THE INTERACTION OF IMAGES AND TEXT DURING COMPREHENSION OF GARDEN-PATH SENTENCES: IS INTEGRATION BETTER THAN GOOD ENOUGH?

BY

CASSIE MARIE PALMER

DISSERTATION

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Doctoral Committee:

Associate Professor Kiel Christianson, Chair
Professor Elizabeth A. L. Stine-Morrow
Professor Daniel Morrow
Professor Peter Golato, Texas State University

Abstract

One of the main goals of reading is to construct a discourse representation. However, when information in the discourse is confusing or ambiguous, readers are often not able to create a fluid, accurate understanding of the text. Decades of research on temporarily ambiguous garden-path sentences have given the field of psycholinguistics a comprehensive understanding of how readers process, and often misinterpret, garden-path sentences. Both online and offline data demonstrate that when reading garden-path sentences (e.g., *As the guard and officer wrestled the thief that was fleeing fell down the stairs*), readers may not arrive at the correct, syntactically-licensed interpretation (i.e., that the guard and officer are wrestling each other) despite apparent reanalysis. The garden-path sentence processing model claims that readers often parse sentences by developing only shallow representations of the structure, and thus never return from "down the garden path" to arrive at the correct, syntactically licensed interpretation (Ferreira, Ferraro, & Bailey, 2002; Ferreira & Patson, 2007).

In this dissertation, I seek to test the bounds of the garden-path model of sentence processing by investigating contextual influences on language processing. Specifically, how are reading processes are affected by the presence of extralinguistic information (e.g., imagery) with garden-path sentences. If readers are able to properly make use of linguistic (words) and nonlinguistic (pictorial) information, does it help them avoid inaccurate interpretation? For means of comparison, a related question is the role of imagery on linguistic disambiguation for less proficient readers who might rely more on the nonlinguistic code (e.g., nonnative speakers). I approach the issue of visual and linguistic (multimedia) processing by investigating specifically whether or not nonnative speakers of English, compared to native speakers, rely differently on non-linguistic information to parse and understand ambiguous, garden-path sentences.

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For my own self. Who is the anomalous wildflower.

This is all for you.

“There is hope in every pothole.”

143

Table of Contents

Chapter 1: Introduction to Temporary Structural Ambiguities and Their Resolution

Language comprehension does not always unfold in a way that allows a detailed and complete understanding of the information. Particularly in reading, individuals are prone to misinterpret ambiguous phrases, thereby interfering with coherent interpretation. Much research has been conducted on how readers comprehend temporarily ambiguous, so-called "garden-path sentences" (Bever, 1970; Frazier & Rayner, 1982), such as in (1) and (2):

1) *While the girl scratched the cat that was gray and white stared at the dog.*
2) *As the explorer paddled the canoe that was long and green headed downstream.*

These sentences pose great comprehension difficulty, and readers often end up with the following syntactically unlicensed (wrong) interpretations:

3) *The girl scratched the cat, and the cat that was gray and white stared at the dog.*
4) *The explorer paddled the canoe, and the canoe that was long and green headed downstream.*

Little is known about how other factors, such as extra information (e.g., additional text or images) may affect ambiguity resolution. Readers of varying language and reading proficiency may make use of text-and-imagery information in varying ways in an attempt to arrive at a coherent interpretation of the input. This dissertation seeks to expand the understanding of ambiguity resolution in the presence of extra, disambiguating information for native speakers of English and to make comparisons to readers who might rely differently on imagery and contextual influences (nonnative speakers). How, if at all, does pictorial information help readers recover from incorrectly parsed sentences? Are readers able to use information from the two separate sources for successful interpretation of the linguistic code? To answer these questions,

in this dissertation, I will first discuss parsing theories and how they relate to contextual information in subsequent sections.

Parsing Theories

Miscomprehension in reading is pervasive. Even highly skilled readers often misanalyse text, and as a consequence, the interpretation that they take away may be illegal according to the syntax. One particular type of sentence that has received much attention in psycholinguistic research to study good-enough processing is the garden-path sentence:

5) *While Frank dried off the car that was red and shiny sat in the driveway.*

Sentence (5) is referred to as a "DO/S" garden-path sentence because *the car* is ambiguous between being the direct object (DO) of *dried off* and the subject (S) of *that red and shiny sat in the driveway*. Although some of the correct interpretation of this sentence is processed (i.e., *that the car that was red and shiny sat in the driveway*), a syntactically unlicensed and incompatible interpretation may linger (i.e., *that Frank dried off the car*). The only syntactically licensed interpretation of (5) is:

6) *While Frank was drying himself off, the car that was red and shiny sat in the driveway.*

Using the sample sentence (5) above, if the reader has interpreted that *the car* is the syntactic object of the verb *dried off*, the reader is left with no option for a subject for the clause *sat in the driveway* (i.e., there is no head to assign to the thematic role). At this point, reanalysis is triggered, proving difficult, however, due to the fact that the wrong interpretation has likely continued (or lingered) until the end of the sentence.

In garden-path sentence processing research, two types of verbs have been investigated in Subordinate-Matrix type ambiguities: optionally transitive verbs (OPT) and reflexive absolute transitive (RAT) verbs (Christianson et al., 2001; Trask, 1993). RAT verbs (e.g., dress, bathe, shave) retain reflexivity (transitive argument structure) and can refer back to the syntactic subject, where as OPT verbs (e.g., hunted, rode, painted) can take an overt syntactic object but did not require one. Take, for example, the RAT verb *shave* in (7):

7) *While the nurse shaved the patient that was tired and weak watched TV*.

Without the disambiguating comma, the initial interpretation could either be that the nurse was shaving him/herself (correct) or the garden-path interpretation that the nurse shaved the patient (incorrect). In English, RAT verbs are rare. (Nearly all of the known English RAT verbs are used in the experiments herein.) In order to correctly interpret these RAT verbs, readers must assign the action of the main verb not to the potential object that gets mentioned, but as an intransitive verb that refers back to the original agent (something readers are largely unsuccessful in doing). Several theories have been posited as to how readers process garden-path sentences: serial (structural) models, parallel (constraint-based) models, and good-enough theory (GE). The ensuing sections discuss these theories and their predictions as they relate to the experiments herein.

Serial models of ambiguous sentence processing. Serial, or structural, models of online sentence processing assume that words are processed individually and successively. Sentence processing during silent reading has been examined for decades with the goal of understanding how readers parse written language (Frazier & Clifton, 1996; Frazier & Fodor, 1978; Frazier & Rayner, 1982; Fodor & Inoue, 1998, MacDonald, Pearlmutter, & Seidenberg, 1994; Trueswell,

Tanenhaus, & Kello, 1993), and advances in eye-tracking technology have improved research methodology to understand how and why readers become garden-pathed. Take, for example, the temporally ambiguous garden-path sentence (8) and its unambiguous counterpart (9):

8) *While Frank dried off the car that was red and shiny sat in the driveway*.

9) *While Frank dried off, the car that was red and shiny sat in the driveway*.

Upon encountering the noun phrase *the car,* readers tend to interpret it as the patient (syntactic object) of *dried off*, rather than as the agent (syntactic subject) of *sat*, which hasn't been encountered yet. Frazier (1978) proposed two principles to explain this initial misparse, Late Closure and Minimal Attachment. Late Closure maintains that new, incoming information will be attached to the currently processed phrase (i.e., *the car* should be processed with *while Frank dried off*). When readers make it to the phrase *sat in the driveway*, the reader receives an error signal that the verb phrase has no overt subject. Readers must then make adjustments and re-analyze to interpret the initial verb *dried-off* as reflexive (that Frank is drying himself off). Similarly, Minimal Attachment maintains that readers will create the most basic structure possible and will backtrack to re-analyze if and when necessary. Minimal Attachment causes the reader to want short dependencies between sentential constituents. This, in addition to Late Closure is an explanation why *dried off the car* is a more likely interpretation than *the car that was shiny and red sat in the driveway*: *dried off* is closer in proximity to *the car* than *sat in the driveway* is.

Both Late Closure and Minimal Attachment have been extensively studied with language processing, however, less is known about how readers process ambiguous sentences when imagery is present. If serial processing holds true for extralinguistic information (as either text or imagery) as it does for words in the sentence, then these extra contextual information should not

show effects for online processing eye movement measures. While the online viewing patterns are of great interest to linguists and psycholinguistic research, in the field of educational psychology, reading comprehension is an equally, if not more important investigation. Considering multimedia text-and-image displays with garden-path sentences, the final interpretation (or misinterpretation) requires equal consideration. Because structural-based models are built serially, they should predict that there would be no contextual effects on the online comprehension of the garden-path sentences. The offline comprehension, however, might reflect that syntactically illegal interpretations of garden-path sentences will result.

Parallel model of ambiguous sentence processing. In contrast to serial models, parallel, or constraint-based models of sentence processing compete with the notion that information in the sentence is processed serially. Unlike serial models, a constraint-based theory of sentence processing predicts an eventual correct parse/interpretation. The constraint-based theory of sentence processing claims that readers parse language based on constraints from statistical learning from world-knowledge (MacDonald, Pearlmutter, & Seidenberg, 1994; Trueswell, Tanenhaus, & Kello, 1993). The premise of the parallel model is that people (readers) learn the likelihood of world-events and then use that information as a guide for how one should process language. Consider the ambiguous sentence (10):

10) While Tom grilled the hot dog that was long and fatty began to burn,

The constraint based model of sentence processing would predict that readers should be garden-pathed because people generally grill food (hot dogs), in spite of the fact that the syntax can optionally take *hot dogs* as the syntactic object of *grilled*. For example in sentence (11) arguably,

it is more common to hear the verb *walked* when referring to someone walking as opposed to walking a thing (a pet of some sort).

11) As the man walked the poodle that was small and white barked loudly,

Stated differently, there are numerous constraints (structural, discourse, and lexical) within sentences that readers must use to interpret ambiguous sentences. However, it is presumed that lexical constraints carry more weight in garden-path sentence processing than other constraints (Huettig, Rommers, & Meyer, 2011). In addition to the aforementioned constraints, the experimental stimuli that will be used for the present research, an additional factor that we will explore (and a manipulated variable) is the punctuation: a comma, or lack thereof. Due to the parallel nature of constraint-based models, effects of context should be seen in online measures of reading times in garden-path sentences. Final interpretation effects of context should be present in both serial and parallel models, however, online effects should only be seen if constraint-based models are the best account for garden-path sentence processing.

Chapter 2: Good-Enough Theory

An alternative to serial and parallel sentence processing is a different kind of model known as Good-Enough (GE) processing. GE does not assume a stable, faithful final interpretation. Instead, it predicts that misinterpretations should exist, if both the morphosyntactic parsing route and heuristic processing route run, and the former can be abandoned in favor of the latter when outputs conflict or structural parse runs into trouble. GE maintains that unfaithful representations that are systematic, predicted by the nature of the heuristics available to the heuristic processing route. Several recent studies have systematically investigated how readers misparse these types of garden-path sentences (see e.g., Christianson, 2002; Christianson, Hollingworth, Halliwell, & Ferreira, 2001; Ferreira & Henderson, 1999; Ferreira, Christianson, & Hollingworth, 2001; Slattery, Sturt, Christianson, Yoshida, & Ferreira, 2013), demonstrating that initially, misinterpretations often linger in the minds of readers. Importantly, perseverant misinterpretation is not expected under traditional accounts, which assumed either full recovery or total comprehension failure. Sentences with temporary ambiguities are usually misinterpreted on the first parse, thereby causing the reader to reanalyze, and even despite the apparent reanalysis, misinterpretations linger.

Garden-path sentence processing assumes minimal effort from the parser, even at the cost of necessitating extra time and energy for subsequent reanalysis. This underspecificity may have evolved partially to the way in which people understand spoken language. Disfluencies and mistakes in speech are common, and listeners must swiftly make changes to their interpretation in order to remain engaged and active in communication (Ferreira & Patson, 2007). Despite the fact that readers are able to refer back (regress) to difficult part of the sentence (whereas listeners cannot), blatant misinterpretations of ambiguities remain. In speech processing, being garden-

pathed is less likely as prosody provides strong cues of syntactic awareness so as to remedy the problem of knowing where to assign the ambiguous noun phrase (i.e., disfluency resolution as discussed in Bailey & Ferreira, 2003; Ferreira et al., 2004). Ferreira et al (2002) discussed these processing differences in the tasks using everyday language versus in psycholinguistic experiments: when parsers encounter temporarily ambiguous sentences in an experiment with explicit comprehension tasks, it was suggested that readers were more aware of the alternate interpretations of the sentences than they would have been in a more natural reading paradigm. This is important to note when considering the role that artificial experimental tasks place on the language user and how it can severely alter comprehension processes altogether. Perhaps when parsers encounter ambiguity in rapid communication the garden-path disambiguating system is not triggered to consider all other possible interpretations. Considering all interpretations of an utterance would be far too unrealistic in communication. Written language is different, however: without disambiguation cues from prosody, processing ambiguous language during silent reading is highly problematic. Experiments that employ online, biometric methodology, however, give psycholinguists who study this phenomenon more insight into the complexities of reading processing.

Based on the theory of incomplete representations, GE processing also predicts that readers will misparse and misunderstand other difficult, noncanonical sentences as well. To test GE processing and whether plausibility and morphosyntactic information may compete in sentence processing, Ferreira (2003) used passive sentences and found that readers rendered interpretations of the sentences based on the order in which the noun phrases were presented for both passive sentences (*The dog was bitten by the man*.) and cleft sentences (*It was the man who bit the dog.)*. The results indicated that even very simple sentences can be easily misinterpreted.

Similarly, Tabor, Galantucci, and Richardson (2004) demonstrated effects of good-enough processing in a self-paced reading paradigm with sentences that required small, local parses to then get packaged together with the overall meaning of the sentence (e.g., *The anthropologist interviewed a woman knitted a shawl by her mother*.) In this self-paced reading study, participants had longer reading latencies on the verb *knitted;* the authors interpreted this finding as evidence that local interpretations interfered with the global meaning of the sentence (that the mother knitted the shawl and not the woman). Interpretation of local structures within the sentences interfered with global processing.

Reaction time measures in self-paced reading and online, eyetracking data give indices of cognitive processing of language. These data are invaluable to studies of sentence ambiguity resolution as the data elucidate the precise sentence region where readers encounter difficulty. Ferreira and Henderson (1991, 1998) established a problematic portion of garden-path sentences as the distance between the head and the error signal (and not the length of the ambiguous phrase, as previously suggested by Warner & Glass, 1987). Referring back to an original example sentence, (5) *While Frank dried off the car that was red and shiny sat in the driveway,* studies of reading processing which use eyetracking and self-paced reading have established that when the reader encounters the error signal (i.e., *sat in the driveway*), they realize the misparse and then must reanalyze. However, knowing what final interpretation readers come away with has been less well documented. Many of the initial garden-path experiments either did not explicitly ask the reader whether they understood the correct interpretation (e.g., *Did Frank dry the car*?). Christianson et al. (2001), Ferreira et al. (2001), and Patson et al. (2006) were some of the first studies that investigated ambiguity comprehension directly by presenting the participant with a

forced-choice yes/no comprehension question after sentence reading. Overall, results from these studies indicated that in fact, the original misparse lingered even after apparent reanalysis.

Reading is dependent on many individual factors such as age, fluency, speed, and linguistic competence. However, individual differences in processing garden-path sentences and the success rate of parsing RAT and OPT garden-path sentences remains largely unexplored. A few exceptions in the literature exist. For example, Christianson, Williams, Zacks, and Ferreira (2006) found differences in older and younger adults' processing. In using both OPT and RAT verbs in garden-path sentences, older adults were less able to arrive at the correct interpretation of garden-path sentences than younger readers. Although older readers have more constrained cognitive resources overall than younger readers (e.g., working memory), they also have more life experience. Take, for example the temporarily ambiguous, OPT sentence in (12):

12) *While the man hunted the deer ran into the woods*.

Older adults were more likely to be garden-pathed and respond "yes" to the question "*Did the man hunt the deer?"* than the younger adults. The authors attribute this higher error rate among older participants as an effect of the older readers' deficiency in working memory capacity and their over-reliance on world knowledge heuristics (i.e., that people hunt deer). The good-enough representation was derived from heuristics rather than from the morphosyntactic structure, such as plausibility or word order.

In GE, structure and semantics run independently, and context effects should be especially apparent where structure gets harder and where context might be applied as a heuristic to compensate for underspecified or fragile syntactic parse. GE Theory offers an alternative to traditional models of sentence processing, which generally assume that readers will derive a final interpretation that is faithful to the structure and content of the input. Psycholinguistic

experiments of garden-path sentences with contextual information (i.e., heuristics) are one of the ways in which this phenomenon can be explored.

In garden-path sentence processing, context effects may be especially apparent where structure gets harder, and where context might be applied as a heuristic to compensate for underspecified or fragile syntactic parse. Put another way, ambiguous language may be better understood with real-world referents, namely accompanying visual information, such as images. Particularly for struggling readers such second language learners (or as is often used with emergent reading material for children), the presence of extralingusitic cues (e.g., images) can create the opportunity for reference in language comprehension (Ariasi & Mason, 2011; Hyona, 2010; Mason, Tornatora, & Pluchino, 2013; Mayer 2010; van Gog & Scheiter, 2010). To my knowledge, little to nothing is known about how imagery interacts with garden-path sentences to affect final sentence interpretation. An overarching goal of the current and proposed experiments is to test the bounds of the ambiguous sentence processing to understand how readers interpret garden-path sentences accompanied by visual imagery. With an understanding of how native speakers of English (L1 readers) approach linguistic disambiguation in the presence of accompanying imagery, I can then compare data from less proficient readers (nonnative speakers of English or L2 readers) as a principled way to further investigate the role of text and imagery on learning. The data from the L2 readers are expected to look differently from the L1 data. To further discuss, I turn to the work of Allan Paivio's Dual Coding Theory as a principled way to discuss the unique combination of heuristics and garden-path sentence processing.

Chapter 3: Dual Coding Theory

The investigation of graphic/environmental context compared to linguistic context on garden-path sentence processing cannot be fully discussed without mention of the Dual Coding Theory (DCT). The tenet DCT asserts that human cognition manages information from distinctly, separate representational systems (Paivio, 1971, 1990). Verbal and nonverbal information enter the sensory system independently and are processed individually. DCT assumes "two classes of phenomena that are handled cognitively by separate subsystems: one specialized for the representation and processing of information concerning nonverbal objects and events, the other specialized for dealing with language" (Paivio, 1986, p. 53). According to DCT, the visual and verbal system together can enhance memory more effectively than just one system alone. This work stems from Fodor's *Modularity of Mind* (1980, 1983), which assumes that cognitive input mechanisms are separate, distinct, and do not need to reference other information systems. The underlying assumptions of DCT are of specific interest in the current work: when readers process GP sentences, what does imagery do in creating the discourse representation versus when there is verbal disambiguation alone? Specifically, can the visual system and language system be kept active and remembered separately long enough for the reader to judge whether or not the two sources have the same interpretation? And if the reader can accomplish this, how much processing effort is required?

Although DCT was originally thought of as a theory of mind, since its inception, it has been widely accepted and incorporated into the literacy domain. Reading comprehension and decoding strategies are easily embodied by DCT, which posits the modality-specific mental representations can be empirically investigated. Critically, DCT does not assert the representation of abstract mental mechanisms or schemata; instead, DCT classifies modality-

specific mental representations as verbal or non-verbal as a way to decipher input comprehension. Sadoski & Paivio, 2007 claim that "DCT is therefore an associationist or connectionist theory that differs from all others in that class in that what gets connected is as important as the strength of the connections" (p. 349).

This is an important addition to the work of GE processing in critical ways. Namely, it is the investigation of how (if at all) imagery may help readers disambiguate and comprehend confusing linguistic input. One way to achieve this goal is to use reaction time and biometric data (eye movements) to predict and precisely understand how readers disambiguate confusing language. With this in mind, it is important to discuss eyetracking in text-and-image research.

Eye-tracking is an essential research tool in multimedia "because attention plays a central role in visual processing, and because eye movements are an overt behavioral manifestation of the allocation of attention in a scene, eye movements serve as a window into the operation of the attentional system" (Henderson & Ferreira, 2004, p. 18). Reading a multimedia display necessitates the coordination of eye movements for reading, scene perception, and visual search. Rayner (2009) gives a comprehensive overview of research on eye movements. To clarify forthcoming topics, a few terms of cognitive processing and eye movements must first be explained and defined. In reading, the eyes move forward (to the right or left, depending on the language) in a series of fixations and saccades. Fixations are when the eyes are still, focused on one point, taking in information. Saccades are when the eyes move between fixations; during saccades, the viewer is functionally blind and not taking in new information (Matin, 1974). In silent reading, fixations tend to average about 250 milliseconds while saccade latency is about 2 degrees of visual angle (covering about 8 letters, depending on the font and script). During reading, saccade size is very much dependent upon the difficulty of text, whereas in scene

perception, image clutter predicts fixation duration and saccade latency (Morrison & Rayner, 1981).

Readers are able to take in more information than just what is situated in the current fixation. In visual search and in reading, the preview benefit allows viewers to perceive and process small amounts of information in the parafovea. There are three distinct regions of eye perception: the fovea, the parafovea, and the periphery. Rayner (2009) defines the fovea as 2 degrees in the center of vision, the parafovea as the fovea plus 5 degrees to either side of fixation, and the periphery as anything beyond the parafovea. The preview benefit allows readers to access and integrate upcoming information prior to directly fixating it (see e.g., Ashby & Rayner, 2004; Balota, Pollatsek, & Rayner, 1985; Briihl & Inhoff, 1995; Chace, Rayner, & Well, 2005; McConkie & Zola, 1979; Rayner, McConkie, & Zola, 1980a).

When discussing eye movements in text and imagery research, it is important to understand the systematic differences that are inherent between reading and scene perception though the same visual system is performing the comprehension task. Of the differences between reading and scene perception, the most prominent are that in scene perception, fixations tend to be longer, saccades are larger, and the preview benefit is also larger. These size differences have a remarkable impact on speed of processing since more information can be taken in per fixation in scenes, depending complexity or quantifiable clutter. Whether the display is ambiguous or not, when viewing multimedia, deciding where to allocate attention is key to processing speed and accuracy. The representation of meaning from text that readers form when processing ambiguity in multimedia should be able to account for the need to sustain meaning from both the image source and the text source in order to be able to understand how the two sources are contextually connected.

No doubt, imagery can be a powerful source of information. Stephens (1998) argues that technology has given images the strength to overpower writing as a medium of information transmission, in much the same way that literacy overthrew the need for extensive memory (for transmitting histories, for example). Although this strong claim makes its point about the importance of imagery, it is wise to be skeptical of an all-or-nothing approach. Although some logical examples of important imagery systems come to mind (e.g., ancient Egyptian hieroglyphs), it is not likely that modern writing should fall to pictures. Glenberg and Langston (1992) assert more moderately that images act as motivators to attend more to text and that they "can assist in the construction of a mental model because the structure of the picture (the relations between the parts) is often identical to the required structure of the mental model" (p. 5). However, not all images are beneficial to learning; choosing pictorial elements is equally as crucial as choosing the proper words in writing. When viewers understand relationship between text and images, they may achieve a richer concept of the display and a better mental model overall. This may especially be the case with less proficient readers who rely more heavily on imagery in the presence of confusing language.

