders, poor readers) will likely have more problems identifying which meaning to suppress and consequently suppressing the inappropriate information necessary to resolve the ambiguity. Furthermore, this view accounts for the large amount of individual variability in lexical representations that is likely to be present in our sample of low-literacy adults. Under this view, the variability in the quality of lexical representations individually would explain some of the variability in our sample of low-literacy adults.

Additionally, this study provides somewhat compelling evidence that literacy development may have positive implications for age-related slowing in early lexical processing. When considering the middle-aged and older readers, we found evidence that the high-literacy readers tended to get faster with age, whereas the low-literacy readers tended to get slower with age. However, this was true for only measures of early lexical processing (FFD and GD). This result can be most reasonably explained by the notion that the continued engagement with print (and thus an increase in vocabulary and literacy experiences) affords automaticity of early lexical processes such as word recognition, lexical access, and meaning selection. Conversely, the lack of engagement with print results in age-related slowing of early lexical processing. Furthermore, this result is consistent with previous work in our lab regarding the interactions of age and literacy experience on sentence processing (Steen et al., under review). However, in previous work in our lab, we observed these effects continually across the lifespan, an effect we do not replicate in this study due to the younger adults, particularly in the low-literacy group. Although

this is the smallest of the age by literacy groups (n = 8), it remains unclear why this group would show such qualitatively different results relative to the other groups.

Finally, our study is consistent with the literature regarding age differences in ambiguity resolution. While each of the 6 age by literacy groups showed the tendency toward an ambiguity effect, the older high-literacy adults were the only group to show a significant ambiguity effect. Specifically, it was the older high-literacy adults who showed significantly more interference of the inappropriate meaning than the other groups (as shown in figure 5), suggesting that this group in particular maintained the inappropriate meaning more so than the other groups. This finding is consistent with notion that older adults have a decreased ability to inhibit irrelevant information. Notably, this finding is consistent with Hasher and Zacks' (1988) inhibitory deficit hypothesis, according to which, older adults are less able to discard information once it has entered working memory. Although this theory does not directly predict that this inhibitory deficit would be true only for high-literacy adults, it is possible that the low-literacy adults did not show this inhibitory deficit simply because they are less practiced in maintaining and integrating meanings during reading.

In conclusion, this study addresses the limitations of the current literature on ambiguity resolution by providing a process approach to examining comprehension as it occurs in time. Importantly, this study provides a perspective on suppression mechanisms that is more ecologically valid than previous studies by observing reading processes. Furthermore, the current study is different from previous literature because it examined a diverse population that more closely represents the general public. More specifically, our sample addresses the need to learn more about a disturbingly large population of adults in the United States who are not able to fully participate in daily life due to literacy limitations (the very population that will benefit most from

research on reading processes). Additionally, results from this study demonstrate that the previous literature examining ambiguity resolution may not capture the processes of reading as they occur. Our results suggest that our previous impression of suppression mechanisms does not represent the processes that occur during reading. More research should be done to improve our understanding of the interactions between age, literacy skill, and suppression mechanisms during reading.

Tables and Figures

Table 1.
Participant Characteristics

	High Literacy			Low Literacy			Effects (p-value)		
	Y (n=20)	MA (n=11)	O (n=13)	Y (n=8)	MA (n=15)	O (n=15)	Age	Lit	A x L
Age	25.8	42.1	54.6	28.8	41.3	57	**<0.01**	0.20	0.40
Reading Level*	12.5	11.5	12	6.1	6.9	7.1	0.82	**<0.01**	0.14
Education	12.8	13.6	14.3	10.8	11.2	11.5	**<0.05**	**<0.01**	0.67
Gf **	0.6	0.4	0.2	0	-0.5	-0.8	0.06	**<0.01**	0.78
Gc **	0.5	0.4	0.6	-0.4	-0.7	-0.3	0.47	**<0.01**	0.96
Working Memory**	0.5	0.2	0.3	-0.2	-0.3	-0.6	0.34	**<0.01**	0.73
Comprehension	82%	77%	83%	74%	72%	72%	0.31	**<0.01**	0.28

*Reading Level = composite grade level: SORT (vocabulary), and WJ Reading Fluency (speeded sentence

 **Average Z-score of composite (WASI block design/matrices and WASI vocabulary/similarities, and Listening/Counting span respectively)

Table 2.

Examples of Stimulus Items

Condition		Text
Ambiguous	Early	At the beach, she played under the *palm* . Her <u>hand</u> still got sunburnt even though she was in the shade.
	Late	At the beach, she played under the *palm* . Even though she was in the shade, her <u>hand</u> still got sunburnt.
Unambiguous	Early	At the beach, she played under the *tree* . Her <u>hand</u> still got sunburnt even though she was in the shade.
	Late	At the beach, she played under the *tree* . Even though she was in the shade, her <u>hand</u> still got sunburnt.

Comprehension Probe: Did she stay in the shade at the beach? (yes)

Table 3.
Eye-Tracking Measures

		High Literacy			Low Literacy			Effects (p-value)		
		Y (n=20)	MA (n=11)	O (n=13)	Y (n=8)	MA (n=15)	O (n=15)	Age	Lit	A x L
Ambiguous Word	FFD	213	241	223	257	242	282	0.32	**0.00**	**0.02**
	GD	273	318	310	396	339	405	0.30	**0.00**	**0.04**
	RPD	573	586	507	877	739	791	0.55	**0.00**	0.36
	pRO	0.38	0.33	0.30	0.45	0.36	0.29	**0.03**	0.42	0.67
Target Word	FFD	225	236	210	278	253	286	0.47	**0.00**	0.19
	GD	280	307	256	405	330	395	0.49	**0.00**	**0.03**
	RPD	432	455	382	727	577	668	0.24	**0.00**	0.17
	pRO	0.23	0.21	0.23	0.35	0.28	0.27	**0.01**	0.33	0.45

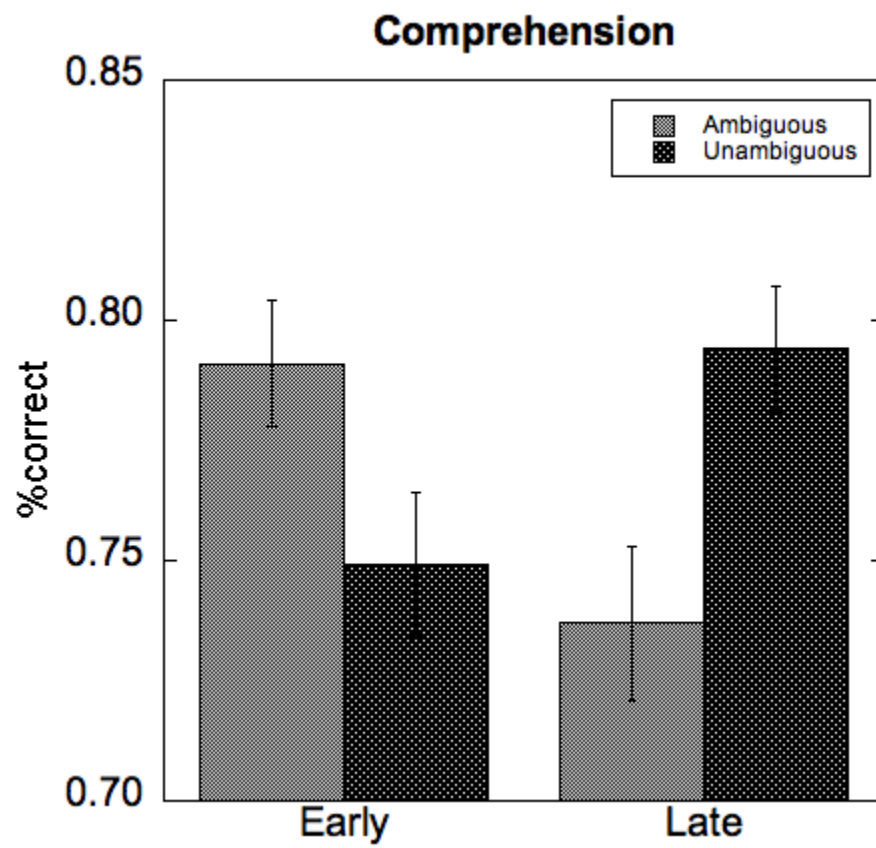**bolded** are significant at or below alpha 0.05

Figure 1.
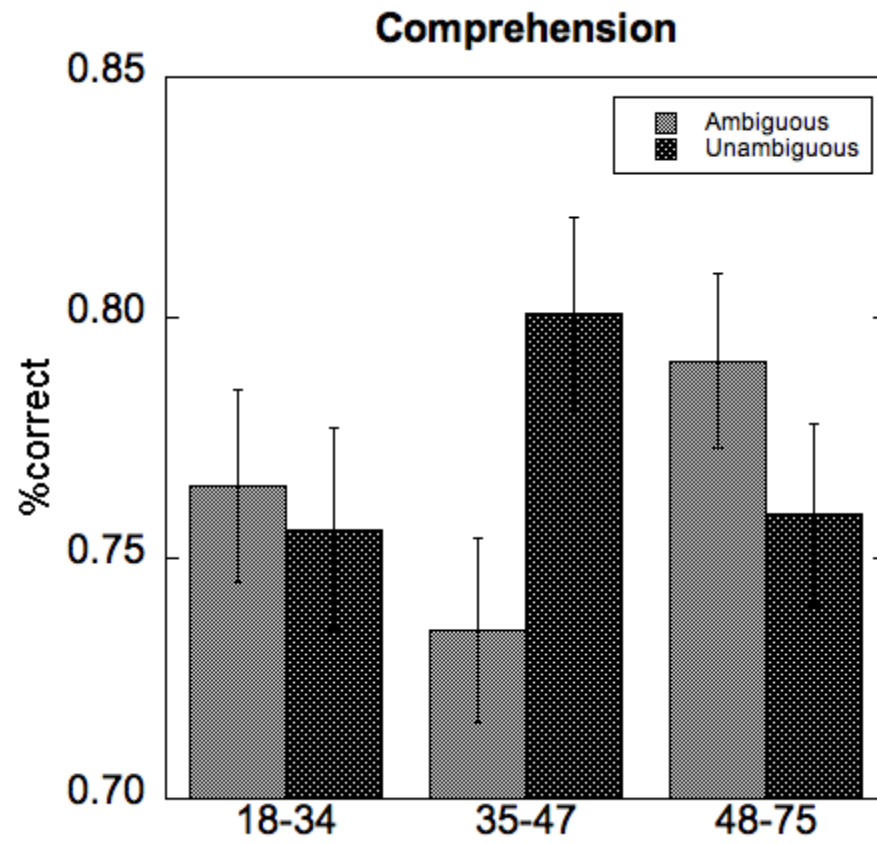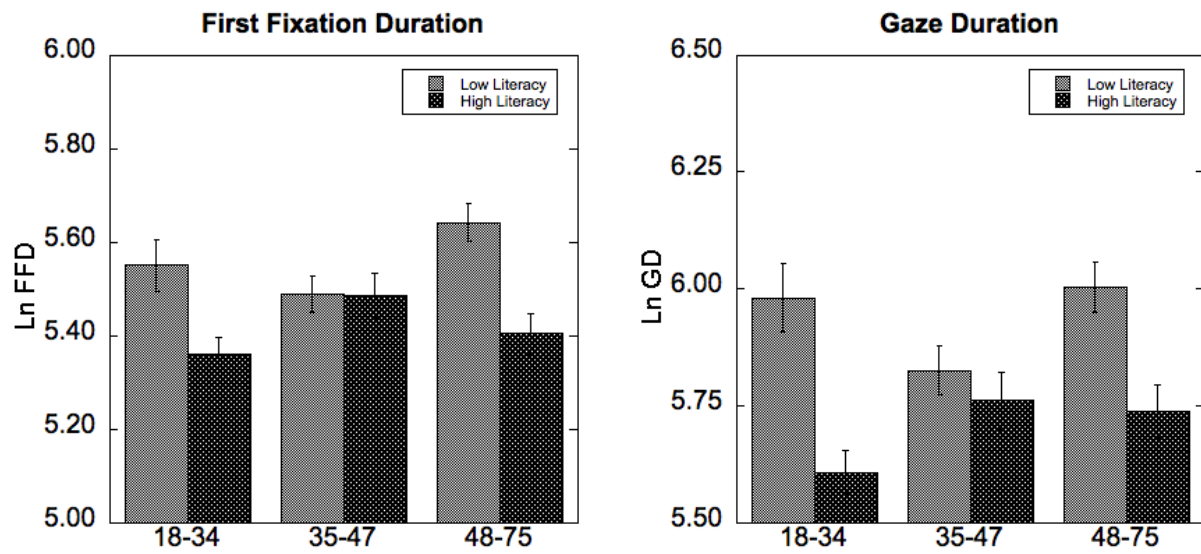

Comprehension

Figure 2.
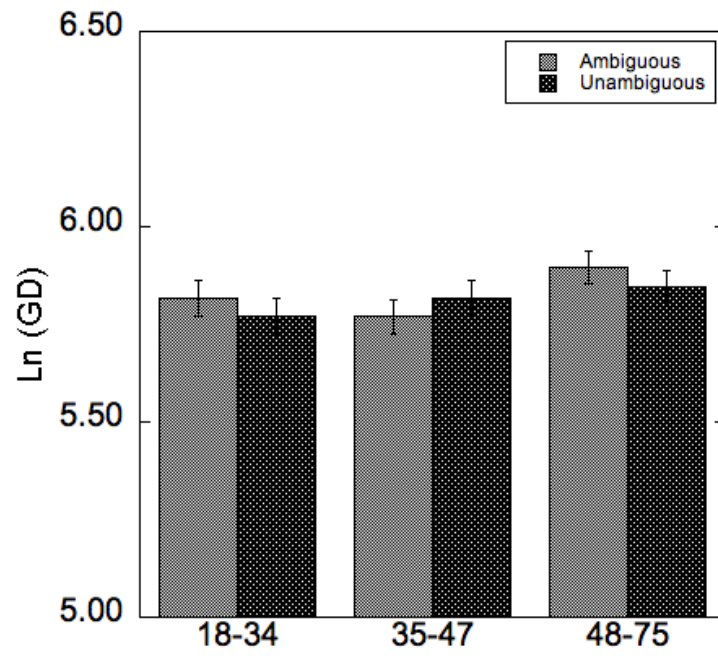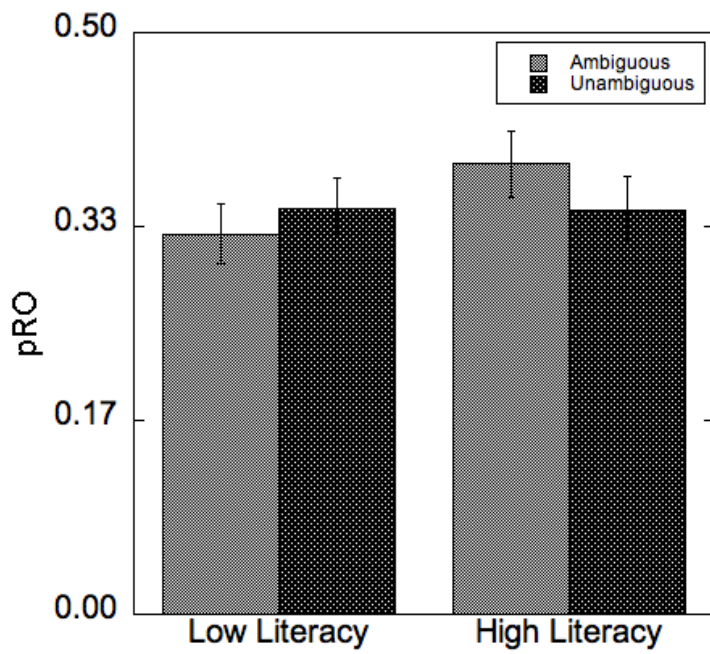