When carefully implemented, dual-coded information from text and images has positive effects on memory (e.g., Glenberg, 1979; Greene, 1989). For example, Levin, Anglin, and Carney (1987) suggested that learning is facilitated when people make use of organizational graphs or when images offer concrete examples for novel or less comprehensible text. Schieter and Eitel (2010) investigated how text and images affected learning for technical information; in this experiment, readers were asked to read and show understanding of how the human heart functions. Not only were participants better able to comprehend the passages of text when the image offered explicit cues to show the relationship of the image to the text, but the images were

also looked at earlier in the temporal analysis relative to the images that had no explicit cue. There is obvious merit to having graphics for text that is dense and difficult to understand: images can explicitly serve the role of guiding attention to language regions that may be most helpful in reading comprehension (as in the example of understanding a scientific display of the human heart). In the current investigation, I seek to understand whether or not this holds true for shorter, garden-path sentences for readers of varying language proficiency.

According to Brookshire, Scharff, and Moses (2002), when framed properly, imagery can have enormous effects on comprehension and can "literally replace a large number of words" (p. 323). On the other hand, Cianciolo (1970) strongly warns against imagery that is too distracting (for example, in children's books) as the purpose of books is to be read. (The importance and motivation of "wordless books" in emergent literacy classrooms as a means to strengthen and encourage literacy skills should not be discounted.) Fang (1996) maintains that images in children's books help keep the young readers engaged and curious about the text (a direct disagreement with Ciancolo). Peeck (1974) investigated the role of images and text in comic strips for young readers and found that in both an immediate and week-long delayed memory assessment, the children in the congruent text-and-image condition retained the most information about the comic overall. Multimedia continues to hold an important place in other linguistic realms, such as in language learning classrooms, largely due to the ability to transmit information through a non-language modality (Jones & Plass, 2002). For example, in Chun and Plass (1996) L2 readers learned more new vocabulary when they were presented with material as text and images (vs. text + videos or text only). The authors refer to this as a "hypermnesia effect" whereby, images are remembered best, while words along tend to be forgotten and attrite over time.

Researchers have proposed a Picture Superiority Effect (Paivio, 1971, 1986; Paivio, Rogers, and Smythe 1968) whereby images are recalled better and understood more easily than text alone. These effects have been demonstrated in experimental cognitive tasks from matching paradigms, free recall, reading comprehension, etc. Recently, for example, in a foreign word-learning task, Carpenter and Olson (2011) demonstrated that new words and their reference images were better learned than new words and their translation; interestingly, participants in their experiments were explicitly instructed not to be overconfident in their reliance on the facilitative power of imagery. These results imply the subjective power of imagery on language: images can serve as beneficial learning tools, so long as the learner is not overconfident in their reliance on them. The Picture Superiority Effect also claims that forming a mental image of a word is more difficult than viewing an image and coming up with language to accompany or describe it (Snodgrass, Wasser, Finkelstein, & Goldberg, 1974). Put differently, the Picture Superiority Effect hypothesizes that imagery evokes language, and thus activates both the visual and linguistic codes within DCT. If this is in fact the case, then the present studies should demonstrate significant effects of imagery on ambiguous sentence processing. However, research demonstrates that L1 and L2 readers do not have the same processing capabilities. Much is dependent upon the availability of syntactic knowledge in the L2. To further discuss, I turn to the Shallow Structure Hypothesis.

Chapter 4: L2 Sentence Processing and The Shallow Structure Hypothesis

The shallow structure hypothesis (SSH) (Clahsen & Felser 2006a,; Felser & Clahsen, 2009) claims that L2 readers are less able to understand long-distance syntactic dependencies, such as the kind present in garden-path sentences. SSH suggests that this shallow dependency resolution causes disruption in the ability to establish properly assigned dependencies. The SSH suggests that L2 readers are particularly susceptible creation of poor long-distance syntactic dependencies because they lack the ability to create the necessary hierarchical syntactic structure. Clahsen and Felser (2006b) maintain that L2 speakers who acquired their L2 long after the L1 use different processing mechanisms in their L2 than native speakers. It is not that nonnative speakers cannot form these dependencies at all, however, instead that they are less able to form them across words and are more restricted to local domains between close constituents (such as within word segmentation). SSH argues that although both native and nonnative speakers have two different routes for computing ambiguous sentence interpretations, the shallow processing route may is more prevalent due to the restricted knowledge and use of the L2. Although the SSH does not speak to the influences of exralinguistic information, it is the main goal of the work herein to discover whether the presence of language-free disambiguating information may help L2 readers better determine deep syntactic structure connections for decreased likelihood of being garden-pathed.

At its core, SSH is a variant of GE Theory for L2 readers; it holds a similar assumption for garden-path sentence processing: readers result in unfaithful representations that are predictable. SSH posits that syntactic processing is qualitatively different for native and nonnative speakers of a language. According to SSH, L2 online reading patterns are different than L1 readers due to their weaknesses in L2 grammar structure, which causes L2 readers to

have an over-reliance on knowledge of pragmatics. Using self-paced reading and translation tasks, Lim and Christianson (2013a,b) tested the bounds of SSH in investigating how L2 readers process L2 input with both comprehension and translation tasks. Building upon past studies, the current research aims to determine how readers process DO/S garden path sentences when those sentences are encountered together with imagery. Furthermore, it also compares the effects of images as context for garden-path sentences to textual contexts to better understand the relationship of ambiguous language and its image referent. Finally, it also compares performance on these tasks by native English speakers to that of English L2 speakers.

To our knowledge, these are the first eye tracking studies to explore garden-path sentence comprehension in conjunction with images for the purpose of comparing native and nonnative speakers. The findings will have broad applications both in sentence processing (L1 and L2) and multimedia research. Using garden-path sentences for which I can predict precisely the nature of misinterpretations allows us to measure in a very controlled way the effect of images on language processing. The overarching research question is as follows: How do images impact the interpretation of garden-path sentences? More specifically, how well can readers keep the representations of images and texts active and separate in memory (Experiment 1)? How do image-based contexts presented prior to garden-path sentences affect comprehension (Experiment 2)? Do linguistic contexts presented prior to garden-path sentences differ from image-based contexts in their effect on comprehension (Experiment 3)? In each case, both the eye movement patterns and comprehension rates of native and non-native English speakers will be compared.

Chapter 5: Experiment 1

Experiment 1 was designed to investigate how well readers can keep linguistic and visual interpretations separate and active for comparison. Experiment 1 used already-existing sentence items from Christianson et al. (2006) and Christianson et al. (2001) and had 3 manipulated, independent variables: sentence ambiguity (ambiguous vs. unambiguous), order of information presentation (image first vs. sentence first), and image interpretation (GP-consistent vs. GP-inconsistent). I investigated these variables with both native language (L1) and nonnative language (L2) readers to have an understanding of image-text comprehension for a variety of readers. In an experimental paradigm that employed eye-tracking methodology, the participant's task was to read and view the image and sentence stimuli and then to decide if the picture and the sentence were of the same event or not by answering a forced-choice yes/no question. The motivation for this task was: 1) to establish baseline reading patterns for L1 and L2 participants in the garden-path sentence and image paradigm, 2) to use both online (eye movement and reaction time) and offline measures (responses to the question) in statistical analyses to better understand the nature of the (mis)parse, and 3) to compare the results herein results to those of previous studies as a principled way to further study garden-path sentence processing with extralingusitic information. When participants are presented with an image that is consistent with the syntactically-licensed interpretation, their response should be that the image and the sentence match. A wrong response to this question is an indicator that one of the sources (pictorial or linguistic) has stronger encoding than the other.

Experiment 1 Predictions

In line with the previously reviewed studies, I predict that unambiguous sentences should cause readers to have faster processing times. Imagery presented prior to ambiguous language

should help guide the readers' attention in the ambiguous text and could perhaps help the reader avoid being garden-pathed (or at least, lessen the lingering tendency of the wrong interpretation). I predict that the visual code may give both L1 and L2 readers more frames of reference with which to parse and understand garden-path sentences. More specifically, having the correct imagery presented before the ambiguous sentence should lead to higher accuracy on the comprehension question.

Method

Participants. Seventy-two participants from the University of Illinois community were recruited for this experiment. Thirty three were native speakers of English, thirty one were nonnative speakers of English, and eight participants were excluded due to experimenter error or withdrawing from the experiment. Native language was not a specifically controlled factor in this experiment. The following native languages were represented among the 31 nonnative English participants: Chinese (13), Korean (4), Spanish (4), Hindi (2), Polish (2), French (2), Malay (1), Serbian (1), Turkish (1), and Yoruba (1). On a self-report of English proficiency 48% rated themselves as "average," 32% as "very good," and 19% "excellent." Within the nonnative readers, the average age was 25 years, with 41% male participants and 59% female participants. Mean scores on the English cloze test were 85.15% (12.14% standard deviation); the minimum score was 47.50% and the maximum score was 100%. The cloze test, used with permission from the lab of Guili Dussias at Pennsylvania State University, is a standardized metric of a nonnative speaker's proficiency of English. The assessment consists of a block of text with certain words removed. The participant's task is to replace the missing words as an assessment vocabulary and context understanding. Cloze scores were not significant predictors in any of the models of online eye movements and the models of offline accuracy/reaction time models. Due to this and

the unnecessary complexity that the cloze scores added to the results, L2 language proficiency as measured by the cloze test was removed from the analyses.

Materials. Seventy-two token sets were constructed of garden path sentences and accompanying images, which were hand-sketched by an artist from the University of Illinois community. Participants read 72 experimental items and 72 filler items in randomized order (see *Table **1***).

Table 1: Experiment 1 Factorial Design

	Ambiguous Sentence	Unambiguous Sentence
GP-Consistent Image	 *While Anna dressed the baby that was small and cute spit up on the bed.*	 *While Anna dressed, the baby that was small and cute spit up on the bed.*
GP Inconsistent Image	 *While Anna dressed the baby that was small and cute spit up on the bed.*	 *While Anna dressed, the baby that was small and cute spit up on the bed.*

For clarity, RAT sample sentences are presented in 13) and OPT sentences are presented in 14). (A full set of experimental and filler items are available in Appendix A: All Stimuli).

13) RAT verb sentence example:

Ambiguous: *While Jim bathed the child that was happy and pudgy giggled with delight.*

Unambiguous: *While Jim bathed, the child that was happy and pudgy giggled with delight.*

14) OPT verb sentence example:

Ambiguous: *While the man hunted the deer that was fast and graceful ran /into the woods.*

Unambiguous: *While the man hunted, the deer that was fast and graceful ran /into the woods.*

Filler sentences were a mix of simple and complex sentences, and comprehension questions were presented to participants after each filler sentence as a way to gauge their ability to remain on task. No feedback was given to participants on their accuracy of any of the items. Overall, participants were highly accurate on the filler items. Mean accuracy for native speakers of English was 93% (0.25) and 89% (0.31) for nonnative speakers.

Norming. The sentence and image pairs were normed by forty-two participants who did not participate in the experiment. This was done to ensure that the GP-consistent and GP-inconsistent images were drawn differently enough from one another to match or not match the sentence interpretation. Norming participants were presented with the sentence-image pairs and were asked how closely the meanings of the image and sentence matched on a 1-7 Likert scale. Average matching score for the ambiguous sentence-image frames was 4.71 (1.24), and 5.61 (0.74) for the unambiguous sentence-image frames. These differences were significant in a paired t-test ($t = -4.72$, $df = 71$, $p < .0001$). See Appendix B: Norming, Experiment 1.

Design. Experiment 1 was designed such that participants saw all seventy-two experimental items in the 2 x 2 x 2 fully factorial design: sentence ambiguity (ambiguous sentence vs. unambiguous sentence), image interpretation (GP-consistent vs. non GP-inconsistent), and order condition (image first vs. sentence first). Nine items were seen in each of the possible eight ways.

Apparatus. During the test trials, a desktop mounted SR Eyelink 1000 eye tracker recorded participants' eye movements at 1000 Hz. Viewing was binocular, but only the position of the right eye was sampled. Participants viewed text in 14 point Courier New font and were seated 69 centimeters away from the display monitor. For this font and distance, approximately 3 characters subtended 1° of visual angle. To stabilize the reader, a chin rest with forehead rest was used.

Procedure. Participants completed the experiment individually, and the entire session lasted approximately 45 minutes. After consent forms were signed, at the beginning of the eye-tracking session, a 9-point calibration was performed. If the calibration was inaccurate, a new calibration was conducted. Calibration accuracy was monitored during the course of the experiment by the experimenter, and a new calibration was performed whenever accuracy was deemed unsatisfactory. Once the experiment began, participants were given verbal instructions to read each sentence silently and then to view the images for comprehension. Once participants comprehended both the sentence and the image, they pressed a button that advanced them to the offline question. On experimental trials, the question was "*Did the image and the sentence match?*" On filler trials, the question varied as a simple sentence comprehension question to ensure that participants were staying on-task. Experimental items were randomly interleaved with filler images and sentences. Filler images were simple line drawings, also used in Christianson (2002; dissertation) and Christianson, Luke, & Ferreira (2010). All experimental and filler trials were not blocked; they were automatically randomized by the experimental program. To better gauge the nonnative speakers' English proficiency, the second language (L2) readers were given an English proficiency cloze assessment as well as a language survey, which

included a self-report of English proficiency. At this point, participants were paid, debriefed, and dismissed.

Results

Eye movement analyses were conducted for five different regions: 1) the subordinate verb region 2) the ambiguous noun region, 3) the disambiguating verb region, 4) the spillover region, and 5) the image region. The subordinate verb region consisted of the main verb with or without the comma (i.e., the ambiguous or unambiguous factor). The ambiguous noun region consisted of the main clause subject. The disambiguating verb region was the main clause verb. The spillover region was the rest of the sentence. The image region was simply the entire image that was displayed to participants on each trial (see *Table **2***).

Table 2: Garden-Path Sentence Eye Movement Regions

	1) Subordinate Verb	2) Ambiguous Noun		3) Disambiguating Verb	4) Spillover Region
While Anna	*dressed*	*the baby*	*that was small and cuddly*	*spit up*	*on the bed.*

While Anna dressed / the baby / that was small and cuddly / spit up / on the bed.

Up to four eye-movement measures were examined for the three sentential regions of interest. *First fixation duration* is the duration of the first fixation and is a measure of lexical recognition. *Gaze duration*, or first-run dwell time, is the summed duration of all fixations in a region from when a region is first entered until it is first exited (a measure of lexical access). *Go-past time*, or regression path duration, is the summed duration of all fixations in a region from when it is first entered until it is first exited to the right. *Total time* is the summed duration of all fixations in a region during the trial (an indice of processing time). The four duration variables are presented in milliseconds. The only eye movement variable used and analyzed for the image region is total time (as the other eye movements are not interpretable on an image).

Continuous measurements were trimmed so that any values beyond three standard deviations from the mean were removed; continuous reading time and reaction time data were also log transformed and centered to reduce collinearity. Both online (eye movement) and offline (accuracy and reaction time) data were analyzed using linear mixed effects regression models (LME) (Baayen, Davidson, & Bates, 2008). The R software package was used for model fitting with the lmer() function of the lme4.0 package (Bates, Maechler, & Bolker, 2011). The lmer() function does not provide p-values for the duration measures, and any *t*-value greater than 2 or less than -2 is considered significant at $p < .05$. Binomial measures of accuracy (1 being an accurate response, and 0 being inaccurate) were analyzed using logit mixed models (Jaeger, 2008), in which significance is demonstrated with *p*-values less than .05. Models included the maximum random effects structure justified by the design with the pre-set conditions as fixed effects: sentence ambiguity, image ambiguity, and presentation order. Each model also included random slopes and intercepts for participants and items so that all within subjects and within items factors are allowed to vary by subjects and items. The following sections outline the online analyses at the three interest region levels; offline measurements of accuracy and reaction time were then analyzed.

Online data: Eye movements.

Subordinate Verb Region

L1 speakers.

Table 3: Mean Reading Measures on the Subordinate Verb Region for L1 Readers (Experiment 1)

	Image First								Sentence First							
	GP Consistent Image				GP Inconsistent Image				GP Consistent Image				GP Inconsistent Image			
	Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence	
First Fixation	182	(91)	171	(90)	178	(117)	177	(87)	204	(83)	195	(89)	202	(90)	194	(97)
Gaze Duration	199	(113)	175	(123)	188	(129)	194	(117)	209	(128)	198	(129)	213	(125)	216	(126)
Go-past time	422	(305)	451	(294)	444	(419)	444	(309)	510	(411)	558	(449)	493	(351)	543	(392)
Total time	438	(376)	378	(302)	442	(306)	349	(269)	591	(464)	518	(407)	615	(456)	528	(368)

As predicted, the results demonstrate that L1 readers had significantly shorter first fixation durations (b = -30.90, SE = 8.06, t = -3.84) and gaze durations (b = -29.09, SE = 10.02, t = -2.90) on the subordinate verb region when the sentences were unambiguous. L1 readers had significantly longer gaze durations (b = 24.83, SE = 10.02, t = 2.48), go-past times (b = 73.10, SE = 18.81, t = 3.89), and total times (b = 115.38, SE = 17.96, t = 6.42) on the subordinate verb region when the sentence was presented first. These main effects were qualified by an interaction arose such that L1 readers had significantly longer first fixation durations (b = 30.68, SE = 11.39, t = 2.70) and gaze durations (b = 34.85, SE = 14.17, t = 2.46) on the subordinate verb region when the GP inconsistent image was presented with the unambiguous sentence. This result indicates that for L1 readers, convergent images and text takes time to integrate. This effect is only apparent in the GP-inconsistent image and unambiguous sentence condition because perhaps the being garden-pathed in the ambiguous sentence condition disallows integration.

L2 speakers.

Table 4: Mean Reading Measures on the Subordinate Verb Region for L2 Readers (Experiment 1)

	Image First								Sentence First							
	GP Consistent Image				GP Inconsistent Image				GP Consistent Image				GP Inconsistent Image			
	Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence	
First Fixation	209	(116)	197	(122)	206	(113)	201	(112)	225	(114)	211	(122)	232	(120)	213	(131)
Gaze Duration	263	(174)	228	(153)	240	(157)	238	(160)	295	(198)	280	(213)	304	(229)	297	(235)
Go-past time	531	(371)	626	(481)	554	(429)	667	(521)	599	(495)	825	(622)	631	(547)	847	(634)
Total time	606	(436)	508	(345)	628	(521)	525	(428)	987	(743)	822	(597)	937	(437)	905	(672)

Several main effects arose for L2 readers on the subordinate verb region. Similar to L1 readers, L2 readers had significantly shorter gaze durations (b = -27.79, SE = 11.62, t = -2.35), go-past times (b = 55.52, SE = 21.02, t = 2.64), and total times (b = -54.48, SE = 20.95, t = -2.60) on the subordinate verb region when the sentences were unambiguous. L2 readers also had significantly longer first fixation durations (b = 17.86, SE = 8.73, t = 2.05), gaze durations (b = 25.31, SE = 11.62, t = 2.18), and total times (b = 189.63, SE = 20.95, t = 9.05) on the subordinate verb region when the sentence was presented first. The main effect of order of presentation is expected due to the fact that readers have no background context with which to understand the garden-path sentences. There were no interactive effects on the subordinate verb region for L2 readers. See Appendix C for full LME analysis.

Ambiguous Noun Region

L1 Speakers.

Table 5: Mean Reading Measures for the Ambiguous Noun Region, L1 Readers (Experiment 1)

	Image First								Sentence First							
	GP Consistent Image				GP Inconsistent Image				GP Consistent Image				GP Inconsistent Image			
	Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence	
First Fixation	184	(93)	188	(89)	195	(91)	197	(103)	207	(90)	200	(82)	198	(84)	192	(80)
Gaze Duration	198	(108)	203	(107)	241	(158)	210	(122)	257	(156)	235	(128)	258	(157)	220	(112)
Go-past time	570	(661)	512	(410)	665	(643)	458	(417)	592	(409)	579	(305)	611	(420)	591	(321)
Total time	533	(389)	502	(346)	612	(403)	450	(301)	734	(489)	531	(381)	791	(683)	519	(387)

L1 readers showed inflated first fixation durations (b = 26.07, SE = 7.66, t = 3.40), gaze durations (b = 48.73, SE = 9.57, t = 5.09), and total times (b = 128.99, SE = 21.24, t = 6.07) on the ambiguous noun region when the sentence was presented first. This main effect continues to arise in the analyses, due to the fact that readers are using extra processing times to understand the garden-path sentence without image context. Within the first few trials of the experiment, readers would have already understood that on certain half of the time they would see an image first and vice versa. When readers encounter a sentence-first trial, they must devote extra processing time to it for better comprehension. Lastly for this region, L1 readers had shorter go past times (b = -60.14, SE = 29.22, t = -2.06) and total times (b = -67.70, SE = 30.00, t = -2.26) on the ambiguous noun region for a GP inconsistent image and an ambiguous sentence. This did not interact with presentation order.

L2 readers.

Table 6: Mean Reading Measures on the Ambiguous noun region, L2 readers (Experiment 1)

	Image First								Sentence First							
	GP Consistent Image				GP Inconsistent Image				GP Consistent Image				GP Inconsistent Image			
	Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence	
First Fixation	234	(126)	218	(106)	216	(112)	227	(129)	231	(102)	228	(102)	229	(105)	247	(178)
Gaze Duration	308	(206)	301	(220)	293	(207)	290	(180)	370	(244)	314	(170)	355	(220)	335	(237)
Go-past time	777	(647)	781	(687)	818	(658)	697	(546)	870	(584)	789	(613)	842	(613)	865	(565)
Total time	777	(539)	686	(502)	874	(643)	600	(406)	1168	(832)	786	(541)	1030	(780)	826	(630)

Again, the facilitation of reading less-confusing sentences is demonstrated in that L2 readers spent less total time on the ambiguous noun region when the sentence was unambiguous (b = -56.08, SE = 24.17, t = -2.32). Additionally, L2 readers demonstrated shorter first fixation durations (b = -16.05, SE = 8.04, t = -2.00) yet longer total times (b = 49.61, SE = 24.17, t = 2.05) on the ambiguous noun region when the image was GP-inconsistent. This main effect indicates that L2 readers were facilitated by the GP-inconsistent images on the ambiguous noun region, perhaps due to a reduction of spillover effects, but total processing time was still longer due to integration of image and sentence content. L2 readers had inflated gaze durations (b = 47.46, SE = 12.30, t = 3.86) and total times (b = 185.32, SE = 24.17, t = 7.67) on the ambiguous noun region when the sentence was presented first.