Comprehension

Figure 3 (T1).
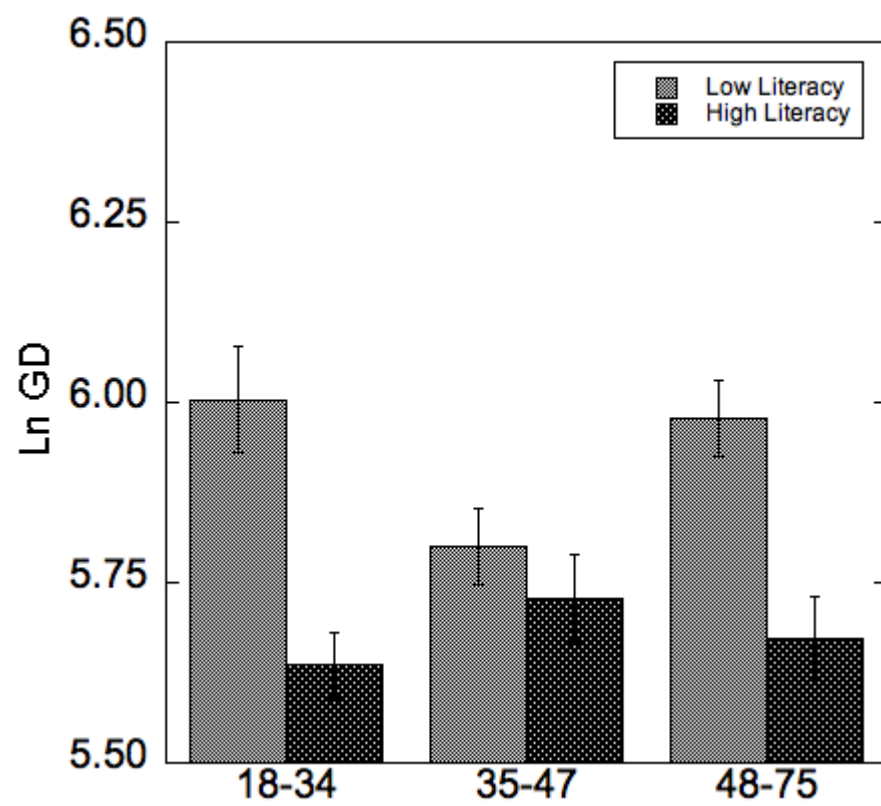
Figure 4 (T1).

Figure 5 (T1).

Figure 6 (T2).

Figure 7 (T2).
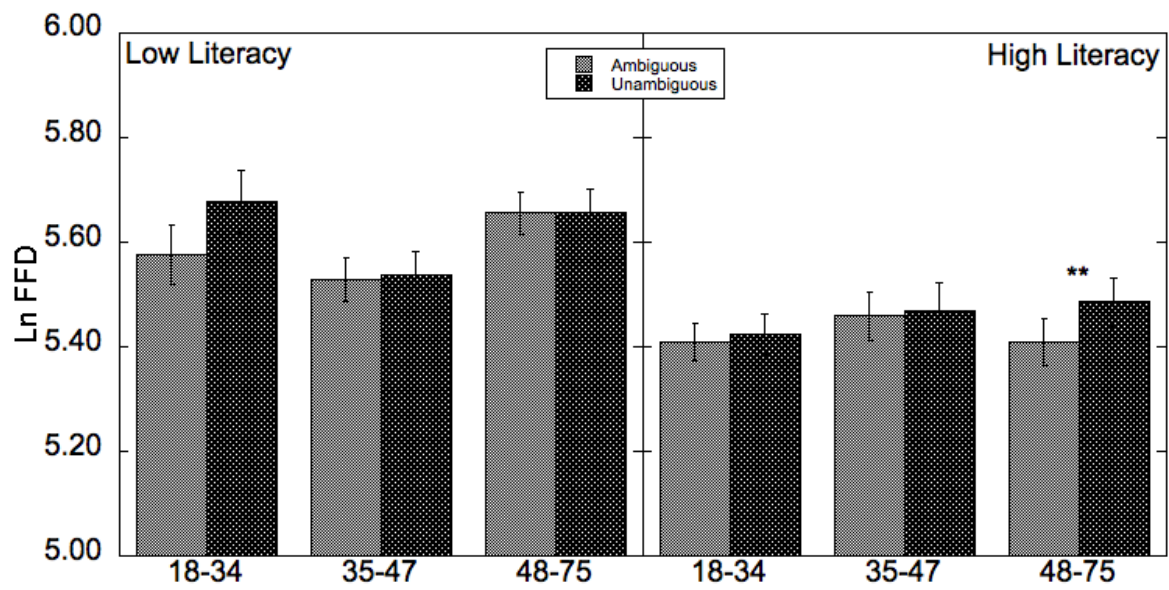
Figure 8.
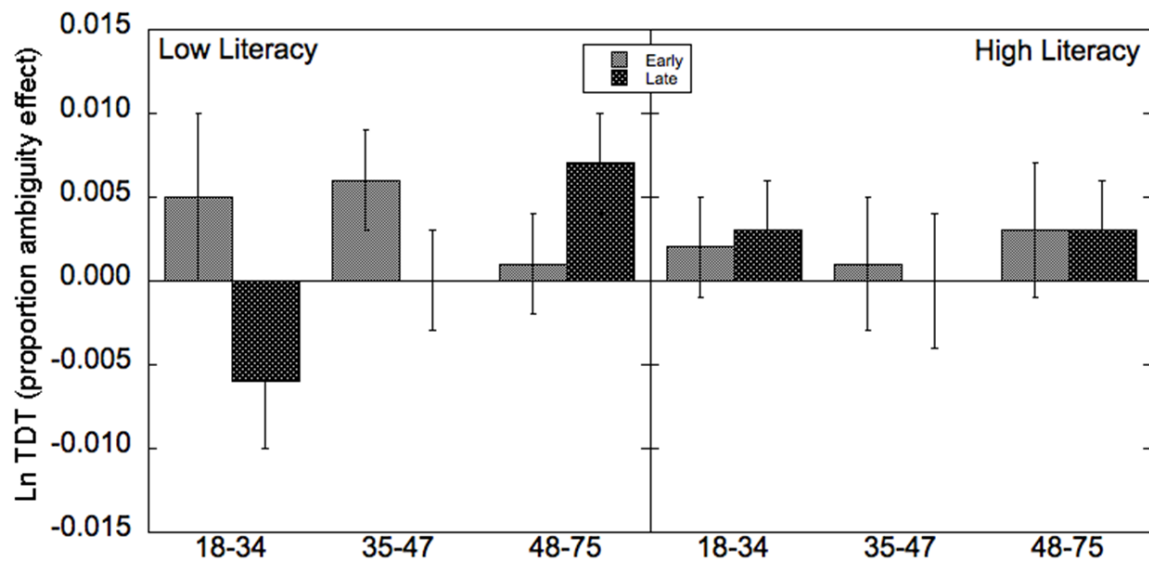
Figure 9 (T2).
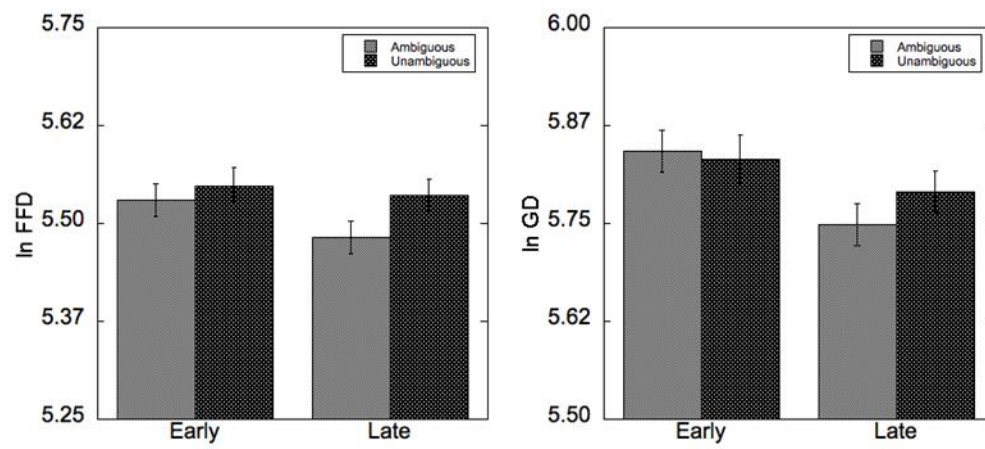
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Appendix A: Reading Materials Used in Current Study