Interactions arose such that L2 readers spent less total time on the ambiguous noun region when the sentence was unambiguous and the image was GP-inconsistent (b = -113.19, SE = 34.19, t = -3.31), irrespective of presentation order. Additionally, L2 readers had shorter gaze durations (b = -35.55, SE = 17.40, t = -2.04) and total times (b = -137.54, SE = 34.19, t = -3.49) on the ambiguous noun region when reading an unambiguous sentence when the GP-inconsistent image was presented first. L2 readers spent less total time on the ambiguous noun region when the image was first and the image was GP-inconsistent (b = -119.27, SE = 34.19, t = -3.49). A three-way interaction arose such that L2 readers spent less total time on the ambiguous noun region when the image was presented first, when the image was GP-inconsistent, and the sentence was unambiguous (b = 208.97, SE = 48.35, t = 4.32). This is consistent with the notion that only in the GP-inconsistent image and unambiguous sentence condition do the image and the sentence match. This is the only condition where late-stage integration of the image and sentence can occur. Given that the instructions of the experiment were not to integrate the image and the

sentence (but to keep them separate to determine whether or not they match), it seems that this late processing occurs automatically, as long as the mis-match between the image and the sentence does not block it.

Disambiguating Verb Region

L1 readers.

Table 7: Mean Reading Measures, Disambiguating Verb Region, L1 Readers (Experiment 1)

	Image First								Sentence First							
	GP Consistent Image				GP Inconsistent Image				GP Consistent Image				GP Inconsistent Image			
	Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence	
First Fixation	244	(107)	249	(111)	239	(113)	241	(94)	243	(93)	249	(114)	251	(110)	253	(121)
Gaze Duration	279	(143)	290	(172)	270	(135)	269	(121)	282	(128)	282	(146)	279	(144)	288	(153)
Go-past time	725	(573)	494	(538)	758	(609)	458	(358)	738	(578)	661	(589)	810	(734)	548	(451)
Total time	498	(353)	426	(289)	431	(300)	391	(243)	488	(350)	435	(275)	525	(404)	453	(301)

The effects on the disambiguating verb region were minimal. L1 readers had reduced gaze durations (b = 22.99, SE = 10.59, t = 2.17) and total times (b = 99.73, SE = 20.85, t = 4.78) on the disambiguating verb region when the image was presented first. Although there are no other significant effects present on this region, this main effect demonstrated facilitative power on late processing measures of the disambiguating verb.

L2 readers.

Table 8: Mean Reading Measures, Disambiguating Verb Region, L2 Readers (Experiment 1)

	Image First								Sentence First							
	GP Consistent Image				GP Inconsistent Image				GP Consistent Image				GP Inconsistent Image			
	Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence	
First Fixation	290	(126)	289	(181)	271	(105)	274	(122)	279	(108)	279	(131)	277	(110)	271	(124)
Gaze Duration	359	(190)	367	(261)	356	(220)	343	(193)	360	(199)	359	(196)	350	(182)	333	(202)
Go-past time	623	(580)	507	(466)	643	(484)	516	(492)	727	(394)	534	(504)	633	(504)	552	(643)
Total time	621	(455)	648	(549)	673	(470)	613	(476)	817	(676)	696	(493)	767	(596)	679	(518)

L2 readers also had reduced total times on the disambiguating verb region when the image was first, but only when it was paired with ambiguous sentence (*b* = -60.89, *SE* = 29.49, *t* = -2.07). This interaction was not modulated by what kind of image was presented them, indicating that L2 speakers relied on the image in the presence of an ambiguous sentence whether or not the image was helpful.

Spillover Region

L1 Readers.

Table 9: Mean Reading Measures, Spillover Region, L1 Readers (Experiment 1)

	Image First								Sentence First							
	GP Consistent Image				GP Inconsistent Image				GP Consistent Image				GP Inconsistent Image			
	Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence	
First Fixation	219	(108)	217	(110)	235	(116)	236	(114)	219	(121)	227	(104)	224	(126)	208	(91)
Gaze Duration	320	(215)	320	(182)	320	(214)	369	(239)	322	(229)	329	(222)	317	(225)	318	(227)
Go-past time	1707	(527)	1563	(827)	1658	(715)	1408	(897)	2270	(991)	1694	(713)	2197	(969)	1764	(767)
Total time	410	(302)	377	(224)	384	(242)	414	(275)	401	(343)	400	(290)	435	(295)	397	(309)

In the region right after the disambiguating verb, a two way interaction between order condition and sentence ambiguity condition appears on go-past time: L1 readers have shorter go-past times when the image is presented before an ambiguous sentence, regardless of image type (b = -81.71, SE = 40.53, t = -2.02). This result demonstrates that L1 readers are facilitated in processing in the final stages of ambiguous sentence reading when any kind of image is presented before a confusing sentence.

L2 Readers.

Table 10: Mean Reading Measures, Spillover Region, L2 Readers, (Experiment 1)

	Image First								Sentence First							
	GP Consistent Image				GP Inconsistent Image				GP Consistent Image				GP Inconsistent Image			
	Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence	
First Fixation	269	(118)	264	(129)	259	(107)	264	(116)	262	(110)	267	(118)	262	(110)	258	(138)
Gaze Duration	515	(365)	505	(367)	476	(314)	546	(409)	500	(381)	487	(370)	466	(326)	476	(333)
Go-past time	2392	(1294)	2061	(1270)	2648	(1722)	1859	(1229)	3995	(2549)	2808	(1507)	3603	(2396)	2829	(1546)
Total time	790	(610)	762	(545)	782	(586)	747	(586)	951	(800)	806	(647)	897	(703)	768	(630)

Overall, L2 readers demonstrate a main effect of presentation order on longer go-past times (b = 31.78, SE = 35.82, t = 6.47) and longer total times (b = 58.71, SE = 20.96, t = 2.80) within the spillover region when the sentences are presented first. This main effect was qualified by a three-way interaction: presenting a GP-inconsistent image before an unambiguous sentence led to shorter go-past times (b = 169.76, SE = 71.64, t = 2.37). Put differently, when the visual and linguistic code matched in interpretation and the visual code was presented prior to the sentence, L2 readers were facilitated in sentence wrap-up processing.

Image

Table 11: Mean Dwell Times on the Image for Both L1 and L2 Readers (Experiment 1)

	Image First								Sentence First							
	GP Consistent Image				GP Inconsistent Image				GP Consistent Image				GP Inconsistent Image			
	Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence	
L1 Readers	3452	(2807)	3393	(2034)	3676	(2009)	3700	(2181)	3263	(2043)	3164	(2259)	3265	(2050)	3061	(1728)
L2 Readers	3635	(2193)	3713	(2577)	4290	(2712)	4017	(2876)	3208	(2036)	3146	(1936)	3238	(1828)	3308	(2041)

L1 readers.

L1 readers had longer total dwell times on the image when it was GP-inconsistent (*b* = 18.61, *SE* = 6.76, *t* = 2.76), yet they spent less total times looking at the image when it was presented second (*b* = -38.70, *SE* = 6.74, *t* = -5.74). These two variables interacted such that L1 readers spent the most time looking at the image when it was presented first and when it was GP-

inconsistent (b = -22.38, SE = 6.76, t = -3.31). It is important to note that the readers would not yet be aware that the image would be inconsistent with the sentence, however, so these images must have been more salient somehow.

L2 speakers.

Similar to the L1 readers, L2 readers spent more time looking at the image when it was GP-inconsistent (b = 38.17, SE = 8.30, t = 4.60) and when the image is presented first (b = -80.38, SE = 8.30, t = -9.68). The interaction of these variables was the same for L2 readers and L1 readers: L2 readers spent the most time looking at the image when it was presented first and when it was GP-inconsistent (-20.93, SE = 8.30, t = -2.52). Once again, these data demonstrate the power on intrinsic eye movement data for having imagery prior to reading garden-path sentences.

Offline data: Accuracy and reaction time.

Accuracy

Experimental conditions resulted in all significant main effects and interactions for both L1 and L2 readers, in the same directions. For ease of discussion and interpretation, I focus on the three-way interaction here. Although having an ambiguous sentence made accuracy overall quite low, accuracy was better for both L1 (b = 0.32, SE = 0.03, z = 11.36, $p < 0.001$) and L2 readers (b = 0.15, SE = 0.02, z = 7.49, $p < 0.001$) when an ambiguous sentence was paired with a GP-inconsistent image and the image was presented first. This finding is robust and consistent with the image dwell times previously reported: having a GP-inconsistent image presented first causes readers to view it longer and it also leads to higher accuracy. As with the image dwell time, the interactive effect of sentence type here is perhaps spurious, because if the image is

presented before the sentence, there is no way that this could possibly affect image-viewing patterns. *Figure **1*** and *Figure **2*** demonstrate graphically the direction of the interactions.

Figure 1: L1 readers' Accuracy by Condition (Experiment 1)

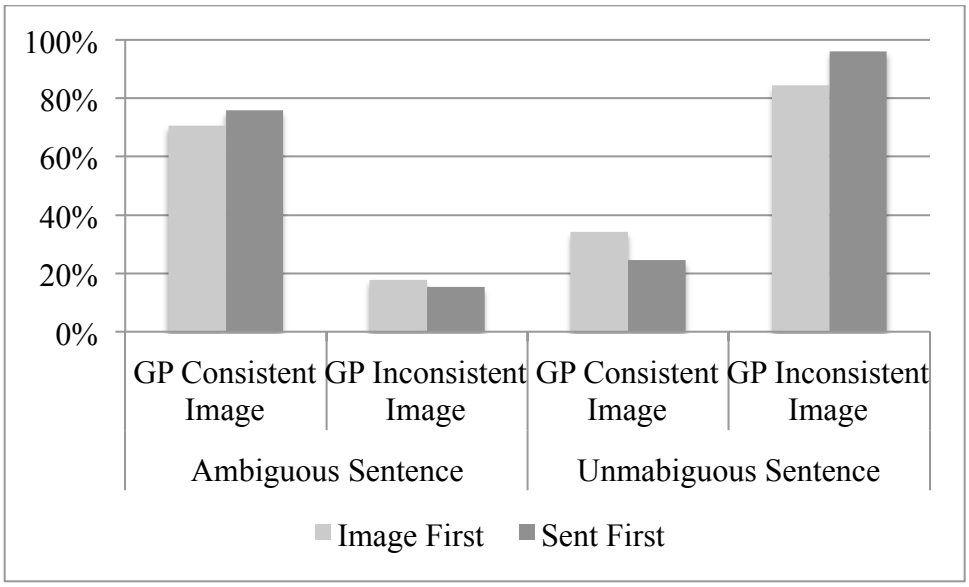
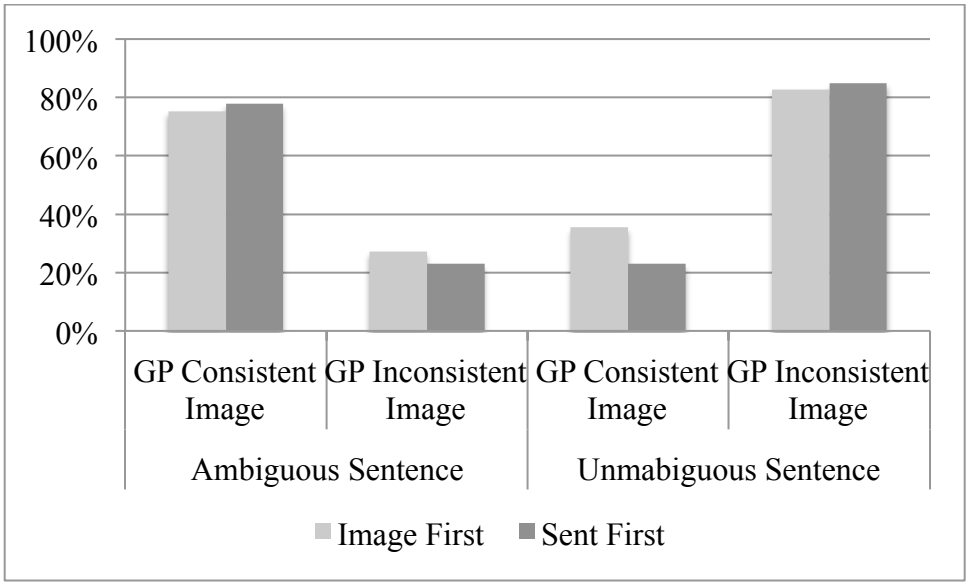


Figure 2: L2 readers' Accuracy by Condition (Experiment 1)



Reaction Time

Table 12: Reaction Time to Question for L1 and L2 Readers (Experiment 1)

Reaction Time	Image First								Sent First							
	GP Consistent Image				GP Inconsistent Image				GP Consistent Image				GP Inconsistent Image			
	Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence		Ambiguous Sentence		Unambiguous Sentence	
L1	1605	(1242)	1553	(1088)	1446	(1121)	1407	(1163)	1516	(1350)	1462	(1842)	1436	(1571)	1263	(828)
L2	1740	(1393)	1552	(1263)	1842	(1114)	1632	(1274)	1604	(1383)	1621	(960)	1634	(1356)	1572	(1188)

As expected, there is a main effect of sentence ambiguity on longer reaction time measures for both L1 (b = -0.01, SE = 0.00, t = -4.76) and L2 (b = -0.01, SE = 0.00, t = -5.77) readers. No other main effects were present. A model was run to test the relationship between accuracy and reaction time, and found no significant effects for either L1 (b = -22.24, SE = 23.30, t = -0.96) or L2 (b = 1.19, SE = 20.47, t = 0.06) readers.

Discussion: Experiment 1

Experiment 1 found that overall, as expected, both L1 and L2 readers required less time to process the subordinate verb and disambiguating verb regions in unambiguous sentences. Additionally, both L1 and L2 readers read sentences more slowly when they were presented before the image. Both L1 and L2 readers got a boost in processing on the disambiguating verb region of the sentence when the image was presented first. This result is striking in light of the result that also having the image first boosted accuracy. Not only did all readers get processing advantages in reading the sentences, but also they were more accurate in keeping the sources distinctly separate, which is what was required to respond correctly.

Both L1 and L2 readers inspected GP-inconsistent images longer than GP-consistent images. This result is not easily interpretable as doing fine-grained image clutter comparison across images is beyond the scope of the current investigation. As previously mentioned, it is

obvious that the GP-inconsistent images are perhaps more salient in some way. I leave this determination to future work.

The offline measures demonstrate that both L1 and L2 participants were able to determine when an image and a sentence pair did match, however, the low accuracy results demonstrate that determining that a pair did not match proved to be very difficult. The current investigation seeks to understand how readers can make sense of ambiguous language to avoid being garden-pathed. As such, when looking at the accuracy results in the ambiguous sentence condition, when a GP-inconsistent image was present, both L1 and L2 readers were significantly better at determining that the two sources did not match when the image was presented first. This demonstrates the power of the garden-path sentence misanalysis: when image with the GP-inconsistent was presented second, readers were unable to revise the original, incorrect parse of the ambiguous sentence, even when provided with a correct visual representation. The goal of the offline task in Experiment 1 was to keep the two codes distinct and separate. In order to do this, readers had to maintain two streams of processing (visual and linguistic) for later comparison. These results point to the importance of imagery as a tool for visually grounding the context for subsequent language input.

Although the results of Experiment 1 are meaningful in beginning to understand multimedia with good-enough processing, more investigation is needed to determine if the imagery actually helps readers understand GP sentences better and if they can avoid the misparse. As such, Experiment 2 and Experiment 3 were carefully designed to delve deeper into the question of comprehension. The goal to establish a language-free context for less proficient readers has the potential to speak volumes about the power of text and imagery presentation, which has largely gone overlooked in educational and psycholinguistic research.

Chapter 6: Experiment 2

Experiment 1 presented evidence that viewing an image prior to reading a garden-path sentence facilitated sentence processing for native and non-native speakers in accuracy when experimental sentences were ambiguous. In order to more fully measure ambiguous sentence comprehension, and with the Experiment 1 results in mind, Experiment 2 was designed to further test ambiguous sentence comprehension with multimedia display. Experiment 2 was modified from Experiment 1 as follows. First, the image always preceded the sentence. Second, a total of three image variations were used: the image was either consistent with the garden-path interpretation of the sentence (GP-consistent image), was consistent with the non-garden-path interpretation (i.e., the correct interpretation) of the sentence (GP-inconsistent image), or was neutral with respect to the interpretation of the sentence (neutral image). This third image condition was implemented in order to test whether the correct or incorrect interpretation helped readers understand the garden-path, or whether any image at all was helpful. The sentences were either temporarily ambiguous (no comma present) or unambiguous (comma present). This resulted in a 2 x 3 factorial design with both native speakers and nonnative speakers. The question after each trial also differed from Experiment 1: instead of asking the participant if the sentence and image matched, a comprehension question was asked: *"Did Anna dress the baby?"* (cf. Christianson et al., 2001, 2006), the correct answer to which was always "no." Note that this question was specifically asked about the *sentence*, so that, if the sentence and image did not match, the image would need to be inhibited in the unambiguous condition, but integrated in the ambiguous condition. Either way, if the image is exploited to constrain the parse of the sentences, as in parallel parsing models (e.g., MacDonald et al., 1994), then evidence of effects of the image

on online reading times should be observable, either facilitatory or inhibitory, depending on the condition of any given item.

Note that in Experiment 1, the task was one that encouraged maintenance of distinct image and sentence representations to compare their meanings; correct "(mis)match" judgments (depending on the condition) signaled full reanalysis and accurate sentence interpretation along with maintenance of memory for the image. In contrast, answering a comprehension question requires integration of the image and the sentence. Of particular interest in Experiment 2 is how the different imagery manipulations, as a type of context, affect the online processing of the ambiguous sentence. Will context in the form of GP-inconsistent visual imagery trigger faster or more in-depth reanalysis processes? Or will the visual imagery's effects be limited to offline comprehension, i.e., high accuracy rates and/or faster response times compared to the neutral condition? In other words, when integration of images and text is beneficial, does this integration happen immediately, or is it delayed until post-interpretive processing?

Experiment 2 Predictions

In Experiment 1, readers had to keep the codes separately distinct, whereas in Experiment 2, integration should occur so that the GP-inconsistent image might protect the reader against being garden-pathed, whereas the GP-consistent image might prime or strengthen garden-pathing, both compared to the neutral condition. I predict that all readers should be less severely garden-pathed when a GP-inconsistent image is presented prior to an ambiguous sentence. The neutral imagery is intended to serve as a baseline against which to compare the effects of the GP-consistent and GP-inconsistent images on overall comprehension.

Method

Participants.

Eighty participants from the University of Illinois community were recruited for this experiment, none of whom participated in Experiment 1. Forty were native speakers of English and thirty were nonnative speakers of English. A total of ten participants were excluded due to experimenter error or withdrawing from the experiment. The following native languages were represented among the nonnative English participants: Bulgarian (1), Chinese (11), French (1), Japanese (2), Korean (7), Russian (2), Spanish (2), Swedish (1), Telugu (1), Turkish (2). On a self-report of English proficiency, 4% rated themselves as "below average," 22% as "average," 44% as "very good," and 30% as "excellent." For L2 readers, the mean age was 24 years, with 48% male participants and 52% female participants. The mean score on the English cloze test was 82.5% correct (SD = 3.59%). Similar to Experiment 1, the L2 proficiency cloze scores were not significant predictors of any of the online eye movement data or any of the offline accuracy or reaction time data. Due to this and to overly complicated models, the cloze scores were removed as factors from the LME analyses.

Materials.

Materials (both experimental and filler) used in Experiment 2 were the same as those used in Experiment 1, with two exceptions: (1) all items were followed by comprehension questions, as opposed to asking participants whether or not the picture and sentence interpretations matched, and (2) a neutral image was added to the experiment for the 2 x 3 factorial design. Neutral images were developed with the intent to establish a context that provides additional information in the form of imagery, yet does not intentionally lead towards or away from a particular interpretation of the experimental sentence. See *Table **13**: Experiment 2 Stimuli*.

Table 13: Experiment 2 Stimuli: Factorial Design

	Ambiguous Sentence	Unambiguous Sentence
GP-Consistent Image	 *While Anna dressed the baby that was small and cute spit up on the bed.*	 *While Anna dressed, the baby that was small and cute spit up on the bed.*
GP Inconsistent Image	 *While Anna dressed the baby that was small and cute spit up on the bed.*	 *While Anna dressed, the baby that was small and cute spit up on the bed.*
Neutral Image	 *While Anna dressed the baby that was small and cute spit up on the bed.*	 *While Anna dressed, the baby that was small and cute spit up on the bed.*

Norming:

The sentence and image pairs were normed by sixty Mechanical Turk participants who did not participate in the experiment. This was done to ensure that the GP-consistent, GP-inconsistent, and neutral images were different enough from one another to match, not match, or to be neutral with respect to the sentence interpretation. Norming participants were presented with the sentence-image pairs and were asked how closely the meanings of the image and sentence matched on a 1-7 Likert scale. Based on the norming results of Experiment 1, when an image and a sentence matched interpretations, participants should have responded “7”, indicating

a perfect match. Vice versa, for an image-sentence pair that did not match, a response of "1" was expected. For a neutral image and either an ambiguous or unambiguous sentence, a response of "4" was expected. Average matching scores were 6.49 (0.31), average mismatching scores were 1.98 (0.43), and average neutral scores were 4.49 (0.80). In comparison to the matching images and sentences, the neutral images paired with either an ambiguous or unambiguous sentence were significantly different ($t = 19.97$, $df = 71$, $p < 0.001$). This pattern and significance was the same for neutral images paired with either kind of sentence as compared to mismatching image-sentence pairs ($t = 22.67$, $df = 71$, $p < 0.001$). These results indicate the validity of the images for the purposes of this experiment.

Design.

The apparatus and procedure for Experiment 2 were the same as Experiment 1. All participants were instructed to answer the questions based on all the information given to them, not just the image or the sentence.

Results

Online Data: Eye Movements.

The following sections contain the online results from the L1 and L2 readers. Less than 0.05% of data were removed due to tracking loss. The data were treated in the same manner as in Experiment 1: outliers beyond three standard deviations from the mean were removed. For LME analyses, continuous variables were log transformed and mean centered. The LME analyses proceeded in the same fashion as Experiment 1. Once again, an example sentence divided by the regions is presented in *Table **14***.

Table 14: Experimental Sentence Divided into Areas of Interest

	1) Subordinate Verb	2) Ambiguous Noun		3) Disambiguating Verb	4) Spillover Region
While Anna	*dressed*	*the baby*	*that was small and cuddly*	*spit up*	*on the bed.*

Subordinate Verb Region.