List	Text	Question
1	At the beach, she played under the palm. Even though she was in the shade, her hand still got sunburnt.	Did she stay in the shade at the beach?
1	He was excited that his class was taking a trip to the new mint. To make the trip even better, they visited the candy store next door.	Was the candy store down the street?
1	The police officer could smell the joint. The man fell on the pavement and his knee was bleeding.	Was the police office smoking?
1	For this scam, the con artist had a new angle. Without thinking, the math teacher fell for the gimmick.	Did the conartist succeed?
1	To stop the loud music the town council passed an act. After it had passed, the play in the park was easier to hear.	Did the vote benefit the play in the park?
1	The editor took her time reading the passage. The description of the path in the book was confusing.	Would the readers understand the description?
1	The house shook because of a shift in the fault. The rotting wood in the foundation was to blame.	Did the foundation cause the house to shake?
1	At the voice recital, she sang every note. That day, the pages of music were brought to life.	Did she sing the music incorrectly?
1	Tim would not go out since his chin had such a big boil. Since he missed yesterday's shift the cook was keeping him late.	Did he stay home instead of going out?
1	All he needed to win the bowling competition was a spare. When he got to his car later that night, his tire was flat.	Did someone harm the tire?
1	The woman waited for her friend while sitting in a velvet lounge. They were in a hurry because the bar was closing soon.	Were they taking their time?
1	Before the wedding started her mother smiled and fixed her bow. When the groom saw his bride, an arrow of love struck his heart.	Was the mother getting married?
1	The rope was tied around the man's leg at the middle of his calf. He was dragged behind the cow for a whole mile!	Was the rope tied around his arm?
1	Marko the clown fish was missing a scale. His defect had thrown off his weight and balance.	Was the missing scale causing a problem?

	Statement	Question
1	After the splash, her glasses were covered with a goopy film. Also covered in mud was the movie she rented.	Did she rent the movie after getting splashed?
1	The rooster flashed his red fleshy comb. The hair on the cat's back was standing straight up.	Was the cat happy?
1	The man showed his grandson the collection of swords and arms. His elbow showed a scar from the Vietnam War.	Was the scar on his face?
1	All of the event dates are kept in the church's log. The wood of the church pews was over 100 years old.	Did the pews of the church get replaced?
1	On Election Day it is important to vote for the right party. The fun starts after all the votes are counted.	Is voting the fun part of election day?
1	The red carpet was covered by today's hottest stars. The sky was full of rain clouds about to let loose.	Was the carpet covered with rain?
1	She thought she didn't get the job because of her race. The marathon tomorrow would help her to blow off some steam.	Was she witheld employment due to her race?
1	They waited by the fire while her son went to find a long poker. The game they played after eating s'mores lasted all night!	Was there a fire nearby?
1	The man was so tired from his shift he decided to hit the sack. That mailbag he had been carrying all day had really worn him out.	Was the woman tired from traveling?
1	His wife wanted to throw a party, but he had a lot of reservations. The hotel for the event was booked but had not yet confirmed.	Was the husband nervous about the party?
1	The sarcasm was mumbled so he didn't understand the rib. The cage of the parrot was covered but the mocking was loud.	Did the bird pay him a compliment?
1	As soon as he looked down he saw the untied lace. The dress on his wife surprised him when he looked up.	Did his wife look stunning?
1	The jailor met the criminal but couldn't even look at his nasty mug. The coffee tasted bitter as he prepared to move him to his cell.	Did the jailor have some coffee?
1	The nun woke up late and forgot to put on her habit. Her routine was a little strange for the rest of the day.	Did the nun forget something important?
1	The nurse probed the arm but had a difficult time finding a vessel. The ship hit another wave so she missed again.	Was the patient on a ship?