Table 15: Continuous Reading Measures on the Subordinate Verb Region for L1 readers (Experiment 2)

	Ambiguous Sentence						Unambiguous Sentence					
	GP Consistent Image		Neutral Image		GP Inconsistent Image		GP Consistent Image		Neutral Image		GP Inconsistent Image	
First Fixation	188	(101)	195	(92)	202	(194)	185	(97)	189	(101)	187	(104)
Gaze Duration	216	(134)	221	(119)	228	(210)	206	(122)	219	(155)	207	(132)
Go-past time	500	(419)	496	(302)	475	(379)	552	(365)	506	(370)	502	(409)
Total time	590	(449)	566	(410)	575	(428)	472	(357)	471	(341)	414	(309)

L1 Readers

Analyses on the subordinate verb region reveal a main effect that L1 readers had longer first fixation durations (b = -13.51, SE = 3.06, t = -4.41), longer gaze durations (b = -18.65, SE = 3.67, t = -4.96), and longer total times (b = -107.81, SE = 8.19, t = -13.17) when the sentence was ambiguous (GP). This effect is straightforward and expected; there were no interactions.

L2 readers.

Table 16: Continuous Reading Measures on the Subordinate Verb Region for L2 Readers (Experiment 2)

	Ambiguous Sentence						Unambiguous Sentence					
	GP Consistent Image		Neutral Image		GP Inconsistent Image		GP Consistent Image		Neutral Image		GP Inconsistent Image	
First Fixation	206	(127)	198	(109)	208	(123)	201	(130)	200	(110)	199	(120)
Gaze Duration	249	(158)	243	(151)	257	(109)	247	(182)	247	(185)	230	(152)
Go-past time	567	(456)	556	(452)	601	(457)	628	(516)	610	(523)	653	(558)
Total time	784	(594)	784	(596)	845	(616)	588	(441)	667	(500)	574	(404)

Similar to the L1 readers, L2 readers had longer gaze durations (b = -12.61, SE = 5.55, t = -2.27) and longer total times (-98.22, SE = 10.47, t = -9.39) on the subordinate verb region when the sentence was ambiguous. When comparing the GP-consistent images and the GP-inconsistent images to the neutral image, L2 readers had longer total times on the subordinate verb region when they viewed neutral images (b = -29.75, SE = 14.83, t = -2.01). In Experiment 1, the GP-inconsistent images were speculated to be more visually salient somehow. The neutral images here appeared to have been similarly more salient to the readers in some way. But given that this speculation only held for L2 readers, it seems unlikely, and the difference should thus be viewed with caution. L2 readers also had longer total times on the subordinate verb region when the sentence was ambiguous and the image was GP-inconsistent (b = -70.60, SE = 29.64, t = -2.38). This indicates confusion, as the linguistic and visual codes clearly were not matching. The most salient difference in the subordinate verb region between ambiguous and unambiguous sentences is the lack of a comma in the ambiguous condition. It seems likely that the this interaction was due to the mismatch between the expectations set up by the GP-inconsistent image (e.g., Anna was dressing herself and therefore there should be a comma after the subordinate verb) and the absence of the expected comma. If this interpretation of the result is correct, then there is evidence that the L2 readers were more actively using the image contexts to generate predictions about upcoming linguistic material. It is possible that the previously mentioned inhibitory effect of the neutral image could even derive from this same source: the lack of apparent connection between the neutral image and sentence may have slowed reading on the subordinate verb, as the action described by that verb was not (generally) depicted in the neutral images (see Appendix D).

Ambiguous Noun Region.

L1 Readers.

Table 17: Continuous Reading Measures on the Ambiguous noun region for L1 Readers (Experiment 2)

	Ambiguous Sentence						Unambiguous Sentence					
	GP Consistent Image		Neutral Image		GP Inconsistent Image		GP Consistent Image		Neutral Image		GP Inconsistent Image	
First Fixation	230	(131)	235	(140)	232	(127)	237	(161)	248	(160)	232	(132)
Gaze Duration	274	(174)	274	(165)	282	(175)	278	(192)	286	(186)	269	(157)
Go-past time	756	(536)	741	(532)	778	(510)	778	(475)	818	(596)	760	(509)
Total time	742	(531)	747	(530)	783	(549)	626	(410)	664	(438)	587	(354)

On the ambiguous noun region, L1 readers had a main effect of longer total dwell times when the sentence was ambiguous (b = -88.94, SE = 10.25 t = -8.67), and longer first fixation durations when the image was neutral (in comparison to the GP-consistent and GP-inconsistent image) (b = -10.94, SE = 5.02, t = -2.18). A two-way interaction arose: L1 readers had longer total dwell times on the ambiguous noun region when the sentence was ambiguous and the image was GP-inconsistent (b = -60.29, SE = 25.11, t = -2.40), which is once again an indication of confusion between the image context and the sentence. The interpretation of this effect is consistent with the one provided for L2 speakers in the previous region: expectations derived from the GP-inconsistent image context were not borne out in the subsequent garden-path sentence. This pattern is expected, though the somewhat earlier appearance of this image-sentence inconsistency in the L2 eye movement record is notable.

L2 Readers.

Table 18: Continuous Reading Measures on the Ambiguous noun region for L2 Readers (Experiment 2)

	Ambiguous Sentence						Unambiguous Sentence					
	GP Consistent Image		Neutral Image		GP Inconsistent Image		GP Consistent Image		Neutral Image		GP Inconsistent Image	
First Fixation	228	(106)	241	(156)	251	(152)	237	(135)	246	(166)	240	(151)
Gaze Duration	287	(141)	320	(203)	323	(180)	303	(175)	324	(217)	305	(200)
Go-past time	883	(689)	1000	(633)	979	(772)	878	(738)	921	(637)	946	(719)
Total time	977	(743)	1031	(776)	1045	(753)	757	(468)	841	(580)	751	(494)

Similar to L1 readers, L2 readers demonstrated a main effect of sentence ambiguity such that ambiguous sentences led to inflated go past times (b = -36.82, SE = 14.12, t = -2.61) and total times (b = -111.65, SE = 12.12, t = -9.21). L2 readers' data also displayed a significant main effect of neutral image type such that there were inflated total times on the ambiguous noun region when the image was neutral in comparison to the GP-consistent and GP-inconsistent image (b = -48.29, SE = 17.18, t = -2.81). L2 readers again displayed inflated gaze durations when the interpretations were conflicting: there was a significant two-way interaction such that an unambiguous sentence preceded by a neutral image triggered the longest gaze durations on the ambiguous noun region (b = -40.25, SE = 14.95, t = -2.69).

Disambiguating Verb Region.

L1 Readers.

Table 19: Continuous Reading Measures on the Disambiguating Verb Region for L1 Readers (Experiment 2)

	Ambiguous Sentence						Unambiguous Sentence					
	GP Consistent Image		Neutral Image		GP Inconsistent Image		GP Consistent Image		Neutral Image		GP Inconsistent Image	
First Fixation	247	(109)	249	(111)	246	(126)	239	(104)	242	(106)	236	(109)
Gaze Duration	293	(153)	297	(169)	280	(161)	282	(155)	284	(136)	273	(142)
Go-past time	743	(612)	694	(508)	683	(427)	569	(515)	577	(392)	543	(348)
Total time	533	(372)	540	(404)	501	(346)	447	(285)	458	(316)	418	(290)

L1 readers had inflated gaze durations (b = -0.01, SE = 0.01, t = -2.02) go past times (b = -0.07, SE = 0.01, t = -5.92) and total times (b = -0.07, 0.01, t = -7.69) when the sentence was ambiguous (main effect). These replicate findings in previous studies of garden-path sentence processing. The native speakers also demonstrated longer gaze durations (b = -0.02, SE = 0.01, t = -2.17), go past times (b = -0.03, SE = 0.01, t = -2.31), and total times (-0.03, SE = 0.01, t = -2.97) when the image was neutral, in comparison to the GP-consistent and GP-inconsistent images. This result can possibly be explained by the fact that the neutral images did not offer the reader much grounded context with which to understand the sentences (as suggested above in relation to the L2 reading times on the subordinate verb region). However, when comparing only the GP-consistent and GP-inconsistent images, L1 readers had longer gaze durations (b = -0.02, SE = 0.01, t = -2.27) and total times (b = -0.03, SE = 0.01, t = -2.59) on the disambiguating verb region when a GP-inconsistent image preceded an ambiguous sentence, signaling increased effort devoted to revising the garden-path interpretation when the image provided the correct interpretation prior to reading. It appears that a strong preference for late closure – i.e., for an initial garden-path interpretation – drove the current effects. Even when a comma was present, the GP-consistent context did not seem to conflict as much with a potential non-reflexive transitive interpretation for the sentence. In other words, the comma may have been discounted to some extent when preceded by GP-consistent context, consistent with data reported by Christianson and Luke (2011). On the other hand, when the image context led away from the garden-path interpretation, this interpretation nevertheless maintained strong sway over the parser, and the resulting conflict slowed processing.

L2 Readers.

Table 20: Continuous Reading Measures on the Disambiguating Verb Region for L2 Readers (Experiment 2)

	Ambiguous Sentence						Unambiguous Sentence					
	GP Consistent Image		Neutral Image		GP Inconsistent Image		GP Consistent Image		Neutral Image		GP Inconsistent Image	
First Fixation	256	(121)	259	(101)	261	(109)	250	(106)	256	(111)	263	(122)
Gaze Duration	321	(163)	320	(149)	320	(154)	321	(189)	319	(159)	321	(178)
Go-past time	617	(431)	562	(419)	615	(398)	516	(472)	482	(503)	520	(361)
Total time	665	(549)	656	(544)	653	(511)	565	(398)	584	(454)	520	(425)

Similar to L1 readers, L2 readers had longer go-past times (b = -0.05, SE = 0.01, t = -3.25) and total times (b = -0.06, SE = 0.01, t = -5.33) on the disambiguating verb region when the sentence was ambiguous. Once again, this result is expected. There were no interactive effects on the disambiguating verb region for L2 readers. Rather strikingly, the early indications at the subordinate that the image influenced expectations appear to have faded quickly into non-significance for the L2 speakers. It may be that early attempts to integrate context and sentence failed early on (in conflicting conditions, anyway), and the cognitive load became too great for the L2 readers. As a result, they abandoned the attempt, and the effects of the image disappeared as more of the sentence was read. L1 readers, on the other hand, being more proficient in English and thus, presumably, requiring fewer resources to read the sentence, continued to attempt integration, so signs of continued conflict persisted.

Spillover Region.

L1 Readers.

Table 21: Continuous Reading Measures on the Spillover Region for L1 Readers (Experiment 2)

	Ambiguous Sentence						Unambiguous Sentence					
	GP Consistent Image		Neutral Image		GP Inconsistent Image		GP Consistent Image		Neutral Image		GP Inconsistent Image	
First Fixation	227	(107)	226	(98)	221	(94)	233	(127)	225	(108)	227	(108)
Gaze Duration	348	(245)	355	(246)	337	(264)	390	(284)	392	(289)	394	(290)
Go-past time	1973	(917)	1945	(1050)	1872	(932)	1469	(995)	1517	(1052)	1284	(922)
Total time	535	(400)	588	(472)	528	(454)	522	(392)	553	(406)	509	(360)

Effects in the spillover region for Experiment 2 were minimal for both L1 and L2 readers. A main effect of sentence ambiguity led to longer gaze durations (b = 0.06, SE = 0.01, t = 3.86) and longer go past times (b = -0.07, SE = 0.02, t = -3.44) for L1 readers.

L2 Readers.

Table 22: Continuous Reading Measures on the Spillover Region for L2 Readers (Experiment 2)

	Ambiguous Sentence						Unambiguous Sentence					
	GP Consistent Image		Neutral Image		GP Inconsistent Image		GP Consistent Image		Neutral Image		GP Inconsistent Image	
First Fixation	245	(102)	238	(110)	240	(108)	237	(117)	248	(120)	242	(107)
Gaze Duration	455	(332)	486	(306)	455	(295)	495	(368)	502	(344)	501	(340)
Go-past time	2871	(1877)	2963	(1248)	2942	(1670)	2105	(1340)	2336	(1355)	1971	(1203)
Total time	779	(420)	818	(566)	762	(592)	728	(586)	739	(529)	699	(513)

Just as with the L1 readers, L2 readers demonstrated the same main effect of ambiguous sentences leading to longer gaze durations (b = 0.04, SE = 0.02, t = 2.00) and longer go past times (b = -0.09, SE = 0.03, t = -3.47). There were no interactive effects on the spillover region for L1 or L2 readers.

Image.

Table 23: Total Time on Image for L1 and L2 Readers (Experiment 2)

	Ambiguous Sentence						Unambiguous Sentence					
	GP Consistent Image		Neutral Image		GP Inconsistent Image		GP Consistent Image		Neutral Image		GP Inconsistent Image	
L1	794	(597)	803	(696)	783	(665)	705	(579)	723	(576)	654	(517)
L2	1013	(808)	1056	(785)	1048	(658)	866	(713)	920	(756)	849	(523)

Overall both L1 and L2 readers dwelled longer on the neutral images: L1 readers (b = 0.04, SE = 0.01, t = 10.49), L2 readers (b = 0.05, SE = 0.00, t = 10.62). Although there were interactive effects with the sentence condition, they are uninterpretable as the image was presented before the sentence. Once again, these results demonstrate that in some way, the neutral images were more salient in some way. An alternative explanation could be that many of the neutral images did not have enough explanatory power for sentences that the readers knew

were difficult. Perhaps studying the image longer before going on to the sentence was a way for readers to pre-emptively search for the meaning they were hoping to gain from them.

Offline Date: Accuracy and Reaction Time

Accuracy.

Both L1 and L2 readers demonstrated main effects whereby unambiguous sentences (b = 0.83, SE = 0.03, z = 23.82, $p < 0.001$) (b = 0.97, SE = 0.05, z = 21.03, $p < 0.001$) resulted in greater accuracy, and GP-inconsistent images resulted in greater accuracy (b = 1.75, SE = 0.04, z = 39.34, $p < 0.001$) (b= 1.39, SE = 0.06, z = 24.08, $p < 0.001$). However, a significant interaction was observed only for L1 readers, such that they were most accurate when an ambiguous sentence was paired with a GP-inconsistent image (b = 0.68, SE = 0.09, z = 7.95, $p < 0.001$). This is a clear indication that images that led L1 readers away from the garden-path significantly helped their ability to correctly parse an ambiguous sentence. Although it is unclear why this interaction was nonsignificant for the L2 readers, the L2 data can be seen (Figure 4) to be trending in the same direction as the L1 data. Several possibilities for the lack of a significant interaction will be explored in the discussion section.

Figure 3: L1 Readers' Accuracy by Condition (Experiment 2)

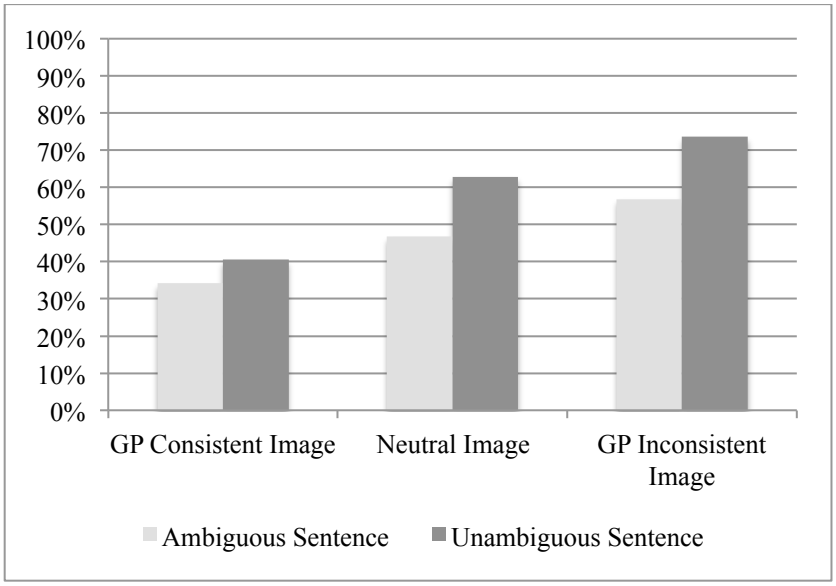
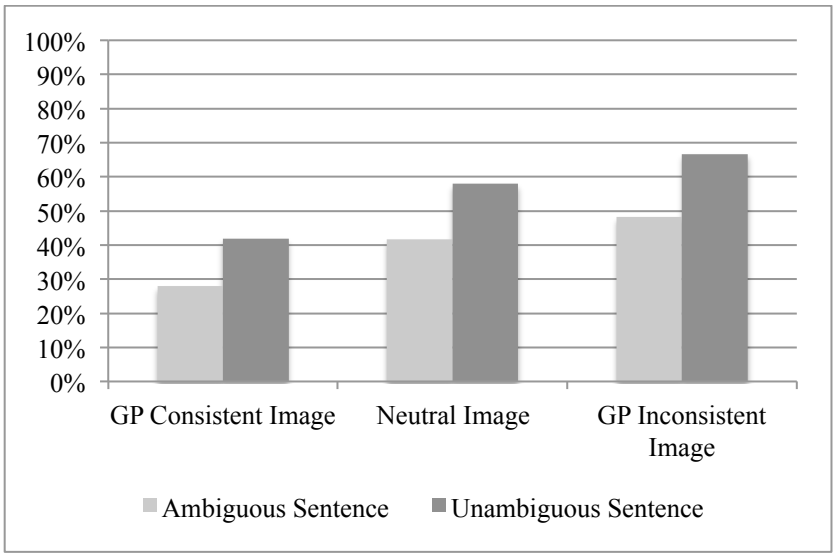


Figure 4: L2 Readers' Accuracy by Condition (Experiment 2)



Reaction Time.

Table 24: Reaction Time Measures for L1 and L2 Readers (Experiment 2)

	Ambiguous Sentence						Unambiguous Sentence					
	GP Consistent Image		Neutral Image		GP Inconsistent Image		GP Consistent Image		Neutral Image		GP Inconsistent Image	
L1	2095	(1435)	2086	(1405)	2200	(1315)	2426	(1501)	2446	(1623)	2244	(1277)
L2	2463	(2027)	2374	(1705)	2542	(1626)	2667	(1829)	2885	(2066)	2793	(2153)

For the reaction time data, there was an expected main effect that both L1 and L2 readers were slowest to respond when the sentence was ambiguous: L1 readers (b = 0.05, SE = 0.00, t = 19.10), L2 readers (b = 0.05, SE = 0.00, t = 13.06). L2 readers took longer to respond when the image was GP-inconsistent (b = 0.01, SE = 0.00, t = 2.62). This result suggests that L2 readers were attempting to use their memory of the GP-inconsistent image to inform their question response (which would have helped them, as the GP-inconsistent images always depicted the correct interpretations). Yet the failure to find an advantage for the GP-inconsistent image condition in the L2 accuracy data (above) suggests that they were not (quite) successful in doing to.

There is, however, another interesting result for the accuracy and reaction time relationship in the L1 data. Only L1 readers demonstrated significant effects of accuracy as a predictor of reaction time: correct accuracy was associated with longer reaction time to the comprehension question (b = 102.02, SE = 21.21, t =4.81). This relationship was not significant for L2 readers (b = 59.25, SE = 36.32, t =1.33). This result suggests that post-interpretive recall of both image and sentence was available to the L1 readers and, furthermore, benefitted comprehension. This interpretation is consistent with earlier speculation that the L2 readers attempted early integration of image context and the incoming sentence, but that these effects faded, perhaps due to the heavier cognitive burden associated with L2 language processing. The lack of post-interpretive effects of the image in the L2 data further supports this hypothesis.

Experiment 2 Discussion

The prediction for Experiment 2 that both L1 and L2 readers should be able to better parse garden-path sentences presented after a disambiguating image was confirmed only by the L1 readers' data. L1 readers displayed better comprehension of ambiguous sentences when

paired with a GP-inconsistent images. It is clear from these data that the meaning of the visual code impacted L1 readers, and this ultimately helped them to correctly parse ambiguous sentences. This is taken as evidence that L1 readers processed both the meaning of the image and the sentence in a way that helped them avoid being garden-pathed. The clearest example of this is that the L1 readers had longer go-past times on the disambiguating verb region when a GP-inconsistent image was presented prior to an ambiguous sentence, thereby demonstrating increased processing efforts to better understand the error signal of the sentence. Importantly, inflated go-past times following disambiguating images could be considered counterintuitive: One might imagine that if the image "primed" readers for a certain event, I might have observed *shorter* go-past times, as participants were expecting a certain event structure and thus would parse the sentence in the expected way on the first pass. This would have been consistent with parallel-parsing models. Contrary to this expectation, however, readers still misparsed garden-path sentences, even after disambiguating imagery, consistent with serial parsing accounts (cf. Ferreira & Clifton, 1986; Frazier & Rayner, 1982). Consistent with Good Enough Theory (e.g., Ferreira et al., 2002), readers spent more time working to revise the sentence structure so that it would match the previous image. As such, they derived a more accurate, less good-enough, interpretation from the sentences.

The non-significant result for this interaction for L2 readers was not expected. In fact, the opposite was anticipated: that the L2 readers should have been even more greatly impacted by the GP-inconsistent image + ambiguous-sentence condition. However, it should be stressed that, numerically, the trend was in the same direction for L2 readers as for the L1 readers.

The eye movement data for L2 readers partially help to elucidate the lack of significance for this interaction in accuracy. In the GP-inconsistent image and ambiguous-sentence condition,

L1 readers demonstrated longer total time and gaze duration on the disambiguating verb region. I believe this extra processing time to have helped the L1 readers integrate the visual and linguistic sources. L2 readers, on the other hand, were unable to use these same sentence-processing mechanisms to integrate the sources, perhaps due to the difficulty of ambiguous sentence processing in their nonnative language. The data from the L2 readers' inflated go-past times on the disambiguating verb region in the ambiguous-sentence condition (main effect) demonstrate that the L2 readers were more severely garden-pathed than the L1 readers such that being able to use the meaning of the imagery to disambiguate proved unsuccessful.

Chapter 7: Experiment 3

Considering the data from Experiment 1 and Experiment 2, the next question is whether it is an image or simply extra information in any form is more effective at steering the reader away from a garden path. In other words, does text or imagery inoculate the reader better against being garden-pathed? In order to approach this question, I designed Experiment 3 similar to Experiment 2 as a 2 x 3 experimental design: Factor 1 – ambiguous (no comma present) vs. unambiguous (comma present) sentence; Factor 2 – sentence context informativeness: GP-consistent sentence, GP-inconsistent sentence, neutral sentence. For clarity, (15) provides an example of an item with a neutral sentence (a), a GP-consistent sentence (b), and a GP-inconsistent sentence (c). The sentence was followed by either an ambiguous (d) or unambiguous sentence on a separate screen (e), which was followed by the comprehension probe (f).

15) a. Anna held the baby for a moment.

b. Anna needed to dress the baby quickly because she was late.

c. Anna needed to get dressed quickly because she was late.

d. While Anna dressed the baby that was small and cute spit up on the bed.

e. While Anna dressed, the baby that was small and cute spit up on the bed.

f. Did Anna dress the baby?