60

1	The front page headline was about the robber and the battery. The power went out quickly after the attack.	Was the article about energy?
1	The House of Representatives did not pass the vote. The people would be given back every dollar they saved.	Did the people lose money because of the vote?
1	It was their tradition to get together and play rummy. When they got thirsty, they got the tonic from the side table.	Was this their first time playing that game?
1	She waited until April 12th to plant the seed. On the side of the house, the light was perfect for plant-life.	Did she plant the flowers in the spring?
1	The crown jewels would soon be presented to the new queen. In order to fit her new tiara, the measure of her head was taken.	Was the crown for the king?
1	She knew the manager of the cooking store was impatient and frank. She was fired on the spot because the knife was not sharp enough!	Was the manager fired?
1	She bought a new gown to go to the dance. Later that month, the bounce of her check was a nasty surprise.	Was the check invalid?
1	Her new manicure set was missing the clippers. A back-up kit was surely in the cabinet in the bathroom.	Was the nail kit missing something?
1	The zoo visitor was careful of the horns when petting the goat. The baby at the zoo had the child very excited!	Were they allowed to pet the baby goat?
1	By the end of the date she had figured out that he was a jerk. She was even more annoyed by the hammer in his floorboard.	Was the date going well?
1	The old man walked through the woods using a stick. By noon, the hard work had him exhausted and weak.	Did the man need help walking in the forest?
1	The teens were told not to make so much noise. Soon after, the ball broke through the neighbor's window.	Did the neighbors make the noise?
1	The farmer threw the feed into the corner of the pig sty. When he leaned over the fence, his pencil fell into the grub.	Was the farmer's pencil on the ground?
1	There are many rules in the game of Yahtzee. Before they even started, the water on the table was spilled.	Did they play cards on the table?
1	Once it started raining, he pulled the canoe onto the mud. When he stood up the money in his pocket spilled out.	Was he kayaking in the lake?
1	The best man was nervous about his speech. The stain on his shirt from jam was really not helping.	Was the groom nervous about the stain on his shirt?

1	In the shower she slipped on the soapy wet floor. After the shower her strong drink helped with the pain.	Was the pain caused by the fall?
1	The journalist went downtown to make sure he got the news. The ice cream parlor had completely burned down that night.	Did the journalist go to the countryside?
1	The safari guide spotted an animal with a large hump. The honk from the jeep was loud and scared it away.	Did the vehicle scare away a lion?
1	While powdering her nose, she noticed she had lost a gold earring. The man at the desk found it later that week.	Did she lose an earring?
1	She couldn't see so the doctor looked into her eye. A student came into the room before the procedure to watch.	Was the student able to see?
1	He took the car back to the garage and said he had a gripe. The burger that the mechanic was eating sure looked good.	Was there a problem with the car?
1	Everything was closed so a cake was their last choice. The vacation would not be the same without some candy.	Were they happy about having a cake?
1	Agnes said she climbed to the top and looked off the cliff. Her trick fooled only the gullible people in the office.	Did everyone believe her story?
1	After he cried for hours, they figured he was just being a wimp. The tree they had decided to cut down was dying anyway.	Would saving the tree make him happy?
1	The new doctor in pediatrics turned out to be a fool. The ducks he asked to be painted on the walls are creepy.	Was the doctor smart and well-qualified?
1	At the finish line, the sponsors gave her a pink bracelet. The music was so loud she could hardly hear them speak.	Were the sponsors part of the band?
1	They searched the dictionary but could not find the word. The paper was very thin and often ripped while turning the pages.	Was the definition in the dictionary?
1	He was so famous that his ticket sales broke all kinds of myths. The songs by Elvis are still played today and loved by many people.	Did Elvis have a lot of fans?
1	She watched her favorite team with great pride and pleasure. The mustard from her hotdog dripped on her when she stood up.	Did she enjoy watching sports?
1	Her apartment just didn't have enough space. The bath was the smallest of all at only two square feet.	Was the kitchen the smallest room?
2	At the beach, she played under the palm. Her hand still got sunburnt even though she was in the shade.	Did she stay in the shade at the beach?

2	He was excited that his class was taking a trip to the new mint. The candy store next door would make the trip even better.	Was the candy store down the street?
2	The police officer could smell the joint. His knee was bleeding from falling on the pavement.	Was the police office smoking?
2	For this scam, the con artist had a new angle. The math teacher fell for the gimmick without thinking.	Did the conartist succeed?
2	To stop the loud music the town council passed an act. The play in the park was easier to hear after it had passed.	Did the vote benefit the play in the park?
2	The editor took her time reading the passage. The path described in the book was confusing.	Would the readers understand the description?
2	The house shook because of a shift in the fault. The blame was placed on the foundation's rotting wood.	Did the foundation cause the house to shake?
2	At the voice recital, she sang every note. The pages of music were brought to life that day.	Did she sing the music incorrectly?
2	Tim would not go out since his chin had such a big boil. The cook was keeping him late since he missed yesterday's shift.	Did he stay home instead of going out?
2	All he needed to win the bowling competition was a spare. His tire was flat when he got to his car later that night.	Did someone harm the tire?
2	The woman waited for her friend while sitting in a velvet lounge. The bar was closing soon so they were in a hurry.	Were they taking their time?
2	Before the wedding started her mother smiled and fixed her bow. An arrow of love struck the groom's heart when he saw his bride.	Was the mother getting married?
2	The rope was tied around the man's leg at the middle of his calf. The cow dragged him behind for a whole mile!	Was the rope tied around his arm?
2	Marko the clown fish was missing a scale. His weight and balance was thrown off by his defect.	Was the missing scale causing a problem?
2	After the splash, her glasses were covered with a goopy film. The movie she rented was also covered in mud.	Did she rent the movie after getting splashed?
2	The rooster flashed his red fleshy gobbler. The cat's back hair was standing straight up.	Was the cat happy?
2	The man showed his grandson the collection of swords and guns. His scar from the Vietnam War was on his elbow.	Was the scar on his face?

2	All of the event dates are kept in the church's book. The church pews were made of wood over 100 years ago.	Did the pews of the church get replaced?
2	On Election Day it is important to vote for the right person. After all the votes are counted the fun starts.	Is voting the fun part of election day?
2	The red carpet was covered by today's hottest leads. The rain clouds in the sky were about to let loose.	Was the carpet covered with rain?
2	She thought she didn't get the job because of her color. She hoped to blow off some steam at the marathon tomorrow.	Was she witheld employment due to her race?
2	They waited by the fire while her son went to find a long twig. After eating s'mores the game they played lasted all night!	Was there a fire nearby?
2	The man was so tired from his shift he decided to hit the hay. He was really worn out from carrying that mailbag all day.	Was the woman tired from traveling?
2	His wife wanted to throw a party, but he had a lot of doubts. The event was booked but the hotel had not yet confirmed.	Was the husband nervous about the party?
2	The sarcasm was mumbled so he didn't understand the joke. The mocking was loud even with the parrot's cage covered.	Did the bird pay him a compliment?
2	As soon as he looked down he saw the untied shoe. When he looked up the dress on his wife surprised him.	Did his wife look stunning?
2	The jailor met the criminal but couldn't even look at his nasty face. As he prepared to move him to his cell, the coffee tasted bitter.	Did the jailor have some coffee?
2	The nun woke up late and forgot to put on her socks. For the rest of the day her routine was a little off.	Did the nun forget something important?
2	The nurse probed the arm but had a difficult time finding a vein. She missed again as the ship hit another wave.	Was the patient on a ship?
2	The front page headline was about the robber and the assault. After the attack the power went out quickly.	Was the article about energy?
2	The House of Representatives did not pass the vote. Every dollar they saved would be given back to the people.	Did the people lose money because of the vote?
2	It was their tradition to get together and play rummy. The tonic was on the side table when they got thirsty.	Was this their first time playing that game?
2	She waited until April 12th to plant the seed. The light on the side of the house was perfect for plant-life.	Did she plant the flowers in the spring?

2	The crown jewels would soon be presented to the new queen. The measure of her head was taken to fit her for a new tiara.	Was the crown for the king?
2	She knew the manager of the cooking store was impatient and frank. The knife was not sharp enough so she was fired on the spot!	Was the manager fired?
2	She bought a new gown to go to the dance. The bounce of her check was a nasty surprise later that month.	Was the check invalid?
2	Her new manicure set was missing the clippers. The cabinet in the bathroom surely had a back-up kit in there.	Was the nail kit missing something?
2	The zoo visitor was careful of the horns when petting the goat. The child was very excited to see the new arrival!	Were they allowed to pet the baby goat?
2	By the end of the date she had figured out that he was a jerk. The hammer in his floorboard made her even more annoyed.	Was the date going well?
2	The old man walked through the woods using a stick. The hard work had him exhausted and weak by noon.	Did the man need help walking in the forest?
2	The teens were told not to make so much noise. The ball broke through the neighbor's window soon after.	Did the neighbors make the noise?
2	The farmer threw the feed into the corner of the pig sty. His pencil fell into the grub when he leaned over the fence.	Was the farmer's pencil on the ground?
2	There are many rules in the game of Yahtzee. The water on the table was spilled before they even started.	Did they play cards on the table?
2	Once it started raining, he pulled the canoe onto the mud. The money in his pocket spilled out when he stood up.	Was he kayaking in the lake?
2	The best man was nervous about his speech. The jam stain on his shirt was really not helping.	Was the groom nervous about the stain on his shirt?
2	In the shower she slipped on the soapy wet bar. After the shower her strong drink helped with the pain.	Was the pain caused by the fall?
2	The journalist went downtown to make sure he got the scoop. That night the ice cream parlor had completely burned down.	Did the journalist go to the countryside?
2	The safari guide spotted an animal with a large horn. It was scared away by the loud honk from the jeep.	Did the vehicle scare away a lion?
2	While powdering her nose, she noticed she had lost a gold stud. Later that week, the man at the desk found it.	Did she lose an earring?

2	She couldn't see so the doctor looked into her pupil. Before the procedure, a student came into the room to watch.	Was the student able to see?
2	He took the car back to the garage and said he hadhad a beef. The mechanic was eating a burger that sure looked good.	Was there a problem with the car?
2	Everything was closed so a cake was their last resort. Without some candy, the vacation would not be the same.	Were they happy about having a cake?
2	Agnes said she climbed to the top and looked off the bluff. Only the gullible people in the office were fooled by her trick.	Did everyone believe her story?
2	After he cried for hours, they figured he was just being a sap. They had decided to cut down the tree because it was dying.	Would saving the tree make him happy?
2	The new doctor in pediatrics turned out to be a quack. He asked for creepy ducks to be painted on the walls.	Was the doctor smart and well-qualified?
2	At the finish line, the sponsors gave her a pink band. She could hardly hear them speak because the music was so loud.	Were the sponsors part of the band?
2	They searched the dictionary but could not find the term. While turning the pages, the very thin paper often ripped.	Was the definition in the dictionary?
2	He was so famous that his ticket sales broke all kinds of records. Many people love the songs by Elvis and are still played today.	Did Elvis have a lot of fans?
2	She watched her favorite team with great pride and relish. When she stood up the mustard from her hotdog dripped on her.	Did she enjoy watching sports?
2	Her apartment just didn't have enough room. At only two square feet the bath was the smallest of all.	Was the kitchen the smallest room?
3	At the beach, she played under the tree. Even though she was in the shade, her hand still got sunburnt.	Did she stay in the shade at the beach?
3	He was excited that his class was taking a trip to the new factory. To make the trip even better, they visited the candy store next door.	Was the candy store down the street?
3	The police officer could smell the smoke. The man fell on the pavement and his knee was bleeding.	Was the police office smoking?
3	For this scam, the con artist had a new pitch. Without thinking, the math teacher fell for the gimmick.	Did the conartist succeed?
3	To stop the loud music the town council passed a law. After it had passed, the play in the park was easier to hear.	Did the vote benefit the play in the park?

3	The editor took her time reading the paper. The description of the path in the book was confusing.	Would the readers understand the description?
3	The house shook because of a shift in the ground. The rotting wood in the foundation was to blame.	Did the foundation cause the house to shake?
3	At the voice recital, she sang every sound. That day, the pages of music were brought to life.	Did she sing the music well?
3	Tim would not go out since his chin had such a big spot. Since he missed yesterday's shift the cook was keeping him late.	Was there something on his face?
3	All he needed to win the bowling competition was a strike. When he got to his car later that night, his tire was flat.	Did someone harm the tire?
3	The woman waited for her friend while sitting in a velvet chair. They were in a hurry because the bar was closing soon.	Were they taking their time?
3	Before the wedding started her mother smiled and fixed her veil. When the groom saw his bride, an arrow of love struck his heart.	Was the mother getting married?
3	The rope was tied around the man's leg at the middle of his shin. He was dragged behind the cow for a whole mile!	Was the rope tied around his arm?
3	Marko the clown fish was missing a fin. His defect had thrown off his weight and balance.	Was the missing scale causing a problem?
3	After the splash, her glasses were covered with a goopy coating. Also covered in mud was the movie she rented.	Did she rent the movie after getting splashed?
3	The rooster flashed his red fleshy gobbler. The hair on the cat's back was standing straight up.	Was the cat happy?
3	The man showed his grandson the collection of swords and guns. His elbow showed a scar from the Vietnam War.	Was the scar on his face?
3	All of the event dates are kept in the church's book. The wood of the church pews was over 100 years old.	Did the pews of the church get replaced?
3	On Election Day it is important to vote for the right person. The fun starts after all the votes are counted.	Is voting the fun part of election day?
3	The red carpet was covered by today's hottest leads. The sky was full of rain clouds about to let loose.	Was the carpet covered with rain?
3	She thought she didn't get the job because of her color. The marathon tomorrow would help her to blow off some steam.	Was she witheld employment due to her race?

3	They waited by the fire while her son went to find a long twig. The game they played after eating s'mores lasted all night!	Was there a fire nearby?
3	The man was so tired from his shift he decided to hit the hay. That mailbag he had been carrying all day had really worn him out.	Was the woman tired from traveling?
3	His wife wanted to throw a party, but he had a lot of doubts. The hotel for the event was booked but had not yet confirmed.	Was the husband nervous about the party?
3	The sarcasm was mumbled so he didn't understand the joke. The cage of the parrot was covered but the mocking was loud.	Did the bird pay him a compliment?
3	As soon as he looked down he saw the untied shoe. The dress on his wife surprised him when he looked up.	Did his wife look stunning?
3	The jailor met the criminal but couldn't even look at his nasty face. The coffee tasted bitter as he prepared to move him to his cell.	Did the jailor have some coffee?
3	The nun woke up late and forgot to put on her socks. Her routine was a little strange for the rest of the day.	Did the nun forget something important?
3	The nurse probed the arm but had a difficult time finding a vein. The ship hit another wave so she missed again.	Was the patient on a ship?
3	The front page headline was about the robber and the assault. The power went out quickly after the attack.	Was the article about energy?
3	The House of Representatives did not pass the bill. The people would be given back every dollar they saved.	Did the people lose money because of the vote?
3	It was their tradition to get together and play gin. When they got thirsty, they got the tonic from the side table.	Was this their first time playing that game?
3	She waited until April 12th to plant the bulb. On the side of the house, the light was perfect for plant-life.	Did she plant the flowers in the spring?
3	The crown jewels would soon be presented to the new ruler. In order to fit her new tiara, the measure of her head was taken.	Was the crown for the king?
3	She knew the manager of the cooking store was impatient and blunt. She was fired on the spot because the knife was not sharp enough!	Was the manager fired?
3	She bought a new gown to go to the ball. Later that month, the bounce of her check was a nasty surprise.	Was the check invalid?