Experiment 3 serves as the verbal-context counterpart to Experiment 2, and in the analyses, I will examine whether verbal or imagery context is more effective at steering readers away from the garden path. Christianson and Luke (2011) reported the results of three self-paced reading experiments that demonstrated that context sentences that are consistent with garden-path interpretations can lead to entrenched misanalyses of garden-paths, and, if comprehension probes explicitly reinstantiate the spurious object, this effect can even hold for non-garden-paths.

However, it has not yet been determined how effective context can be for avoiding initial misanalyses and/or aiding full reanalysis, nor how garden-path-(in)consistent contexts affect eye movements. The eye-tracking methodology used here allows for examination of both of these processes. Furthermore, taken together Experiment 2 and Experiment 3 will be the first head-to-head comparison of linguistic vs. non-linguistic context effects on garden-path processing.

Experiment 3 Predictions.

I maintain the same predictions as in Experiment 2, despite the fact that the extra-information stimuli are sentences and not imagery: readers should be less likely to be garden-pathed when the sentence preceding the ambiguous sentence leads them away from the garden-path interpretation. With results from Experiment 2, comparisons will be made as to whether it is the visual code or the interpretation of that visual code that is driving the predicted facilitation effect. The prediction in line with the Dual Coding Theory is that readers will be aided by the image context more than the sentence context. Readers should also be garden-pathed more severely by GP-consistent contexts when paired with ambiguous sentences than the neutral or GP-inconsistent conditions (cf. Christianson & Luke, 2011).

Method

Participants.

A total of 65 participants from the University of Illinois at Urbana-Champaign community participated in Experiment 3. None of these had participated in either Experiment 1 or Experiment 2. Three participants were removed due to equipment failure, which left 33 native speakers of English, 30 nonnative speakers of English. After cleaning and trimming less than 0.05% of data were removed for the analyses herein. The following native languages were represented among the 30 nonnative English participants: American Sign Language (1),

Cantonese (3), Chinese (9), Hindi (4), Korean (1), Polish (1), Portuguese (1), Serbian (1), Spanish (6), Turkish (2), Vietnamese (1). On a self-report of English proficiency 14% rated themselves as "average," 34% as "very good," and 52% "excellent." Of the L2 readers, 26% were male and 74% were female, with a mean age of 28. Mean scores on the English cloze test were 85.45% (5.22% standard deviation); the minimum score was 42.50% and the maximum score was 100%. As with Experiment 1 and Experiment 2, not only were cloze scores not significant predictors of online eye movement measures, but the scores worsened models. However, unlike Experiments 1 & 2, cloze scores were significant predictors of accuracy. This will be further discussed in the Experiment 3 accuracy results section.

Materials.

The same garden-path and non garden-path sentences from Experiment 1 and Experiment 2 were used in Experiment 3. Instead of presenting the image first (as in Experiment 2), Experiment 3 presented a context sentence prior to the experimental sentence. Each context sentence was written by verbally describing the interpretation of the original images (used in Experiment 2) in one short sentence. The full stimuli set of context sentences can be seen in Appendix B. The experimental design, apparatus, and procedure were identical to Experiment 2. Although the sentences that replaced the images from Experiment 2 were not normed, the sentences were meticulously generated as verbal counterparts to the normed images. We will discuss this along with future directions of the study.

Results

Online Data: Eye Movements

Subordinate Verb Region.

L1 Readers.

Table 25: Continuous Reading Measures on the Subordinate Verb Region for L1 Readers (Experiment 3)

	Ambiguous Sentence						Unambiguous Sentence					
	GP Consistent Context		Neutral Context		GP Inconsistent Context		GP Consistent Context		Neutral Context		GP Inconsistent Context	
First Fixation	208	(91)	205	(100)	207	(78)	218	(83)	197	(117)	197	(87)
Gaze Duration	239	(135)	236	(135)	260	(93)	230	(97)	214	(135)	213	(107)
Go-past time	473	(384)	489	(389)	486	(321)	477	(310)	476	(399)	489	(418)
Total time	542	(381)	599	(465)	554	(266)	356	(197)	401	(310)	382	(261)

Effects on the subordinate verb region for L1 readers were minimal. L1 readers had longer gaze durations (b = -0.06, SE = 0.02, t = -3.17) and total times (b =0.17, SE = 0.02, t = -7.01) on the subordinate verb region when the sentence was ambiguous. This result was anticipated and fully in line with Experiment 1 and Experiment 2.

L2 readers.

Table 26: Continuous Reading Measures on the Subordinate Verb Region for L2 Readers (Experiment 3)

	Ambiguous Sentence						Unambiguous Sentence					
	GP Consistent Context		Neutral Context		GP Inconsistent Context		GP Consistent Context		Neutral Context		GP Inconsistent Context	
First Fixation	218	(109)	211	(97)	286	(201)	204	(89)	213	(101)	208	(104)
Gaze Duration	263	(148)	246	(140)	344	(269)	283	(169)	259	(162)	257	(191)
Go-past time	547	(420)	546	(460)	536	(390)	529	(392)	620	(500)	599	(501)
Total time	635	(427)	676	(539)	711	(495)	568	(364)	570	(397)	544	(414)

For L2 readers, an expected main effect of sentence ambiguity was present on longer first fixation durations (b = -0.05, SE = 0.02, t = -2.36) and total times (b = -0.08, SE = 0.03, t = -3.02) on the subordinate verb region when the sentence was ambiguous. L2 readers also had longer first fixation durations when the ambiguous sentence was paired with the GP-inconsistent context sentence (b = -0.10, SE = 0.05, t = -2.24). Once again, this is an indication that the L2 readers attempted early integration of the meaning of the context and target sentences, even at the very beginning of the ambiguous region. The absence of this interaction in the native-speaker data suggests somewhat more independence in individual sentence processing, at least in early

measures in L1 parsing (cf. Ferreira & Clifton, 1986). See Appendix F for all LME analysis tables for Experiment 3.

Ambiguous Noun Region.

L1 readers.

Table 27: Continuous Reading Measures on the Ambiguous noun region for L1 Readers (Experiment 3)

	Ambiguous Sentence						Unambiguous Sentence					
	GP Consistent Context		Neutral Context		GP Inconsistent Context		GP Consistent Context		Neutral Context		GP Inconsistent Context	
First Fixation	223	(108)	216	(96)	232	(70)	234	(79)	222	(96)	227	(105)
Gaze Duration	260	(153)	267	(153)	296	(133)	297	(100)	264	(131)	279	(159)
Go-past time	688	(499)	724	(504)	536	(390)	458	(355)	684	(424)	605	(327)
Total time	712	(524)	702	(513)	649	(374)	537	(401)	567	(356)	537	(346)

On the ambiguous noun region, there was again an expected main effect of sentence ambiguity: L1 readers had longer total times on the ambiguous noun region when the sentences were ambiguous (b = -0.09, SE = 0.02, t = -3.61). Additionally, L1 readers had shorter gaze durations (b = 0.05, SE = 0.02, t = 2.09) yet longer go-past times on the ambiguous noun region for the neutral context sentence (b = -0.10, SE = 0.04, t = -2.77). The different directions of these two measures indicate that neutral sentences that offered little contextualized information caused readers to quickly look at the ambiguous noun on first pass. Then, due to the lack of contextual support, they quickly launched regressive saccades and required more time for re-reading to determine whether the ambiguous noun was either the object of the first phrase or the subject of the second phrase (or perhaps develop a syntactically illicit "good enough" parse whereby it served as both [cf. Christianson, 2008; Christianson et al., 2001], a possibility to be examined shortly). There were no interactive effects of the variables on the ambiguous noun region for L1 readers.

L2 readers.

Table 28: Continuous Reading Measures on the Ambiguous noun region for L2 Readers (Experiment 3)

	Ambiguous Sentence						Unambiguous Sentence					
	GP Consistent Context		Neutral Context		GP Inconsistent Context		GP Consistent Context		Neutral Context		GP Inconsistent Context	
First Fixation	242	(130)	236	(104)	256	(131)	242	(107)	233	(101)	245	(126)
Gaze Duration	322	(197)	324	(199)	354	(190)	339	(181)	301	(164)	328	(239)
Go-past time	788	(637)	847	(714)	891	(749)	722	(640)	741	(663)	748	(684)
Total time	791	(542)	884	(587)	941	(575)	699	(396)	689	(483)	701	(493)

Effects on the ambiguous noun region for L2 readers were minimal. The results only revealed a main effect of ambiguity, such that there were inflated total times on the ambiguous noun region when the sentence was ambiguous (b = -0.08, SE = 0.03, t = -3.13). There were no other effects or interactions. These data demonstrate that L2 readers' processing of the ambiguous noun region of the sentence was not affected as much by the previously presented linguistic context (although the linguistic context did affect reading times on the subordinate verb). Note the contrast between this result and the results on the same region in Experiment 2, where the effect of the image was observed on this region. Two interpretations can be derived from this comparison of the two experiments. First, it could be the case that the re-reading observed on in the eye movements on the subordinate verb region successfully resolved the ambiguity, so the influence of the verbal context was reduced. Second, it could be that integrating verbal context across sentences is considerably more difficult than integrating non-verbal (imagery) context across sentences. Under this explanation, there should be observable differences in the context effects on this region between participants in Experiment 3, but perhaps not in Experiment 2. Post-hoc analyses taking L2 speaker proficiency measures into account will be reported below to address these possibilities.

Disambiguating Verb Region.

L1 readers.

Table 29: Continuous Measures on the Disambiguating Verb Region for L1 Readers (Experiment 3)

	Ambiguous Sentence						Unambiguous Sentence					
	GP Consistent Context		Neutral Context		GP Inconsistent Context		GP Consistent Context		Neutral Context		GP Inconsistent Context	
First Fixation	254	(129)	255	(125)	295	(126)	231	(88)	251	(114)	249	(108)
Gaze Duration	291	(154)	295	(158)	328	(165)	266	(127)	294	(155)	283	(136)
Go-past time	756	(631)	757	(426)	642	(512)	780	(349)	565	(312)	582	(392)
Total time	496	(318)	499	(364)	568	(383)	452	(289)	430	(285)	415	(262)

L1 readers showed the predicted a main effect of longer total times on the disambiguating verb region when the sentence was ambiguous (b = -0.06, SE = 0.02, t = -2.72). However, there were no effects of sentence ambiguity on the go-past times of the disambiguating verb region, as is typically reported in traditional garden-path sentence research. As we already know from Experiment 2, L1 readers were able to make use out of the contextualized images that were shown before garden-path sentences. The context sentences in Experiment 3 that replaced the context images from Experiment 2 apparently did not have the strong effects of sentence processing that the images did. This will be discussed more in the discussion section.

L2 readers.

Table 30: Continuous Reading Measures on the Disambiguating Verb Region for L2 Readers (Experiment 3)

	Ambiguous Sentence						Unambiguous Sentence					
	GP Consistent Context		Neutral Context		GP Inconsistent Context		GP Consistent Context		Neutral Context		GP Inconsistent Context	
First Fixation	267	(112)	267	(106)	270	(89)	299	(118)	271	(139)	278	(127)
Gaze Duration	326	(167)	326	(140)	311	(191)	352	(161)	320	(161)	342	(176)
Go-past time	854	(319)	674	(488)	521	(371)	1008	(706)	628	(858)	760	(516)
Total time	593	(411)	580	(395)	530	(296)	546	(251)	504	(333)	551	(358)

L2 readers displayed the expected main effect of inflated go-past times on the disambiguating verb region when the context sentence was GP-consistent (b = -0.13, SE - 0.05, t = -2.44). This main effect was qualified by an interaction such that L2 readers displayed shorter go-past times for ambiguous sentences that were paired with GP-inconsistent contexts (b = 0.19, SE = 0.08, t = 2.31). This remarkable drop in late-measure processing time on the error signal

indicated strong beneficial effects of the helpful preceding context. In comparison to the L1 readers processing times on the disambiguating verb region, the L2 readers were able to use the disambiguating information from the GP-inconsistent context sentence to facilitate processing of the garden-path sentence's disambiguating verb.

Spillover Region

L1 Readers.

Table 31: Continuous Reading Measures on the Spillover Region for L1 Readers (Experiment 3)

	Ambiguous Sentence						Unambiguous Sentence					
	GP Consistent Context		Neutral Context		GP Inconsistent Context		GP Consistent Context		Neutral Context		GP Inconsistent Context	
First Fixation	230	(108)	227	(92)	246	(118)	234	(110)	227	(107)	227	(116)
Gaze Duration	334	(240)	335	(215)	310	(209)	381	(251)	374	(235)	344	(232)
Go-past time	1834	(1143)	1704	(1287)	1893	(1246)	1446	(1014)	1178	(733)	1280	(750)
Total time	507	(387)	484	(405)	549	(448)	508	(340)	474	(308)	468	(340)

There were no significant effects for L1 readers on the spillover region for Experiment 3. It should be noted again, however, that the spillover region consisted of the final prepositional phrase, which was always at least three words. All the other regions of interest were only 1-2 words long. The lack of significance is interesting in light of the strong processing effects that were observed in Experiment 2 with the imagery contexts, and it will be addressed more in the discussion section.

L2 Readers.

Table 32: Continuous Reading Measures on the Spillover Region for L2 Readers (Experiment 3)

	Ambiguous Sentence						Unambiguous Sentence					
	GP Consistent Context		Neutral Context		GP Inconsistent Context		GP Consistent Context		Neutral Context		GP Inconsistent Context	
First Fixation	243	(110)	239	(111)	207	(119)	222	(68)	255	(192)	258	(131)
Gaze Duration	465	(269)	456	(352)	389	(300)	418	(247)	509	(421)	460	(331)
Go-past time	2175	(1000)	2291	(1154)	2229	(1209)	2093	(1250)	1847	(1030)	1992	(1280)
Total time	714	(520)	722	(545)	563	(401)	766	(495)	721	(622)	692	(557)

A two-way interaction of sentence ambiguity and context sentence condition was observed at the spillover region: L2 readers had shorter first fixation durations when a GP-

inconsistent context sentence was presented prior to an ambiguous sentence (in comparison to a GP-consistent context) (b = 0.13, SE = 0.05, t = 2.40). This measure of lexical access at the end of the sentence on a region with more than one word, however, is not easily interpretable. Considering that no other eye movement measures were significantly affected by the manipulated variables on the spillover region, the first fixation result should not be given much weight in the larger picture of the overall results.

Offline Date: Accuracy and Reaction Time

Accuracy.

Two main effects arose such that both L1 and L2 readers had significantly higher accuracy when the experimental sentence was unambiguous: L1 readers (b = 0.92, SE = 0.09, z = 10.22, p < 0.001), and L2 readers (b = 2.06, SE = 0.14, z = 14.96, p < 0.001). All readers also had a main effect higher accuracy when the context sentence was GP-inconsistent: L1 readers (b = 0.85, SE = 0.13, z = 6.56, p < 0.001), L2 readers (b = -0.66, SE = 0.20, z = -3.28, p < 0.001). The first result was predicted by the work of Christianson et al. (2001), and the second by the work of Christianson and Luke (2011). The second effect in particular demonstrates the effectiveness of context in offline comprehension measures. It is especially striking for the L1 participants, who showed no appreciable differences in context conditions at the critical disambiguating verb region. The result strongly suggests that verbal context – in stark contrast to imagery context – does not influence the online structural parsing of temporarily ambiguous sentences by skilled, adult L1 readers. This result is consistent with decades of parsing studies that have showed only vanishingly infrequent effects of context on online parsing measures (e.g., Ferreira & Clifton, 1986; c.f., Kristensen, Engberg-Pedersen, & Poulsen, 2014). On the other hand, both imagery and verbal context influenced both online and offline processing measures

for the L2 readers. This pattern of results could be interpreted as suggesting that less proficient, or less skilled, readers of a given language might consider a wider range of information sources than more proficient/skilled readers, including linguistic information outside of the current sentence. The implications of this interpretation will be explored in the general discussion.

L2 readers were most accurate when answering the comprehension question for an ambiguous sentence when it was paired with a neutral context sentence ($b = 2.17$, $SE = 0.29$, $z = 7.38$, $p < 0.001$). Apparently, comprehension proceeded most efficiently when the context was designed to not lead the L2 readers in either interpretive direction. As can be seen from *Figure **5*** and *Figure **6***, L2 readers' accuracy dropped dramatically when an ambiguous sentence was preceded by a GP-inconsistent contextual sentence. These findings lie in direct opposition to Experiment 2 and will be discusses in depth in the ensuing section.

Additionally, L2 proficiency cloze scores were significant predictors of accuracy such that L2 readers with higher cloze scores were more accurate in answering the comprehension question ($b = 0.09$, $SE = 0.04$, $z = 2.20$, $p < 0.05$). This did not interact with any of the independent variables. Interestingly, across all experiments, cloze scores were only significant in Experiment 3, which was the only experiment without imagery whatsoever. This result demonstrates that with higher language proficiency comes an increased ability to correctly comprehend garden-path sentences overall, in spite of linguistic contexts that may lead the reader towards or away from the garden-path. In Experiments 1 & 2, language proficiency did not make a difference in L2 readers' ability to disambiguate garden-path sentences that were paired with imagery. This result speaks to the different processing mechanisms involved in multimedia display: regardless of language proficiency, L2 readers have equal difficulty parsing information as presented in visual and linguistic codes. However, when the display's presentation is

simplified by having just one mode available (the language input), L2 readers with higher language proficiency do better as garden-path sentence disambiguation. It should be noted, however, that overall, accuracy scores for L2 readers were highest in Experiment 2. As such, the result that L2 readers with higher language proficiency are better able to parse garden-path sentences with linguistic contexts does not mean that L2 readers do better overall without imagery. This simply implies that as L2 readers approach more native-like proficiency, their linguistic competency overall becomes better, which helps in ambiguous sentence processing.

Figure 5: Comprehension Question Accuracy for L1 readers (Experiment 3)

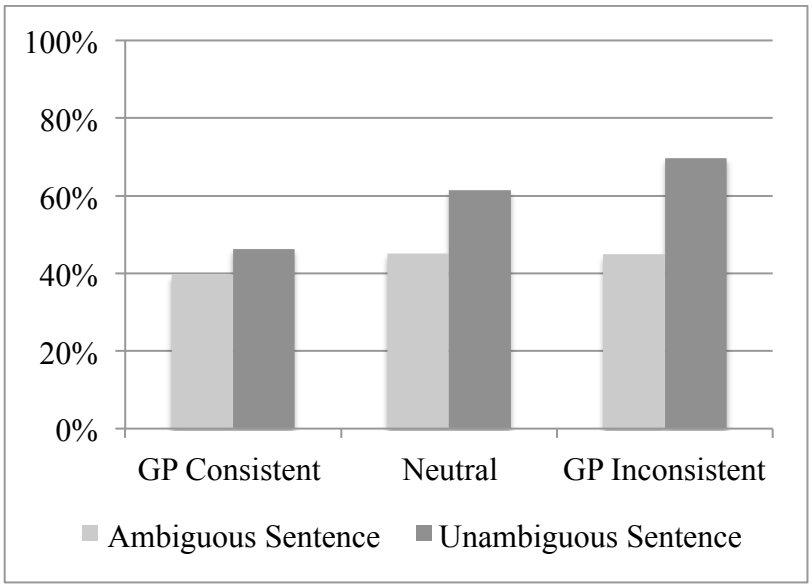
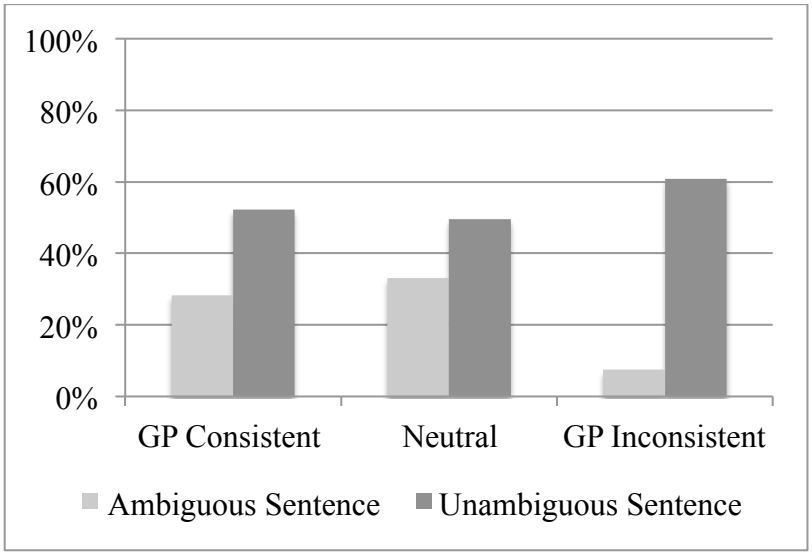


Figure 6: Comprehension Question Accuracy for L2 Readers (Experiment 3)



Reaction Time.

Table 33: Question Reaction Time for L1 and L2 Readers (Experiment 3)

	Ambiguous Sentence						Unambiguous Sentence					
	GP Consistent Context		Neutral Context		GP Inconsistent Context		GP Consistent Context		Neutral Context		GP Inconsistent Context	
L1	1888	(1059)	2022	(1258)	1934	(1065)	2299	(1349)	2281	(1361)	2107	(1176)
L2	2255	(1311)	2367	(1227)	2556	(2240)	3269	(1609)	2566	(1462)	2588	(1465)

Both L1 and L2 readers were slower to respond to the comprehension question when the sentence was unambiguous: L1 (b = 0.06, SE = 0.01, t = 7.66), L2 (b = 0.08, SE = 0.01, t = 10.24). The relationship between accuracy and reaction time was opposite that observed in Experiment 2: L2 readers who took longer to respond to the comprehension question were also more accurate (b = 211.54, SE = 27.27, t = 7.75). This pattern did not hold for L1 readers (b = 41.38, SE = 21.83, t = 1.39). Once again, as there was no relationship in Experiment 1, and no obvious pattern to make comparison to in Experiment 2, I believe this result to be spurious. Consistent with this interpretation is that the reaction times in the condition with the worst accuracy (GP-Inconsistent/Ambiguous) was neither significantly longer nor significantly slower than any other condition, suggesting no clear relationship between reaction time and accuracy.

Experiment 3 Discussion

Significant online effects in Experiment 3 were less widespread than in Experiment 2. In accuracy for Experiment 3, L1 readers patterned similarly to the L1 readers in Experiment 2; however, the strong interactive effects from Experiment 2 were not observed in Experiment 3. The only offline interactive effect that was observed in Experiment 3 was present for L2 readers who were significantly less accurate responding to the comprehension question when an ambiguous sentence was preceded by a GP-inconsistent context sentence. Apparently the mismatch between the context and target sentence caused L2 readers great difficulty in accurately determining the syntactically licensed interpretation of the garden-path sentences. Context sentences did not alter accuracy for unambiguous sentences; however, it did for ambiguous sentences such that accuracy was negatively affected by having a context that led L2 readers away from the garden-path. Put differently, the GP-inconsistent context was more misleading when paired with an ambiguous sentence, which is the opposite of the predictions. However, this result becomes clearer when the eye movements on the disambiguating verb region are considered: L2 readers had shorter go-past times on the disambiguating verb region when a GP-inconsistent context sentence was paired with an ambiguous sentence. Without the comma to help parse the ambiguous sentence, L2 readers had shortened processing times on the error signal, which led to remarkably lower accuracy. This effect is also evident in the shorter first fixation duration on the next region of interest, the spillover region, whereby L2 readers' lexical access on the spillover region was also shortened in these same conditions (GP-inconsistent context sentence and ambiguous sentence).

The dramatic drop in comprehension accuracy for L2 readers in Experiment 3 is noteworthy. Although L1 readers patterned similarly to the accuracy results in Experiment 2, the

L2 readers were severely garden-pathed despite the presence of linguistic context that was designed to drive them away from the garden-path. This strongly suggests that L2 readers experience difficulty integrating information across sentences, especially when the information appears to be in conflict, perhaps due to the decreased ability in L2 language processing. Although the L1 readers were still not as strong in the offline comprehension task as they were in Experiment 2, the L1 readers did not demonstrate the steep decline in accuracy due to conflicting linguistic information as the L2 readers did.

From the data presented here, it seems that readers' comprehension of garden-path sentences was not facilitated across the board by linguistic context. Equally apparent is that the imagery context in Experiment 2 was more effective at helping readers avoid being garden-pathed. Interestingly, in Experiment 3 it was the neutral context sentence that led to the highest accuracy, suggesting that conflicting linguistic information (or even apparently conflicting information) interfered with interpretation. Overall the ability of both groups of readers to correctly parse the garden-path sentence was low in comparison to Experiment 2. These results lead away from serial and parallel models and indicate that readers are using available resources to re-read and revise the structure of the sentence, regardless of reading proficiency and language fluency. This is taken as evidence that Good-Enough Theory and properly designed multimedia presentation is beneficial for all readers, but particularly those who are nonnative speakers.

Chapter 8: General Discussion

The Good-Enough Theory of sentence processing predicts that readers will misparse and miscomprehend ambiguous, garden-path sentences (e.g., Christianson, 2002; Christianson et al., 2001; Ferreira et al., 2001). Even in the face of apparent reanalysis, readers are still often unable to recover from the initial, syntactically unlicensed interpretation. One of the main goals of this dissertation is to add to the body of literature that seeks to understand how readers parse and understand confusing language, particularly ambiguous, garden-path sentences. How, if at all, might contextual information (e.g., images and/or extra text) help readers avoid inaccurate interpretations? Understanding how readers may parse and comprehend ambiguous sentences differently based on the context is of ongoing importance to the field of sentence processing. The work herein used the foundations of the Dual Coding Theory and GE Theory in order to study effects of context in conjunction with good-enough processing. More specifically, an issue in question was whether imagery or textual information helps readers do a better job of avoiding garden-path interpretations.

This was initially tested in Experiment 1 by manipulating the visual and linguistic codes of the multimedia display. Based on the Dual Coding Theory (Paivio, 1971, 1986; Paivio, Rogers, & Smythe, 1968) Experiment 1 predicted that having imagery presented before garden-path sentences was confirmed by higher accuracy for L1 and L2 readers in ambiguous sentence conditions when the GP-inconsistent imagery was presented prior to the garden-path sentence. In Experiment 1, although readers spent more time reading the garden-path sentences when they were presented prior to the imagery, this did not result in greater accuracy to correctly parse the sentence, which is the ultimate goal of reading processing. However, having the imagery presented first gave both L1 and L2 readers an advantage in reading times of processing the

disambiguating verb region (error signal) of the garden-path sentence as well as higher accuracy in the comprehension question.

Based on the results of Experiment 1 that having images presented prior to garden-path sentences, paired with GP-inconsistent context information, resulted in higher accuracy, Experiments 2 and 3 were designed to compare what precisely was most useful: having an image available or having any extra information available to aid in disambiguation.

The predictions for Experiment 2 were that readers should be less severely garden-pathed when ambiguous sentences were paired with GP-inconsistent images. In online data for Experiment 2, there was a lack of significant and notable findings for eye movement patterns on the subordinate verb region for L1 readers. However, L2 readers had inflated total reading times on the subordinate verb region when they viewed a GP-inconsistent image and then read an ambiguous sentence. This is taken as evidence that L2 readers are using their memory of the visual imagery resources and taking more time on the action of the sentence to better determine which agent should go with the subordinate verb. This effect is congruous with the finding that when L2 readers were presented with an ambiguous sentence, having an image that depicted the non-garden path interpretation was most helpful in comprehension accuracy.

In Experiment 3, however, we did not observe these same patterns. In the subordinate verb region, L1 readers had predictable main effects, such as longer gaze durations and total times when the sentence was ambiguous. L2 readers, however, demonstrated an interesting pattern such that their first fixation durations were longer when a GP-inconsistent image was paired with an ambiguous sentence. So, although the early measures of reading were increased by these conditions, unlike in Experiment 2, this did not translate to greater accuracy for L2 readers. In fact, the opposite was true. L2 readers performed the worst in comprehension

accuracy when a GP-inconsistent context sentence was paired with an ambiguous sentence. This could be due to the fact that the salient images were not present for the L2 readers; perhaps when they must process conflicting linguistic information (as in Experiment 3), the cognitive resources become overloaded due to linguistic capacity. This is partially supported by the finding that cloze proficiency scores modulated L2 readers' accuracy such that L2 readers with lower cloze scores performed worse on the comprehension task than L2 readers with high cloze scores. This effect of severely decreased comprehension for ambiguous sentences in the face of contextual language designed to help readers avoid the garden-path points to the notion that, in comparison to the available imagery in Experiment 2, the integration of text and imagery may be most helpful in good-enough processing.

Additionally, it should be noted that accuracy patterns in Experiment 1 look quite different from the patterns in Experiments 2 and 3. In Experiment 1, when the interpretations of the visual and linguistic codes did not match, a severe dip in accuracy was observed. When the manipulation of order of image presentation was removed in Experiment 2, participants performed better in accuracy when the interpretations did not match (i.e., the image led them away from the garden-path). This did not hold to be true for linguistic contexts in Experiment 3 for L2 readers who seemed unable to keep the two linguistic contexts distinct and separate.

These online eye movement and offline accuracy data together help elucidate the finding that when readers (especially those whose native language is not English) can successfully integrate the visual and linguistic resources available to them, the likelihood of being garden-pathed is lessened. The results also demonstrate that it is the visual code overall that helps all readers disambiguate confusing language. The results reported here add to the body of literature on the importance of supportive, well-designed contextual information in the face of confusing

language. The data partially support findings from Christianson and Luke (2011) in that despite sentence ambiguity, having an image interpretation that led readers toward the garden-path interpretation of the sentence led to lowest accuracy scores (Experiment 2). Although this pattern held for L1 readers in Experiment 3 when the imagery context was replaced with linguistic context, this was not true of L2 readers, who had a dramatic decrease in accuracy when linguistic context meant to lead them away from the garden-path ultimately led to confusion. These are the first known studies of imagery effects on ambiguous sentence processing for both L1 and L2 readers. Overall, both the offline and online data show support for GE Theory such that regardless of language proficiency, readers are still working at revising the structure while accuracy at comprehending garden-path sentences remains relatively low. With more research in effects of context in garden-path sentence processing for a variety of readers, the results herein are promising to be foundational as additions to the field of Good-Enough processing and Dual Coding Theory.

Conclusions.

These studies investigated the effects of extra information on reading processing and comprehension of DO/S garden-path sentences. Our results showed that, as predicted, the effects of imagery on ambiguous sentence processing was helpful in coming away with the correct, syntactically-licensed interpretation. Overall, the both the online and offline data support GE theory sentence processing due to the overwhelming re-reading patterns, in spite of the presence of extra-lingusitic information.

The first study (Experiment 1) tested whether or not L1 and L2 readers were able to keep the visual and linguistic code separate and whether or not they understood if the interpretations of each matched. Three variables were manipulated: the order of presentation of the information

(image first vs. sentence first), the meaning of the imagery (GP-inconsistent vs. GP-consistent), and the sentence ambiguity (ambiguous vs. unambiguous). This experiment showed that when paired with ambiguous sentences, L1 and L2 readers were able to determine when an image-sentence pair did match. Crucially, the condition of interest was the GP-inconsistent image and ambiguous sentence condition. Both L1 and L2 readers had highest accuracy in this condition when the image was presented first. Based on this result, I chose to move forward with Experiment 2 in asking comprehension questions about their understanding of the garden-path sentence, keeping the imagery first. Additionally, in order to get rid of the potential for a yes-bias to the yes/no questions in Experiment 1, the offline task in Experiment 2 was modified.

Experiment 2 was designed to study the effects of garden-path sentence processing and multimedia more directly by investigating participants' comprehension of the garden path sentences. The manipulated variables to do so were: imagery (GP-consistent vs. neutral vs. GP-inconsistent) and sentence ambiguity (ambiguous vs. unambiguous). Each item had a comprehension question presented after the image-and-sentence pair. The data from Experiment 2 support the Dual Coding Theory: when L1 readers were successfully able to understand the information from the two sources, their understanding was enhanced. Although this is also numerically the trend for L2 learners, the pattern is not statistically significant: when an ambiguous sentence was presented after a GP-inconsistent image, comprehension was highest.

One of the crucial questions in the design of Experiment 3 was whether or not simply having extra information that was helpful, or whether there was something special about the visual code. In order to understand this, the images in Experiment 2 were replaced with sentences that described the action of the image. Overall, accuracy for Experiment 3 was lower than in Experiment 2. L1 readers did not get the same boost in accuracy with the contextualized

sentences in Experiment 3 as they did with the images in Experiment 2. These data demonstrate the power of visual correctly constructed images in the face of the difficult task of ambiguous sentence comprehension.

In conclusion, the experiments and data discussed herein demonstrate the complex relationship between information availability, cognitive processing of those resources, and language background. The data herein give support for GE theory in that, regardless of language proficiency, there was minimal effort from the parser, even at the cost of necessitating extra time and energy for subsequent reanalysis. With these results, future work in this avenue of research may choose to focus in on a particular group of L2 speakers whose native language lends itself to make specific predictions about what the L2 speakers knowledge of the mechanics of their L1 work perhaps may cause them to approach the DO/S garden-path sentences differently. This in addition to more fine-tuned analysis of visual clutter in images will elucidate more clearly the effects of disambiguating imagery on garden-path sentence processing.

Limitations

The studies reported in this dissertation were designed with two objectives: to discuss and test theories of garden-path sentence processing and to better understand the influence of extra-linguistic factors. In using thoroughly researched garden-path sentences and hand-drawn images, the primary goal of the research was to understand the strength of the dual codes in multimedia as a means of deepening our current understanding of good-enough processing. However, it should be noted that while images may be easily contextualized for most viewers, linguistic input is only meaningful for readers who have proficient command of the linguistic content. That being said, it is important to point out that cultural background is known to play a role on image recognition. Although images can be helpful for most readers, this is not always the case;

controlling images so that they are effective for a broad range of viewers is complex. Unfortunately, cultural bias still persists in multimedia instruction and assessment (Laing & Kahmi, 2003). If multimedia material uses images that are heavily biased and not contextualized for learners from other linguistic and cultural backgrounds, then multimedia becomes ineffective: the facilitative power of images is rendered useless if the learners cannot determine the relationship to the text in multimedia display.

Lastly, it should be noted that the context sentences in Experiment 3 were not normed, in spite of the fact that they were carefully reviewed and based on the existing, normed images from Experiment 2. It is wise to consider that perhaps subsequent studies with more carefully controlled context sentences may give different results, which could speak to the importance of extra linguistic information on garden-path sentence disambiguation.

Although it is beyond the scope of this project, it is of future interest to investigate other individual differences such as metalinguistic knowledge and how native language-specific knowledge affects L2 syntactic processing. For example, does controlling for a specific type of bilingual, for example a German-English bilingual, render different results in comparison to a Portuguese-English bilingual? That is, how much does the syntax and structure of the L1 affect garden-path sentence processing in English? This question remains open for later work.

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Appendix A: All Stimuli

Sentences used in the experimental and filler items are presented. For experimental items, participants viewed the sentences in the ambiguous frame (without commas) or the unambiguous frame (with commas). Backslashes indicate regions of interest; these were not visible to the participants. Filler sentences were seen by all participants in the same way, presented below.

Garden-path and non garden-path Experimental Sentences

1. As Angela /cleaned(,) /the dog /that was spotted and black /sat /in the yard.
2. As Betty /woke up(,) /the neighbor /that was old and cranky /coughed /loudly.
3. As Bill /ate(,) /the turkey /that was plump and delicious /sat /on the table.
4. As Carla /knitted(,) /the mitten /that was warm and fuzzy /fell /to the floor.
5. As Ed and Bea /kissed(,) /the baby /that was heavy /fell /gently to the ground.
6. As Harry /chewed(,) /the steak /that was brown and juicy /fell /to the floor.
7. As Henry /whittled(,) /the stick /that was long and bumpy /oozed /fresh sap.
8. As Jack /ordered(,) /the fish /that was silver and black /cooked /in a pot.
9. As Jane and Mary /met(,) /the men /from Florida /asked /for their phone numbers.
10. As Jerry /played(,) /the violin /that was old and dingy /took /some terrible abuse.
11. As Mark and Janice /touched(,) /the lamp /that was pretty and pink /glowed /brightly.
12. As Raymond /vacuumed(,) /the drapes /that were white and pleated /hung /in the window.
13. As Susan /wrote(,) /the letter /that was long and eloquent /fell /off the table.
14. As the artist /painted(,) /the model /that was tall and thin /sat /in the chair.
15. As the artist /sketched(,) /the worker /that was smiling and strong /sat /in the chair.
16. As the bully /tripped(,) /the girl /that was short and smart /tumbled /down the stairs.
17. As the child /splashed(,) /the lifeguard /that was tall and bald /blew /the whistle.
18. As the child /vomited(,) /the spaghetti /that was organic /bubbled /on the stove.
19. As the cowboy /rode(,) /the horse /that was big and strong /sweated /profusely.
20. As the detective /investigated(,) /the robbery /that was fast and brutal /caused /panic.
21. As the duke and knight /battled(,) /the king /that was loved by all /watched /intently.
22. As the explorer /paddled(,) /the canoe /that was long and green /headed /downstream.
23. As the farmer /steered(,) /the tractor /that was big and sturdy /pulled /the plough.
24. As the Finn and Cuban /raced(,) /the Italian /that was overweight /started /to sweat.
25. As the golfer /swung(,) /the club /that was brand new /glinted /in the sun.
26. As the guard and officer /wrestled(,) /the thief /that was fleeing /fell /down the stairs.
27. As the lion /attacked(,) /the baboon /that was short and hairy /screamed /in terror.
28. As the maid /dusted(,) /the picture /that was black and white /tipped /over.
29. As the man /walked(,) /the poodle /that was small and white /barked /loudly.
30. As the mare /fed(,) /the colt /that was young and black /stamped /its hoof.
31. As the professor /lectured(,) /the students /that were young and bored /fell /asleep.
32. As the teacher and lawyer /debated(,) /the politician /that was tense /paid /close attention.
33. While Al /photographed(,) /the rocket /that was red and gray /sat /on the launch pad.
34. While Anna /dressed(,) /the baby /that was small and cute /spit up /on the bed.
35. While Bill and Sue /hugged(,) /the boy /that was cute /wondered /what all the fuss was about.
36. While Dan and Tim /fought(,) /the bully /that was threatening /loomed /nearby.
37. While Frank /dried off(,) /the car /that was red and shiny /sat /in the driveway.

38. While Janet /baked(,) /the bread /that was wholesome and delicious /rose /in the oven.
39. While Jill and Joe /cuddled(,) /the kittens /that were small /played /quietly.
40. While Jim /bathed(,) /the child /that was happy and pudgy /giggled /with delight.
41. While Jodi and Liz /embraced(,) /the girl /that was pretty /began /to cry.
42. While Kendra /parked(,) /the van /that was brown and green /bumped /the curb.
43. While Rick /drove(,) /the car /that was old and brown /veered /into a ditch.
44. While Sam /counted(,) /the children /that were small and unruly /boarded /the bus.
45. While the acrobat /performed(,) /the stunt /that was very dangerous /amazed /the kids
46. While the boy /washed(,) /the dog /that was white and furry /barked /loudly.
47. While the caricaturist /drew(,) /the child /that was short and cute /stood /on the sidewalk.
48. While the chef /stirred(,) /the soup /that was spicy and tasty /boiled /over.
49. While the chimps /groomed(,) /the baboons /that were large and hairy /sat /in the grass.
50. While the clown /juggled(,) /the balls /that were bright and colorful /fell /on the ground.
51. While the crowd /applauded(,) /the policeman /that was tall and burly /saved /the little girl.
52. While the customer /paid(,) /the man /that was tired and cranky /entered /the amount.
53. While the director /filmed(,) /the actor /that was rich and famous /recited /the lines.
54. While the doctor and dentist /dated(,) /the nurse /that was cute /acted /shy.
55. While the father /calmed down(,) /the children /that were tired and irritable /sat /on the bed.
56. While the girl /scratched(,) /the cat /that was gray and white /stared /at the dog.
57. While the jockey /settled down(,) /the horse /that was sleek and brown /stood /in the stall.
58. While the lawyer /studied(,) /the brief /that was old and yellow /lay/ on the desk.
59. While the man /hunted(,) /the deer /that was fast and graceful /ran /into the woods.
60. While the mother /undressed(,) /the baby /that was bald and helpless /cried /softly.
61. While the nurse /shaved(,) /the patient /that was tired and weak /watched /TV.
62. While the puppy /sniffed(,) /the kitten /that was fluffy and white /sat /on the sofa.
63. While the sailor /smoked(,) /the pipe /that was old and smelly /glowed /brightly.
64. While the scientists /explored(,) /the cave /that was dark and damp /swarmed /with bats.
65. While the secretary /typed(,) /the memo /that was clear and concise /neared /completion.
66. While the skipper /sailed(,) /the boat /that was small and leaky /drifted /off course.
67. While the snake /swallowed(,) /the frog /that was young and slimy /kicked /vigorously.
68. While the student /read(,) /the notes /that were long and boring /blew /off the desk.
69. While the thief /hid(,) /the jewelry /that was elegant and expensive /sparkled /brightly.
70. While the warrior /battled(,) /the soldier /that was small and scared /retreated /swiftly.
71. While the woman /drank(,) /the water /that was clear and cold /spilled /on the floor.
72. While Tom /grilled(,) /the hot dog /that was long and fatty /began /to burn.

Filler Sentences

1. All of the happy children spent the afternoon playing.
2. It just so happened that the girl and the baby were in the room together.
3. Jessica pointed at the pumpkin, and the mother smiled at her.
4. John, the barber, held the scissors, and the cop took a photo of him.
5. Little Susan sat on a chair, and the nurse gave her a bandage.
6. Michael sat in the chair, and the dog, Rex, brought him a newspaper.
7. Michelle played a computer game, and the grandfather helped her.

8. Sammy wore a stethoscope, and Lizzie wore a hat.
9. The alarm clock went off, and the woodchuck reluctantly woke up.
10. The angry bear chased a man, and the man was holding a gun.
11. The angry crocodile and the fisherman were in the river.
12. The barber stood by the door, and the mean man hit him with a camera.
13. The baseball player sang by the river on a sunny, clear day.
14. The bat was in the player's hands for the opening pitch.
15. The bird was on the man's large nose.
16. The boy lifted his injured arm for his mother to bandage.
17. The boy reached for the cup, and the farmer gave him some water.
18. The boy rode a scooter, and papers fell out of his backpack.
19. The boy with the hat held a baby who gave him a kiss.
20. The boys read a book together, and the girl read alone.
21. The boys smiled for the photo, and the girl played a prank.
22. The cat behind the chair was growling.
23. The cat tried to rest by the car, but the dog licked it.
24. The cat was in the woman's arms in the rain.
25. The cat was walking along, and the snake bit it.
26. The cheerleader jumped in the air to show team spirit.
27. The chef and doctor were on the beach.
28. The cow and the pig ran all over the farmyard.
29. The cow hit the goat during the starry night, and the goat fell.
30. The cow kicked the horse, and the horse jumped.
31. The cute boy and girl were playing.
32. The cute little girl with pigtails made a nice gift for mother's day.
33. The eagle and the cow were behind the large boulder.
34. The employees standing around the boss's desk were angry.
35. The fancy new flute was in the young girl's hands.
36. The farmer sang a song while the artist painted the scenery.
37. The father read the nutrition facts while Gweneth ate her cereal.
38. The goat was eating the grass while the deer watched from afar.
39. The happy farmer and the business man chatted together.
40. The happy young kids getting off the bus waved.
41. The jeep and the tank drove down the road in unison.
42. The lady with the large pad of paper was writing.
43. The large bear was sitting in the wagon that the alligator pulled.
44. The large computer was on top of the wooden desk.
45. The large sleepy bear got licked on the face.
46. The large, happy baby and the small, angry frog sat behind the boulder.
47. The lawyer was speaking eloquently to a wise jury.
48. The lonely artist stood in the kitchen, and the nurse kissed him.
49. The man and woman with suitcases stood outside the open door.
50. The man held the sign, and the children carefully crossed the street
51. The mom held a box of fruit snacks, and the boy pointed at it.
52. The mom was holding the shoes, and the young child looked out the window.
53. The musician played the violin, and the soldier measured him.

54. The naive owl was sitting on the branch, and out of nowhere, the eagle grabbed it.
55. The owl sat in the tree, and the porcupine sang to it.
56. The policeman was angry and was pulling the man along.
57. The pretty girl in the skirt was standing on the base.
58. The sad cow standing behind the boulder was crying very hard.
59. The schoolchildren who were sitting at the table were working hard.
60. The skunk stood by the river, and the nice musician waved to it.
61. The small child standing by the computer was very excited.
62. The small dog wearing glasses was reading.
63. The small, exhausted mouse was running very fast.
64. The smiling pig standing by the fire was getting photographed.
65. The smiling teacher with the large book was reading.
66. The snake chased the beaver, and the poor beaver ran away.
67. The teacher read from the book, and the class of young children listened.
68. The toddlers held a book, and they sang a nursery rhyme together.
69. The train was crossing the street, and the truck was driving toward it.
70. The woman stood under a tree while dog took a picture of her.
71. The young and strong football player was running fast.
72. The young teacher sat at the desk, and the kids showed her a picture.