3	Her new manicure set was missing the file. A back-up kit was surely in the cabinet in the bathroom.	Was the nail kit missing something?
3	The zoo visitor was careful of the horns when petting the kid. The baby at the zoo had the child very excited!	Were they allowed to pet the baby goat?
3	By the end of the date she had figured out that he was a tool. She was even more annoyed by the hammer in his floorboard.	Was the date going well?
3	The old man walked through the woods using a staff. By noon, the hard work had him exhausted and weak.	Did the man need help walking in the forest?
3	The teens were told not to make so much racket. Soon after, the ball broke through the neighbor's window.	Did the neighbors make the noise?
3	The farmer threw the feed into the corner of the pig pen. When he leaned over the fence, his pencil fell into the grub.	Was the farmer's pencil on the ground?
3	There are many rules in the game of bridge. Before they even started, the water on the table was spilled.	Did they play cards on the table?
3	Once it started raining, he pulled the canoe onto the bank. When he stood up the money in his pocket spilled out.	Was he kayaking in the lake?
3	The best man was nervous about his toast. The stain on his shirt from jam was really not helping.	Was the groom nervous about the stain on his shirt?
3	In the shower she slipped on the soapy wet bar. Her strong drink after the shower helped with the pain.	Was the pain caused by the fall?
3	The journalist went downtown to make sure he got the scoop. The ice cream parlor had completely burned down that night.	Did the journalist go to the countryside?
3	The safari guide spotted an animal with a large horn. The honk from the jeep was loud and scared it away.	Did the vehicle scare away a lion?
3	While powdering her nose, she noticed she had lost a gold stud. The man at the desk found it later that week.	Did she lose an earring?
3	She couldn't see so the doctor looked into her pupil. A student came into the room before the procedure to watch.	Was the student able to see?
3	He took the car back to the garage and said he hadhad a beef. The burger that the mechanic was eating sure looked good.	Was there a problem with the car?
3	Everything was closed so a cake was their last resort. The vacation would not be the same without some candy.	Were they happy about having a cake?

3	Agnes said she climbed to the top and looked off the bluff. Her trick fooled only the gullible people in the office.	Did everyone believe her story?
3	After he cried for hours, they figured he was just being a sap. The tree they had decided to cut down was dying anyway.	Would saving the tree make him happy?
3	The new doctor in pediatrics turned out to be a quack. The ducks he asked to be painted on the walls are creepy.	Was the doctor smart and well-qualified?
3	At the finish line, the sponsors gave her a pink band. The music was so loud she could hardly hear them speak.	Were the sponsors part of the band?
3	They searched the dictionary but could not find the term. The paper was very thin and often ripped while turning the pages.	Was the definition in the dictionary?
3	He was so famous that his ticket sales broke all kinds of records. The songs by Elvis are still played today and loved by many people.	Did Elvis have a lot of fans?
3	She watched her favorite team with great pride and relish. The mustard from her hotdog dripped on her when she stood up.	Did she enjoy watching sports?
3	Her apartment just didn't have enough room. The bath was the smallest of all at only two square feet.	Was the kitchen the smallest room?
4	At the beach, she played under the tree. Her hand still got sunburnt even though she was in the shade.	Did she stay in the shade at the beach?
4	He was excited that his class was taking a trip to the new factory. The candy store next door would make the trip even better.	Was the candy store down the street?
4	The police officer could smell the smoke. His knee was bleeding from falling on the pavement.	Was the police office smoking?
4	For this scam, the con artist had a new pitch. The math teacher fell for the gimmick without thinking.	Did the conartist succeed?
4	To stop the loud music the town council passed a law. The play in the park was easier to hear after it had passed.	Did the vote benefit the play in the park?
4	The editor took her time reading the paper. The path described in the book was confusing.	Would the readers understand the description?
4	The house shook because of a shift in the ground. The blame was placed on the foundation's rotting wood.	Did the foundation cause the house to shake?

4	At the voice recital, she sang every sound. The pages of music were brought to life that day.	Did she sing the music incorrectly?
4	Tim would not go out since his chin had such a big spot. The cook was keeping him late since he missed yesterday's shift.	Did he stay home instead of going out?
4	All he needed to win the bowling competition was a strike. His tire was flat when he got to his car later that night.	Did someone harm the tire?
4	The woman waited for her friend while sitting in a velvet chair. The bar was closing soon so they were in a hurry.	Were they taking their time?
4	Before the wedding started her mother smiled and fixed her veil. An arrow of love struck the groom's heart when he saw his bride.	Was the mother getting married?
4	The rope was tied around the man's leg at the middle of his shin. The cow dragged him behind for a whole mile!	Was the rope tied around his arm?
4	Marko the clown fish was missing a fin. His weight and balance was thrown off by his defect.	Was the missing scale causing a problem?
4	After the splash, her glasses were covered with a goopy coating. The movie she rented was also covered in mud.	Did she rent the movie after getting splashed?
4	The rooster flashed his red fleshy comb. The cat's back hair was standing straight up.	Was the cat happy?
4	The man showed his grandson the collection of swords and arms. His scar from the Vietnam War was on his elbow.	Was the scar on his face?
4	All of the event dates are kept in the church's log. The church pews were made of wood over 100 years ago.	Did the pews of the church get replaced?
4	On Election Day it is important to vote for the right party. After all the votes are counted the fun starts.	Is voting the fun part of election day?
4	The red carpet was covered by today's hottest stars. The rain clouds in the sky were about to let loose.	Was the carpet covered with rain?
4	She thought she didn't get the job because of her race. She hoped to blow off some steam at the marathon tomorrow.	Was she witheld employment due to her race?
4	They waited by the fire while her son went to find a long poker. After eating s'mores the game they played lasted all night!	Was there a fire nearby?
4	The man was so tired from his shift he decided to hit the sack. He was really worn out from carrying that mailbag all day.	Was the woman tired from traveling?