Context Sentences (Experiment 3)
Garden-path Leading Sentences

1. Al began snapping pictures at the launch pad.
2. Angela's dog was filthy, and the yard was a mess after last night's party.
3. Anna needed to dress the baby quickly because she was late.
4. Betty checked in on her neighbor in the morning.
5. Bill loved Thanksgiving leftovers, so he went to lunch earlier than usual.
6. Carla made winter clothes for her grandkids.
7. Ed and Bea held the baby and puckered up.
8. Frank washed his car every weekend.
9. Harry carelessly ate his dinner.
10. Henry started his new woodworking project.
11. Jack was asking about the seafood at the restaurant.
12. Janet was a skilled baker.
13. Jerry knew the violin needed to be tuned.
14. Jill and Joe adored the new kittens.
15. Jim's son was extra dirty from being outside.
16. Jodi and Liz tried to cheer up the sad girl.
17. Little Michael's lunch of pasta did not sit well with him.
18. Raymond was bothered by the dirty drapes in his new house.
19. Rick was a terrible driver.
20. Sam's job was to get all the kids onto the bus.
21. Susan took time to respond to her pen pal.
22. The acrobat practiced the trapeze performance.

23. The actor loved being in front of the camera.
24. The artist was nearly done with the portrait.
25. The boys darted past the man.
26. The bully made Dan and Tim very angry.
27. The bully often victimized kids on the staircase.
28. The chef prepared the meal and thought about how hot it was.
29. The child pestered the lifeguard at the pool.
30. The child was an ideal model.
31. The chimp tried to please the baboons.
32. The clerk seemed quite angry.
33. The clerk suggested that Mark and Janice feel the lamp that they bought for the living room.
34. The clown was nervous about doing his juggling routine at the party.
35. The confused boy shared the happy moment with Bill and Sue.
36. The cowboy's favorite horse tired easily.
37. The crowd was relieved that the danger had passed.
38. The detective's presence did little to calm the teller's nerves.
39. The dirty dog was not happy.
40. The doctor and dentist both had their eyes on the new nurse in the clinic.
41. The duke and knight were enemies of the king.
42. The explorer sat in the green vessel.
43. The farmer drove through his fields to supervise the work.
44. The girl enjoyed cuddling with her cat.
45. The girl feared that she would hit the fire hydrant.
46. The girls were visibly upset.
47. The golfer left the price tag on the club.
48. The group of four people shook hands.
49. The guard and officer both wanted to get credit for catching the thief.
50. The guard and officer started fighting during the chase.
51. The hunter saw the first deer of the season.
52. The jockey petted the jittery horse on the nose.
53. The lawyer knew the document was the key to the case.
54. The lion got irritated by the baboon.
55. The maid noticed that the picture needed to be cleaned.
56. The man's loud dog always wanted to go outside.
57. The mare was patient with the hungry colt.
58. The mother needed to get the soiled clothes off the baby.
59. The nurse was more concerned about personal grooming than the patient.
60. The professor was not entertaining in class.
61. The puppy was curious about the kitten.
62. The sailor smoked at the wheel of the ship.
63. The scientists had never ventured below ground before.
64. The secretary needed to draft a new memo.

65. The skipper was disappointed with his vessel.
66. The snake's meal was still fighting.
67. The student needed to study his notes.
68. The teacher and lawyer never agreed with the politician.
69. The thief put the necklace in a safe place.
70. The warrior's strength intimidated the soldier.
71. The woman woke up very thirsty and was not entirely alert yet.
72. Tom promised his son a hot dog for lunch.

Neutral Context Sentences

1. Al focused the camera.
2. Angela squeezed the water into the bucket.
3. Anna held the baby for a moment.
4. Bill and Sue were very happy together.
5. Bill sat down to eat his lunch.
6. Carla was enjoying her new yarn.
7. Ed and Bea were a lovely couple.
8. Harry enjoyed his meal.
9. Henry enjoyed woodworking.
10. It was a sunny morning.
11. Jack and his wife were happy to get a good table at the restaurant.
12. Janet read the ingredients in the recipe book.
13. Jerry held the musical instrument.
14. Jill and Joe relaxed with a movie.
15. Jodi and Liz were great friends.
16. Little Michael had a terrible stomach ache.
17. Raymond loved his new vacuum cleaner.
18. Rick waved from his car.
19. Runners were warming up for the event.
20. Sometimes a third party can help settle an argument.
21. Susan wrote with a black pen.
22. The acrobats rehearsed the routine with ease and grace.
23. The artist had just begun his new piece.
24. The artist looked at the blank canvas.
25. The artist worked on the portrait.
26. The bathtub was finally full.
27. The battle was fierce.
28. The boy held the dog.
29. The boys did not get along well.
30. The bully made other kids feel bad about themselves.
31. The bus was full.
32. The car glinted in the sun.

33. The caricaturist concentrated hard on his new piece.
34. The chef brought out the meal.
35. The child jumped into the pool.
36. The chimp held onto her baby.
37. The clerk wrote up the receipt for the customer.
38. The clown was a crowd favorite at the recent circus performance.
39. The cowboy gazed out over the scenery.
40. The detective arrived on the scene to investigate.
41. The director sat in his chair.
42. The explorer looked far into the distance.
43. The farmer wore overalls and a hat.
44. The father didn't know what to do with the cranky child.
45. The girl loved her new cat.
46. The golfer took his time between shots.
47. The guard arrived on the scene.
48. The hunter particularly enjoyed hunting with his dog.
49. The jockey wore the number three in the race.
50. The knight was suited up for battle.
51. The ladies laughed over a lunch date.
52. The lawyer wore his glasses and sat at the desk.
53. The lion prowled the savannah.
54. The living room was finally furnished just as Mark and Janice wanted.
55. The maid prepared to do the dusting.
56. The man enjoyed his daily walk.
57. The mare ran in the open field with the colt.
58. The medial clinic looked calm form the outside.
59. The mother looked at her baby in the bassinet.
60. The nurse prepared to start her rounds at the hospital.
61. The policeman listened intently to the little girl.
62. The professor was unhappy with the administration.
63. The puppy and cat sat side by side.
64. The sailor enjoyed the sunny day.
65. The scientists ventured into the unmapped valley
66. The secretary was very overworked.
67. The skipper was determined to get out on the water.
68. The small coupe sat near the curb.
69. The snake slithered lazily all morning.
70. The students sat down to work together.
71. The thief tried to be sneaky and tiptoed.
72. The woman quenched her thirst.
73. Tom was proud of his chef's hat and grill.

Non-garden path leading sentences

1. Al found the perfect flower for his photography class assignment.
2. Angela had a lot of cleaning to do after the party.
3. Anna needed to get dressed quickly because she was late.
4. Bill enjoyed his sandwich as his pet turkey looked on.
5. Carla was working on a new sweater.
6. Dan and Tim were so violent that the other kids stayed back.
7. During his rounds at the hospital, the nurse took time to get rid of his stubble.
8. Ed and Bea didn't pay attention to the baby as they puckered up.
9. Frank showered before going for a drive.
10. Harry was engrossed in his bubblegum.
11. Henry whittled a wooden duck as his newly gathered wood dried on the ground.
12. Jack was particularly hungry for steak.
13. Janet enjoyed making muffins most of all.
14. Jerry tested the clarinet in order to tune it.
15. Jill and Joe stared lovingly into each other's eyes.
16. Jim needed a hot bath after work.
17. Jodi and Liz ignored the other girl.
18. Kendra drove the small coupe all day.
19. Little Michael suddenly got sick before dinner.
20. Mark and Janice held each other and admired the lamp that they bought for the living room.
21. Mary and Jane shook hands before being interrupted.
22. Raymond was meticulous about sweeping his kitchen floor.
23. Rick saw that the car ahead had taken the curve too fast.
24. Sam figured out how many hours it would take to get home.
25. Susan dashed off a quick response to the letter.
26. The acrobat rehearsed the hand balancing routine.
27. The actor rehearsed until it was his turn to walk into the frame.
28. The artist drew the furniture.
29. The artist worked on a new picture of a flower.
30. The boy stood on the bathroom footstool.
31. The boy watched the two happy adults.
32. The busy chimps ignored the baboons.
33. The caricaturist began each picture with the background.
34. The chef focused on the food in the pan.
35. The child happily played at his favorite pool.
36. The clerk counted the money.
37. The clown practiced his fish juggling routine at the recent circus performance.
38. The clumsy bully often stumbled.
39. The colt waited impatiently for the hungry mare.
40. The cowboy tested out the playground equipment.

41. The detective got distracted by a minor incident at an inopportune time.
42. The doctor and dentist were ready for their date after work.
43. The duke and the knight were enemies.
44. The explorer rowed the strong boat.
45. The farmer spent the day working in the field.
46. The father needed some time before he could talk to the girls.
47. The girl noticed that her head itched.
48. The golfer relaxed between games.
49. The hunter particularly enjoyed hunting rabbits.
50. The jittery jockey tried to relax before the race.
51. The lawyer had to brush up on the relevant laws before getting to the evidence.
52. The lion got irritated by some mice and pounced.
53. The maid noticed that the grandfather clock needed to be cleaned.
54. The man felt hot just standing and watching.
55. The man's morning walk was disrupted by barking dogs.
56. The mother needed to take off her dirty clothes.
57. The neighbor was always up before Betty.
58. The oblivious crowd enjoyed the passing parade.
59. The professor delivered a well-attended conference talk.
60. The puppy smelled something underneath the couch.
61. The sailor didn't notice the pipe on the deck.
62. The scientists did not notice the cave entrance.
63. The secretary focused on the computer work.
64. The skipper was glad his ship wasn't tossed around in the waves.
65. The snake was bulging from his recent meal.
66. The student had just opened the book when a breeze kicked up.
67. The tension between the teacher and lawyer was uncomfortable.
68. The thief under the desk kept his eye on the necklace.
69. The warrior faced the threat of the vicious lion.
70. The woman enjoyed her morning coffee and was not entirely alert yet.
71. Tom forgot about the hot dog in the microwave.

Appendix B: Norming, Experiment 1

Item	Average GP-consistent image	Average GP-inconsistent image
1	4.43	5.48
2	4.48	6.10
3	4.52	4.57
4	4.62	6.00
5	4.67	6.24
6	4.24	4.95
7	5.29	5.05
8	3.00	6.05
9	5.86	5.57
10	5.57	6.00
11	5.52	6.43
12	6.57	4.19
13	3.76	6.25
14	2.71	6.24
15	3.29	6.62
16	5.10	4.33
17	2.57	5.48
18	4.14	6.14
19	4.62	5.76
20	4.48	6.05
21	4.43	4.95
22	4.67	4.52
23	4.76	4.29
24	4.81	5.19
25	2.90	5.86
26	5.90	6.33
27	5.86	5.57
28	5.67	4.10
29	3.76	6.43
30	6.90	6.00
31	6.86	5.95
32	3.67	5.95
33	5.14	5.81
34	6.43	5.24
35	2.62	6.05
36	5.57	5.43
37	6.29	5.76
38	6.24	5.95
39	4.29	6.19
40	3.67	6.67
41	5.62	5.86
42	6.14	4.86

43	3.71	6.43
44	3.81	5.24
45	3.90	5.90
46	6.14	5.33
47	5.48	5.43
48	3.24	6.52
49	5.52	3.29
50	5.67	5.90
51	2.38	5.43
52	3.19	4.81
53	2.62	6.29
54	5.71	3.90
55	5.24	5.14
56	4.38	6.00
57	3.86	6.05
58	3.29	6.00
59	6.19	6.48
60	3.62	6.33
61	5.48	6.10
62	6.05	5.33
63	5.29	5.90
64	6.57	5.38
65	6.05	5.00
66	3.76	5.48
67	4.71	4.57
68	2.38	5.86
69	2.67	6.29
70	5.67	6.86
71	6.52	5.62
72	4.57	4.33

Appendix C

All LME Analysis Tables, Experiment 1

Table 34
Estimates, SEs, and t-Values of Fixed Effects for Continuous Reading Measures on the Subordinate Verb Region for L1 Readers (Experiment 1)

Variable	First Fixation	Gaze Duration	Go-Past Time	Total Time
Sentence Ambiguity				
b	-30.90	-29.09	7.91	-42.64
SE	8.06	10.02	18.81	17.96
t	-3.84	-2.90	0.42	-2.37
Image Ambiguity				
b	-14.71	-14.18	-7.94	9.11
SE	8.06	10.02	18.81	17.96
t	-1.83	-1.41	-0.42	0.51
Presentation Order				
b	13.65	24.83	73.10	115.38
SE	8.06	10.02	18.81	17.96
t	1.70	2.48	3.89	6.42
Sentence Ambiguity x Image Ambiguity				
b	30.68	34.85	7.84	-15.67
SE	11.39	14.17	26.57	25.37
t	2.70	2.46	0.30	-0.62
Sentence Ambiguity x Presentation Order				
b	12.89	11.61	-0.04	-10.99
SE	11.39	14.18	26.60	25.40
t	1.13	0.82	0.00	-0.43
Image Ambiguity x Presentation Order				
b	16.28	16.77	6.95	-0.09
SE	11.39	14.18	26.60	25.40
t	1.43	1.18	0.26	0.00
Sentence Ambiguity x Image Ambiguity x Presentation Order				
b	-10.92	-22.47	-4.68	22.12
SE	16.10	20.04	37.57	35.88
t	-0.68	-1.12	-0.13	0.62

Table 35
Estimates, SEs, and t-Values of Fixed Effects for Continuous Reading Measures on the Subordinate Verb Region for L2 Readers (Experiment 1)

Variable	First Fixation	Gaze Duration	Go-Past Time	Total Time
Sentence Ambiguity				
b	-9.89	-27.29	55.52	-54.48
SE	8.73	11.62	21.02	20.95
t	-1.13	-2.35	2.64	-2.60
Image Ambiguity				
b	-1.49	-19.12	12.09	3.16
SE	8.73	11.62	21.02	20.95
t	-0.17	-1.65	0.58	0.15
Presentation Order				
b	17.86	25.31	32.01	189.63
SE	8.73	11.62	21.02	20.95
t	2.05	2.18	1.52	9.05
Sentence Ambiguity x Image Ambiguity				
b	2.53	21.61	-16.38	-13.57
SE	12.34	16.44	29.73	29.63
t	0.21	1.31	-0.55	-0.46
Sentence Ambiguity x Presentation Order				
b	-2.92	12.18	48.16	-8.23
SE	12.34	16.44	29.73	29.63
t	-0.24	0.74	1.62	-0.28
Image Ambiguity x Presentation Order				
b	9.51	23.86	7.76	-20.53
SE	12.34	16.44	29.73	29.63
t	0.77	1.45	0.26	-0.69
Sentence Ambiguity x Image Ambiguity x Presentation Order				
b	-14.14	-21.78	2.59	53.46
SE	17.45	23.25	42.05	41.90
t	-0.81	-0.94	0.06	1.28

Table 36
Estimates, SEs, and t-Values of Fixed Effects for Continuous Reading Measures on the Ambiguous noun region for L1 Readers (Experiment 1)

Variable	First Fixation	Gaze Duration	Go-Past Time	Total Time
Sentence Ambiguity				
b	-1.66	-1.99	-21.00	-24.93
SE	7.66	9.57	20.69	21.24
t	-0.22	-0.21	-1.02	-1.17
Image Ambiguity				
b	4.56	23.03	30.69	41.64
SE	7.66	9.57	20.69	21.24
t	0.60	2.41	1.48	1.96
Presentation Order				
b	26.07	48.73	33.64	128.99
SE	7.66	9.57	20.69	21.24
t	3.40	5.09	1.63	6.07
Sentence Ambiguity x Image Ambiguity				
b	2.03	-17.78	-60.14	-67.70
SE	10.83	13.52	29.22	30.00
t	0.19	-1.32	-2.06	-2.26
Sentence Ambiguity x Presentation Order				
b	-3.84	-11.59	-9.08	-90.76
SE	10.83	13.53	29.25	30.03
t	-0.36	-0.86	-0.31	-3.02
Image Ambiguity x Presentation Order				
b	-10.74	-20.43	-36.91	-42.12
SE	10.83	13.53	29.25	30.03
t	-0.99	-1.51	-1.26	-1.40
Sentence Ambiguity x Image Ambiguity x Presentation Order				
b	-4.67	2.68	75.87	52.36
SE	15.31	19.12	41.32	42.43
t	-0.31	0.14	1.84	1.23

Table 37
Estimates, SEs, and t-Values of Fixed Effects for Continuous Reading Measures on the Ambiguous noun region for L2 Readers (Experiment 1)

Variable	First Fixation	Gaze Duration	Go-Past Time	Total Time
Sentence Ambiguity				
b	-10.86	-8.57	-4.94	-56.08
SE	8.04	12.30	25.18	24.17
t	-1.35	-0.70	-0.20	-2.32
Image Ambiguity				
b	-16.05	-17.43	18.86	49.61
SE	8.04	12.30	25.18	24.17
t	-2.00	-1.42	0.75	2.05
Presentation Order				
b	0.55	47.46	15.93	185.32
SE	8.04	12.30	25.18	24.17
t	0.07	3.86	0.63	7.67
Sentence Ambiguity x Image Ambiguity				
b	16.24	9.89	-70.25	-113.19
SE	11.38	17.40	35.60	34.19
t	1.43	0.57	-1.97	-3.31
Sentence Ambiguity x Presentation Order				
b	2.90	-35.55	-43.39	-137.54
SE	11.38	17.40	35.60	34.19
t	0.26	-2.04	-1.22	-4.02
Image Ambiguity x Presentation Order				
b	11.71	5.52	-51.90	-119.27
SE	11.38	17.40	35.60	34.19
t	1.03	0.32	-1.46	-3.49
Sentence Ambiguity x Image Ambiguity x Presentation Order				
b	-0.36	15.25	112.15	208.97
SE	16.09	24.61	50.35	48.35
t	-0.02	0.62	2.23	4.32

Table 38
Estimates, SEs, and t-Values of Fixed Effects for Continuous Reading Measures on the Disambiguating Verb Region for L1 Readers (Experiment 1)

Variable	First Fixation	Gaze Duration	Go-Past Time	Total Time
Sentence Ambiguity				
b	4.16	5.64	-28.60	-31.26
SE	8.74	10.59	18.22	16.93
t	0.48	0.53	-1.57	-1.85
Image Ambiguity				
b	-5.01	-5.56	20.93	-31.42
SE	8.74	10.59	18.22	16.93
t	-0.57	-0.52	1.15	-1.86
Presentation Order				
b	15.88	22.99	17.22	24.73
SE	8.74	10.59	18.22	16.93
t	1.82	2.17	0.95	1.46
Sentence Ambiguity x Image Ambiguity				
b	-6.40	-10.44	-40.51	7.27
SE	12.34	14.96	25.73	23.91
t	-0.52	-0.70	-1.58	0.30
Sentence Ambiguity x Presentation Order				
b	-18.36	-27.65	6.88	-18.95
SE	12.35	14.98	25.77	23.95
t	-1.49	-1.85	0.27	-0.79
Image Ambiguity x Presentation Order				
b	1.13	-9.04	-41.28	25.38
SE	12.35	14.98	25.77	23.95
t	0.09	-0.60	-1.60	1.06
Sentence Ambiguity x Image Ambiguity x Presentation Order				
b	23.35	40.13	61.32	23.65
SE	17.45	21.16	36.39	33.81
t	1.34	1.90	1.69	0.70

Table 39
Estimates, SEs, and t-Values of Fixed Effects for Continuous Reading Measures on the Disambiguating Verb region for L2 Readers (Experiment 1)

Variable	First Fixation	Gaze Duration	Go-Past Time	Total Time
Sentence Ambiguity				
b	-1.85	2.82	-13.98	10.56
SE	8.58	10.89	17.07	20.85
t	-0.22	0.26	-0.82	0.51
Image Ambiguity				
b	-12.65	-7.34	3.55	30.24
SE	8.58	10.89	17.07	20.85
t	-1.48	-0.67	0.21	1.45
Presentation Order				
b	2.46	10.92	27.49	99.73
SE	8.58	10.89	17.07	20.85
t	0.29	1.00	1.61	4.78
Sentence Ambiguity x Image Ambiguity				
b	6.26	-2.36	-0.75	-39.14
SE	12.13	15.41	24.13	29.49
t	0.52	-0.15	-0.03	-1.33
Sentence Ambiguity x Presentation Order				
b	-6.18	-8.19	-15.20	-60.89
SE	12.13	15.41	24.13	29.49
t	-0.51	-0.53	-0.63	-2.07
Image Ambiguity x Presentation Order				
b	8.52	0.08	-18.70	-49.69
SE	12.13	15.41	24.13	29.49
t	0.70	0.01	-0.78	-1.69
Sentence Ambiguity x Image Ambiguity x Presentation Order				
b	-5.82	-10.66	6.50	50.79
SE	17.16	21.79	34.13	41.71
t	-0.34	-0.49	0.19	1.22

Table 40: *Estimates, SEs, and t-Values of Fixed Effects for Continuous Reading Measures on the spillover region for L1 Readers (Experiment 1)*

Variable	First Fixation	Gaze Duration	Go-Past Time	Total Time
Sentence Ambiguity				
b	3.13	-6.92	7.43	-18.35
SE	8.26	11.96	28.66	15.65
t	0.38	-0.58	0.26	-1.17
Image Ambiguity				
b	10.48	-1.90	-27.98	-11.20
SE	8.26	11.96	28.66	15.65
t	1.27	-0.16	-0.98	-0.72
Presentation Order				
b	-1.29	-2.11	42.21	3.60
SE	8.26	11.96	28.66	15.65
t	-0.16	-0.18	1.47	0.23
Sentence Ambiguity x Image Ambiguity				
b	-2.08	33.19	-23.00	30.86
SE	11.66	16.88	40.47	22.10
t	-0.18	1.97	-0.57	1.40
Sentence Ambiguity x Presentation Order				
b	3.24	10.39	-81.71	7.98
SE	11.68	16.91	40.53	22.13
t	0.28	0.61	-2.02	0.36
Image Ambiguity x Presentation Order				
b	-4.51	0.16	33.03	14.51
SE	11.68	16.91	40.53	22.13
t	-0.39	0.01	0.82	0.66
Sentence Ambiguity x Image Ambiguity x Presentation Order				
b	-14.36	-35.67	52.80	-39.96
SE	16.49	23.87	57.23	31.25
t	-0.87	-1.49	0.92	-1.28

Table 41: *Estimates, SEs, and t-Values of Fixed Effects for Continuous Reading Measures on the spillover region for L2 Readers (Experiment 1)*

Variable	First Fixation	Gaze Duration	Go-Past Time	Total Time
Sentence Ambiguity				
b	-3.43	-1.93	-16.78	-9.63
SE	7.96	16.04	35.82	20.96
t	-0.43	-0.12	-0.47	-0.46
Image Ambiguity				
b	-5.63	-20.01	48.92	-2.61
SE	7.96	16.04	35.82	20.96
t	-0.71	-1.25	1.37	-0.13
Presentation Order				
b	-3.33	-9.80	231.78	58.71
SE	7.96	16.04	35.82	20.96
t	-0.42	-0.61	6.47	2.80
Sentence Ambiguity x Image Ambiguity				
b	5.68	39.20	-104.90	-13.53
SE	11.25	22.69	50.66	29.65
t	0.51	1.73	-2.07	-0.46
Sentence Ambiguity x Presentation Order				
b	5.21	-5.27	-130.89	-49.82
SE	11.25	22.69	50.66	29.65
t	0.46	-0.23	-2.58	-1.68
Image Ambiguity x Presentation Order				
b	5.19	-1.46	-106.74	-9.79
SE	11.25	22.69	50.66	29.65
t	0.46	-0.06	-2.11	-0.33
Sentence Ambiguity x Image Ambiguity x Presentation Order				
b	-18.51	-24.93	169.76	8.97
SE	15.91	32.08	71.64	41.93
t	-1.16	-0.78	2.37	0.21