4	His wife wanted to throw a party, but he had a lot of reservations. The event was booked but the hotel had not yet confirmed.	Was the husband nervous about the party?
4	The sarcasm was mumbled so he didn't understand the rib. The mocking was loud even with the parrot's cage covered.	Did the bird pay him a compliment?
4	As soon as he looked down he saw the untied lace. When he looked up the dress on his wife surprised him.	Did his wife look stunning?
4	The jailor met the criminal but couldn't even look at his nasty mug. As he prepared to move him to his cell, the coffee tasted bitter.	Did the jailor have some coffee?
4	The nun woke up late and forgot to put on her habit. For the rest of the day her routine was a little off.	Did the nun forget something important?
4	The nurse probed the arm but had a difficult time finding a vessel. She missed again as the ship hit another wave.	Was the patient on a ship?
4	The front page headline was about the robber and the battery. After the attack the power went out quickly.	Was the article about energy?
4	The House of Representatives did not pass the bill. Every dollar they saved would be given back to the people.	Did the people lose money because of the vote?
4	It was their tradition to get together and play gin. The tonic was on the side table when they got thirsty.	Was this their first time playing that game?
4	She waited until April 12th to plant the bulb. The light on the side of the house was perfect for plant-life.	Did she plant the flowers in the spring?
4	The crown jewels would soon be presented to the new ruler. The measure of her head was taken to fit her for a new tiara.	Was the crown for the king?
4	She knew the manager of the cooking store was impatient and blunt. The knife was not sharp enough so she was fired on the spot!	Was the manager fired?
4	She bought a new gown to go to the ball. The bounce of her check was a nasty surprise later that month.	Was the check invalid?
4	Her new manicure set was missing the file. The cabinet in the bathroom surely had a back-up kit in there.	Was the nail kit missing something?
4	The zoo visitor was careful of the horns when petting the kid. The child was very excited to see the new arrival!	Were they allowed to pet the baby goat?

4	By the end of the date she had figured out that he was a tool. The hammer in his floorboard made her even more annoyed.	Was the date going well?
4	The old man walked through the woods using a staff. The hard work had him exhausted and weak by noon.	Did the man need help walking in the forest?
4	The teens were told not to make so much racket. The ball broke through the neighbor's window soon after.	Did the neighbors make the noise?
4	The farmer threw the feed into the corner of the pig pen. His pencil fell into the grub when he leaned over the fence.	Was the farmer's pencil on the ground?
4	There are many rules in the game of bridge. The water on the table was spilled before they even started.	Did they play cards on the table?
4	Once it started raining, he pulled the canoe onto the bank. The money in his pocket spilled out when he stood up.	Was he kayaking in the lake?
4	The best man was nervous about his toast. The jam stain on his shirt was really not helping.	Was the groom nervous about the stain on his shirt?
4	In the shower she slipped on the soapy wet floor. After the shower her strong drink helped with the pain.	Was the pain caused by the fall?
4	The journalist went downtown to make sure he got the news. That night the ice cream parlor had completely burned down.	Did the journalist go to the countryside?
4	The safari guide spotted an animal with a large hump. It was scared away by the loud honk from the jeep.	Did the vehicle scare away a lion?
4	While powdering her nose, she noticed she had lost a gold earring. Later that week, the man at the desk found it.	Did she lose an earring?
4	She couldn't see so the doctor looked into her eye. Before the procedure, a student came into the room to watch.	Was the student able to see?
4	He took the car back to the garage and said he had a gripe. The mechanic was eating a burger that sure looked good.	Was there a problem with the car?
4	Everything was closed so a cake was their last choice. Without some candy, the vacation would not be the same.	Were they happy about having a cake?
4	Agnes said she climbed to the top and looked off the cliff. Only the gullible people in the office were fooled by her trick.	Did everyone believe her story?
4	After he cried for hours, they figured he was just being a wimp. They had decided to cut down the tree because it was dying.	Would saving the tree make him happy?

4	The new doctor in pediatrics turned out to be a fool. He asked for creepy ducks to be painted on the walls.	Was the doctor smart and well-qualified?
4	At the finish line, the sponsors gave her a pink bracelet. She could hardly hear them speak because the music was so loud.	Were the sponsors part of the band?
4	They searched the dictionary but could not find the word. While turning the pages, the very thin paper often ripped.	Was the definition in the dictionary?
4	He was so famous that his ticket sales broke all kinds of myths. Many people love the songs by Elvis and are still played today.	Did Elvis have a lot of fans?
4	She watched her favorite team with great pride and pleasure. When she stood up the mustard from her hotdog dripped on her.	Did she enjoy watching sports?
4	Her apartment just didn't have enough space. At only two square feet the bath was the smallest of all.	Was the kitchen the smallest room?

Appendix B: Dominance Level Based on Twilley et al., 1994

Word	Dominant Meaning	Subordinate Meaning	Proportion Dominant	Proportion Subordinate
act	PERFORM	ACTION	0.74	0.02
angle	MEASURE	ASPECT	0.81	0.01
arms	BODY	WEAPON	0.91	0.05
ball	SHAPE	CELEBRATION	0.92	0.02
band	GROUP	STRAP	0.63	0.01
bank	MONEY	NATURE	0.98	0.00
bar	PLACE	BEAM	0.79	0.00
battery	ENERGY	CRIME	0.84	0.06
beef	FOOD	PROBLEM	0.91	0.00
bill	MONEY	LAW	0.50	0.04
bluff	DECEIT	CLIFF	0.72	0.06
blunt	DULL	DIRECT	0.76	0.09
boil	WATER	SKIN	0.89	0.05
bow	WEAPON	KNOT	0.35	0.26
bridge	STRUCTURE	GAME	0.60	0.20
bug	INSECT	SPY	0.74	0.00
bulb	LIGHT	FLOWER	0.86	0.11
calf	ANIMAL	BODY	0.81	0.11
comb	HAIR	BIRD	0.98	0.01
fault	BLAME	ROCK	0.39	0.19
file	DOCUMENT	TOOL	0.72	0.19
film	MOVIE	LAYER	0.90	0.02
foot	BODY	MEASURE	0.93	0.02
gin	ALCOHOL	GAME	0.87	0.08
habit	BEHAVIOR	CLOTHES	0.79	0.06
horn	SOUND	ANIMAL	0.77	0.17
joint	HINGE	DRUG	0.58	0.20
kid	CHILD	GOAT	0.72	0.10
lace	FABRIC	SHOE	0.67	0.26
log	WOOD	LIST	0.80	0.09
lounge	PLACE	FURNITURE	0.60	0.37
mint	FOOD	MONEY	0.85	0.00
mug	CUP	FACE	0.84	0.07
note	PAPER	MUSIC	0.84	0.10
palm	HAND	TREE	0.59	0.27
party	CELEBRATION	GROUP	0.97	0.01
passage	PATH	WRITING	0.89	0.08

pen	UTENSIL	ENCLOSURE	0.91	0.04
poker	GAME	TOOL	0.87	0.09
pupil	STUDENT	EYE	0.67	0.33
quack	NOISE	FRAUD	0.71	0.23
race	COMPETITION	GROUP	0.92	0.04
racket	SPORTS	NOISE	0.80	0.13
records	MUSIC	AWARD	0.84	0.05
relish	FOOD	ENJOY	0.91	0.07
reservation	APPOINTMENT	DOUBT	0.70	0.02
resort	VACATION	OPTION	0.92	0.04
rib	BONE	TEASE	0.93	0.02
room	HOUSE	SPACE	0.79	0.06
sack	BAG	BED	0.78	0.06
sap	TREE	EMOTION	0.68	0.06
scale	WEIGHT	ANIMAL	0.77	0.05
scoop	AMOUNT/LUMP	NEWS	0.93	0.04
spare	EXTRA	BOWLING	0.90	0.02
staff	FACULTY	STICK	0.80	0.11
stars	SKY	FAMOUS	0.77	0.12
stud	MALE	EARRING	0.71	0.06
term	TIME	WORD	0.73	0.15
toast	BREAD	HONOR	0.88	0.09
tool	DEVICE	JERK	0.90	0.02
vessel	SHIP	CONTAINER	0.75	0.06