Table 42
Estimates, SEs, and t-Values of Fixed Effects for Total Time on the Image for L1 and L2 Readers (Experiment 1)

Variable	L1 Readers	L2 Readers
Sentence Ambiguity		
b	-5.46	-10.58
SE	6.76	8.30
t	-0.81	-1.28
Image Ambiguity		
b	18.61	38.17
SE	6.76	8.30
t	2.76	4.60
Presentation Order		
b	-38.70	-80.38
SE	6.74	8.30
t	-5.74	-9.68
Sentence Ambiguity x Image Ambiguity		
b	-3.53	-6.74
SE	6.74	8.30
t	-0.52	-0.81
Sentence Ambiguity x Presentation Order		
b	-11.87	8.27
SE	6.76	8.30
t	-1.76	1.00
Image Ambiguity x Presentation Order		
b	-22.38	-20.93
SE	6.76	8.30
t	-3.31	-2.52
Sentence Ambiguity x Image Ambiguity x Presentation Order		
b	6.78	8.61
SE	6.74	8.30
t	1.01	1.04

Table 43
Estimates, SEs, z-Values, and p-Values of Fixed Effects for Accuracy Binomial Measures for L1 and L2 readers (Experiment 1)

Variable	L1 Readers	L2 Readers
Sentence Ambiguity		
b	0.56	0.17
SE	0.03	0.02
z	20.02	8.62
p	< 0.001	< 0.001
Image Ambiguity		
b	0.17	0.07
SE	0.03	0.02
z	6.06	3.68
p	< 0.001	< 0.001
Presentation Order		
b	0.15	-0.07
SE	0.03	0.02
z	5.35	-3.53
p	< 0.001	< 0.001
Sentence Ambiguity x Image Ambiguity		
b	1.57	1.26
SE	0.03	0.02
z	55.01	63.02
p	< 0.001	< 0.001
Sentence Ambiguity x Presentation Order		
b	0.12	-0.05
SE	0.03	0.02
z	4.24	-2.59
p	< 0.001	< 0.01
Image Ambiguity x Presentation Order		
b	0.20	0.05
SE	0.03	0.02
z	7.15	2.74
p	< 0.001	< 0.001
Sentence Ambiguity x Image Ambiguity x Presentation Order		
b	0.32	0.15
SE	0.03	0.02
z	11.36	7.49
p	< 0.001	< 0.001

Table 44
Estimates, SEs, and t-Values of Fixed Effects for Reaction Time Measures to the Offline Question for L1 and L2 readers (Experiment 1)

Variable	L1 Readers	L2 Readers
Sentence Ambiguity		
b	-0.01	-0.01
SE	0.00	0.00
t	-4.76	-5.77
Image Ambiguity		
b	-0.01	0.01
SE	0.00	0.00
t	-4.62	3.89
Presentation Order		
b	-0.01	-0.01
SE	0.00	0.00
t	-6.98	-7.09

Appendix D

Norming Averages, Experiment 2

Item	Averages GP-consistent Images	Averages Neutral Images	Averages GP-inconsistent images
1	1.9	3	5.8
2	2.3	3.75	6.15
3	2.65	4.15	6.35
4	1.05	5	6.55
5	1.8	5.45	6.85
6	1.8	3.35	6.9
7	1.75	4.7	6.5
8	2.3	5.2	6.35
9	1.8	4.8	6.55
10	2.7	5.5	6.6
11	1.7	3	5.8
12	1.3	5.2	6.55
13	1.7	4.7	6.5
14	1.85	5.15	7
15	1.5	5.7	6.7
16	2.05	3.4	6.05
17	2.55	4.1	6.3
18	2.75	4.55	6.4
19	2.25	4.2	6.05
20	1.3	4.45	6.3
21	2.05	3.55	6.65
22	1.8	5.05	7
23	2.75	5.55	6.6
24	2.3	3.75	6.9
25	2.65	5.4	6.45
26	2	3.6	6.8
27	1.85	3.5	6.9
28	1.85	5.2	6.3

29	2.75	5.6	6.65
30	1.65	5.95	6.75
31	2	3.4	6
32	2.45	3.9	6.3
33	1.65	4.55	6.35
34	2.2	5.2	6.35
35	2.7	4.3	6.4
36	1	4.95	6.45
37	1.35	4.55	6.35
38	2.2	3.45	6.1
39	2.7	4.4	6.4
40	1.15	4.4	6.3
41	1.15	5.15	6.55
42	1.7	4.65	6.45
43	2	5	6.6
44	2	3.55	6.6
45	1.15	4.15	6.75
46	2.6	4.1	6.3
47	2.4	3.85	6.3
48	2.75	4.75	6.4
49	1.4	5.25	6.7
50	1.8	3.2	6.85
51	1.85	4.95	6.6
52	1.65	4.9	6.9
53	2.4	5.25	6.35
54	2.25	3.6	6.9
55	1.95	3.4	5.9
56	2	3.4	5.95
57	1.7	5.45	6.8
58	2.7	4.3	6.15
59	2.15	3.95	6.65
60	1.75	5	6.9
61	2.95	5.65	6.7
62	1.85	3.45	6.8

63	1.05	4.4	6.3
64	2.15	4	6.65
65	1.65	5.95	6.75
66	1.75	5	6.95
67	2	4.05	6.05
68	1.45	5.4	6.7
69	1.85	4.8	6.55
70	2.95	5.6	6.65
71	1.95	3.75	5.8
72	1.9	3.5	6.8
Grand Mean	1.984722222	4.486111111	6.49375
Standard Deviation	0.4927387452	0.7963482775	0.3068395805

Appendix E

All LME Analysis Tables, Experiment 2

Table 45: *Estimates, SEs, and t-Values of Fixed Effects for Continuous Reading Measures on the Subordinate Verb Region for L1 Readers (Experiment 2)*

Variable	First Fixation	Gaze Duration	Go-Past Time	Total Time
Sentence Condition (Ambiguous, Unambiguous)				
b	-13.51	-18.65	0.11	-107.81
SE	3.06	3.76	8.85	8.19
t	-4.41	-4.96	0.01	-13.17
Image Condition 1 (GP-consistent, GP-inconsistent)				
b	5.78	4.84	-11.00	-18.21
SE	3.75	4.60	10.83	10.02
t	1.54	1.05	-1.02	-1.82
Image Condition 2 (GP-consistent/GP-inconsistent, Neutral)				
b	-5.70	-8.04	-2.25	-9.80
SE	4.32	5.31	12.49	11.56
t	-1.32	-1.51	-0.18	-0.85
Sentence Condition: Image Condition 1				
b	-0.53	-0.82	-9.26	-32.43
SE	7.50	9.21	21.66	20.04
t	-0.07	-0.09	-0.43	-1.62
Sentence Condition: Image Condition 2				
b	1.73	-6.05	1.75	-48.49
SE	8.66	10.63	25.01	23.15
t	0.20	-0.57	0.07	-2.10

Table 46

Estimates, SEs, and t-Values of Fixed Effects for Continuous Reading Measures on the Subordinate Verb Region for L2 Readers (Experiment 2)

Variable	First Fixation	Gaze Duration	Go-Past Time	Total Time
Sentence Condition (Ambiguous, Unambiguous)				
b	-7.18	-12.61	18.71	-98.22
SE	4.35	5.55	10.88	10.47
t	-1.65	-2.27	1.72	-9.39
Image Condition 1 (GP-consistent, GP-inconsistent)				
b	-0.26	-5.57	12.05	1.40
SE	5.32	6.79	13.31	12.80
t	-0.05	-0.82	0.91	0.11
Image Condition 2 (GP-consistent/GP-inconsistent, Neutral)				
b	-0.56	-4.16	18.90	-29.75
SE	6.16	7.86	15.41	14.83
t	-0.09	-0.53	1.23	-2.01
Sentence Condition: Image Condition 1				
b	-6.35	-16.78	-21.88	-25.69
SE	10.65	13.59	26.62	25.63
t	-0.60	-1.23	-0.82	-1.00
Sentence Condition: Image Condition 2				
b	-8.65	-12.04	8.48	-70.60
SE	12.32	15.72	30.80	29.64
t	-0.70	-0.77	0.28	-2.38

Table 47: *Estimates, SEs, and t-Values of Fixed Effects for Continuous Reading Measures on the Ambiguous noun region for L1 Readers (Experiment 2)*

Variable	First Fixation	Gaze Duration	Go-Past Time	Total Time
Sentence Condition (Ambiguous, Unambiguous)				
b	2.17	-2.33	9.17	-88.94
SE	3.56	4.42	12.98	10.25
t	0.61	-0.53	0.71	-8.67
Image Condition 1 (GP-consistent, GP-inconsistent)				
b	0.95	2.69	11.54	-0.09
SE	4.35	5.41	15.88	12.55
t	0.22	0.50	0.73	-0.01
Image Condition 2 (GP-consistent/GP-inconsistent, Neutral)				
b	-10.94	-7.75	-10.94	-26.96
SE	5.02	6.25	18.33	14.48
t	-2.18	-1.24	-0.60	-1.86
Sentence Condition: Image Condition 1				
b	-6.32	-13.22	-29.03	-60.29
SE	8.71	10.83	31.77	25.11
t	-0.73	-1.22	-0.91	-2.40
Sentence Condition: Image Condition 2				
b	-11.35	-17.69	-62.55	-67.77
SE	10.05	12.50	36.69	28.99
t	-1.13	-1.42	-1.71	-2.34

Table 48: *Estimates, SEs, and t-Values of Fixed Effects for Continuous Reading Measures on the Ambiguous noun region for L2 Readers (Experiment 2)*

Variable	First Fixation	Gaze Duration	Go-Past Time	Total Time
Sentence Condition (Ambiguous, Unambiguous)				
b	-4.42	-7.29	-36.82	-111.65
SE	4.56	6.11	14.12	12.12
t	-0.97	-1.19	-2.61	-9.21
Image Condition 1 (GP-consistent, GP-inconsistent)				
b	7.45	11.25	22.87	2.51
SE	5.58	7.47	17.27	14.83
t	1.34	1.51	1.32	0.17
Image Condition 2 (GP-consistent/GP-inconsistent, Neutral)				
b	-2.12	-14.42	-18.12	-48.29
SE	6.45	8.65	20.00	17.18
t	-0.33	-1.67	-0.91	-2.81
Sentence Condition: Image Condition 1				
b	-20.07	-40.25	-34.31	-46.55
SE	11.15	14.95	34.56	29.69
t	-1.80	-2.69	-0.99	-1.57
Sentence Condition: Image Condition 2				
b	-9.62	-7.97	27.35	-29.63
SE	12.90	17.29	39.99	34.33
t	-0.75	-0.46	0.68	-0.86

Table 49: *Estimates, SEs, and t-Values of Fixed Effects for Continuous Reading Measures on the Disambiguating Verb Region for L1 Readers (Experiment 2)*

Variable	First Fixation	Gaze Duration	Go-Past Time	Total Time
Sentence Condition (Ambiguous, Unambiguous)				
b	-0.01	-0.01	-0.07	-0.07
SE	0.01	0.01	0.01	0.01
t	-1.80	-2.02	-5.92	-7.69
Image Condition 1 (GP-consistent, GP-inconsistent)				
b	-0.01	-0.02	-0.03	-0.03
SE	0.01	0.01	0.01	0.01
t	-1.04	-2.17	-2.31	-2.97
Image Condition 2 (GP-consistent/GP-inconsistent, Neutral)				
b	-0.01	-0.02	-0.01	-0.03
SE	0.01	0.01	0.02	0.01
t	-1.01	-2.27	-0.37	-2.59
Sentence Condition: Image Condition 1				
b	0.00	0.01	0.04	0.00
SE	0.02	0.02	0.03	0.02
t	-0.07	0.67	1.36	-0.10
Sentence Condition: Image Condition 2				
b	0.00	0.00	-0.03	-0.02
SE	0.02	0.02	0.03	0.02
t	-0.12	-0.01	-0.96	-0.88

Table 50: *Estimates, SEs, and t-Values of Fixed Effects for Continuous Reading Measures on the Disambiguating Verb Region for L2 Readers (Experiment 2)*

Variable	First Fixation	Gaze Duration	Go-Past Time	Total Time
Sentence Condition (Ambiguous, Unambiguous)				
b	0.00	-0.01	-0.05	-0.06
SE	0.01	0.01	0.01	0.01
t	-0.41	-0.73	-3.25	-5.33
Image Condition 1 (GP-consistent, GP-inconsistent)				
b	0.02	0.00	0.03	-0.01
SE	0.01	0.01	0.02	0.01
t	1.78	0.28	1.77	-0.98
Image Condition 2 (GP-consistent/GP-inconsistent, Neutral)				
b	0.00	-0.01	0.01	-0.03
SE	0.01	0.01	0.02	0.02
t	-0.41	-0.66	0.67	-1.63
Sentence Condition: Image Condition 1				
b	0.00	0.01	-0.03	-0.04
SE	0.02	0.02	0.03	0.03
t	0.03	0.28	-0.74	-1.33
Sentence Condition: Image Condition 2				
b	0.02	0.00	-0.01	-0.03
SE	0.02	0.03	0.04	0.03
t	0.68	-0.06	-0.28	-0.91

Table 51: Estimates, SEs, and t-Values of Fixed Effects for Continuous Reading Measures on the Spillover Region for L1 Readers (Experiment 2)

Variable	First Fixation	Gaze Duration	Go-Past Time	Total Time
Sentence Condition (Ambiguous, Unambiguous)				
b	0.01	0.06	-0.07	0.00
SE	0.01	0.01	0.02	0.01
t	0.60	3.86	-3.44	0.19
Image Condition 1 (GP-consistent, GP-inconsistent)				
b	0.00	0.01	0.01	0.03
SE	0.01	0.01	0.02	0.01
t	0.38	1.01	0.49	1.90
Image Condition 2 (GP-consistent/GP-inconsistent, Neutral)				
b	-0.01	-0.01	0.00	-0.02
SE	0.01	0.01	0.02	0.01
t	-0.53	-0.92	-0.09	-1.19
Sentence Condition: Image Condition 1				
b	-0.01	-0.02	0.01	-0.01
SE	0.02	0.02	0.03	0.02
t	-0.81	-1.03	0.25	-0.66
Sentence Condition: Image Condition 2				
b	0.00	0.01	-0.04	0.01
SE	0.02	0.02	0.03	0.02
t	0.07	0.37	-1.56	0.32

Table 52: Estimates, SEs, and t-Values of Fixed Effects for Continuous Reading Measures on the Spillover Region for L2 Readers (Experiment 2)

Variable	First Fixation	Gaze Duration	Go-Past Time	Total Time
Sentence Condition (Ambiguous, Unambiguous)				
b	-0.03	0.04	-0.09	-0.01
SE	0.01	0.02	0.03	0.02
t	-1.88	2.00	-3.47	-0.69
Image Condition 1 (GP-consistent, GP-inconsistent)				
b	-0.02	0.02	0.01	0.02
SE	0.01	0.02	0.03	0.02
t	-1.49	0.89	0.47	1.09
Image Condition 2 (GP-consistent/GP-inconsistent, Neutral)				
b	-0.02	0.00	-0.02	-0.02
SE	0.01	0.02	0.03	0.02
t	-1.30	-0.07	-0.67	-1.23
Sentence Condition: Image Condition 1				
b	0.04	-0.01	0.04	-0.02
SE	0.02	0.03	0.04	0.03
t	2.22	-0.47	1.12	-0.74
Sentence Condition: Image Condition 2				
b	0.03	0.00	-0.03	-0.01
SE	0.02	0.03	0.04	0.03
t	1.56	0.10	-0.84	-0.27

Table 53: *Estimates, SEs, and t-Values of Fixed Effects for Total Time on the Image Region for L1 and L2 Readers (Experiment 2)*

Variable	L1 readers	L2 readers
Sentence Condition (Ambiguous, Unambiguous)		
b	0.00	-0.01
SE	0.00	0.00
t	-1.66	-2.18
Image Condition 1 (GP-consistent, GP-inconsistent)		
b	0.04	0.05
SE	0.00	0.00
t	10.49	10.62
Image Condition 2 (GP-consistent/GP-inconsistent, Neutral)		
b	0.11	0.10
SE	0.00	0.01
t	28.14	19.02
Sentence Condition: Image Condition 1		
b	-0.04	0.02
SE	0.01	0.01
t	-5.95	2.58
Sentence Condition: Image Condition 2		
b	-0.01	0.01
SE	0.01	0.01
t	-1.24	1.32

Table 54: *Estimates, SEs, z-Values, and p-Values of Fixed Effects for Accuracy Binomial Measures for L1 and L2 readers (Experiment 2)*

Variable	L1 Accuracy	L2 Accuracy
Sentence Condition (Ambiguous, Unambiguous)		
b	0.83	0.97
SE	0.03	0.05
z	23.82	21.03
p	$p < 0.001$	$p < 0.001$
Image Condition 1 (GP-consistent, GP-inconsistent)		
b	1.75	1.39
SE	0.04	0.06
z	39.34	24.08
p	$p < 0.001$	$p < 0.001$
Image Condition 2 (GP-consistent/GP-inconsistent, Neutral)		
b	-0.25	-0.29
SE	0.05	0.06
z	-5.30	-4.60
p	$p < 0.001$	$p < 0.001$
Sentence Condition: Image Condition 1		
b	0.68	0.13
SE	0.09	0.11
z	7.95	1.14
p	$p < 0.001$	0.25
Sentence Condition: Image Condition 2		
b	-0.29	0.08
SE	0.10	0.13
z	-3.06	0.64
p	$p < 0.01$	0.53

Table 55: *Estimates, SEs, and t-Values of Fixed Effects for Reaction Time Measures for L1 and L2 readers (Experiment 2)*

Variable	L1 Readers	L2 Readers
Sentence Condition (Ambiguous, Unambiguous)		
b	0.05	0.05
SE	0.00	0.00
t	19.10	13.06
Image Condition 1 (GP-consistent, GP-inconsistent)		
b	0.00	0.01
SE	0.00	0.00
t	0.49	2.62
Image Condition 2 (GP-consistent/GP-inconsistent, Neutral)		
b	0.00	0.01
SE	0.00	0.01
t	-0.59	1.26

Appendix F

All LME Analysis Tables, Experiment 3

Table 56: Estimates, SEs, and t-Values of Fixed Effects for Continuous Reading Measures on the Subordinate Verb Region for L1 Readers (Experiment 3)

Variable	First Fixation Duration	Gaze Duration	Go-Past Time	Total Time
Sentence Condition 1				
b	-0.01	-0.06	-0.01	-0.17
SE	0.02	0.02	0.03	0.02
t	-0.77	-3.17	-0.51	-7.01
Context Sentence Condition 1				
b	-0.02	0.02	0.02	0.03
SE	0.03	0.03	0.04	0.03
t	-0.67	0.85	0.46	0.81
Context Sentence Condition 2				
b	0.02	0.04	0.00	-0.03
SE	0.02	0.02	0.03	0.03
t	0.97	1.56	0.14	-1.02
Sentence Condition 1: Context Sentence Condition 1				
b	-0.01	-0.07	0.00	0.01
SE	0.06	0.07	0.09	0.08
t	-0.13	-1.00	0.05	0.14
Sentence Condition 1: Context Sentence Condition 2				
b	0.03	-0.02	0.02	-0.02
SE	0.04	0.04	0.06	0.05
t	0.84	-0.45	0.35	-0.32

Table 57: Estimates, SEs, and t-Values of Fixed Effects for the Subordinate Verb Region for L2 Readers (Experiment 3)

Variable	First Fixation Duration	Gaze Duration	Go-Past Time	Total Time
Sentence Condition 1				
b	-0.05	-0.03	0.04	-0.08
SE	0.02	0.02	0.03	0.03
t	-2.36	-1.16	1.25	-3.02
Context Sentence Condition 1				
b	0.05	0.02	-0.01	0.01
SE	0.03	0.03	0.04	0.04
t	1.76	0.50	-0.29	0.35
Context Sentence Condition 2				
b	0.02	0.05	0.00	0.00
SE	0.03	0.03	0.04	0.03
t	0.99	1.88	0.10	-0.07
Sentence Condition 1: Context Sentence Condition 1				
b	-0.08	-0.13	-0.05	-0.06
SE	0.07	0.08	0.10	0.10
t	-1.15	-1.64	-0.49	-0.60
Sentence Condition 1: Context Sentence Condition 2				
b	-0.10	-0.07	-0.04	-0.04
SE	0.05	0.05	0.07	0.06
t	-2.24	-1.36	-0.56	-0.59

Table 58: Estimates, SEs, and t-Values of Fixed Effects for the Ambiguous noun region for L1 Readers (Experiment 3)

Readers	First Fixation Duration	Gaze Duration	Go-Past Time	Total Time
Sentence Condition 1				
b	0.00	0.02	-0.04	-0.09
SE	0.02	0.02	0.03	0.02
t	0.24	1.07	-1.42	-3.61
Context Sentence Condition 1				
b	0.00	0.01	0.01	-0.01
SE	0.02	0.03	0.04	0.03
t	0.19	0.20	0.14	-0.17
Context Sentence Condition 2				
b	0.04	0.05	-0.10	-0.03
SE	0.02	0.02	0.04	0.03
t	1.93	2.09	-2.77	-1.14
Sentence Condition 1: Context Sentence Condition 1				
b	-0.07	-0.12	0.17	0.05
SE	0.05	0.06	0.10	0.07
t	-1.49	-1.99	1.65	0.68
Sentence Condition 1: Context Sentence Condition 2				
b	-0.02	0.03	-0.03	-0.03
SE	0.04	0.04	0.07	0.05
t	-0.48	0.65	-0.39	-0.50

Table 59: Estimates, SEs, and t-Values of Fixed Effects for the Ambiguous noun region for L2 Readers (Experiment 3)

Variable	First Fixation Duration	Gaze Duration	Go-Past Time	Total Time
Sentence Condition 1				
b	-0.01	-0.02	-0.06	-0.08
SE	0.02	0.02	0.03	0.03
t	-0.38	-0.79	-1.67	-3.13
Context Sentence Condition 1				
b	0.02	0.02	0.02	0.03
SE	0.03	0.03	0.05	0.04
t	0.54	0.59	0.37	0.75
Context Sentence Condition 2				
b	0.02	0.04	0.02	-0.01
SE	0.02	0.03	0.04	0.03
t	0.85	1.42	0.39	-0.30
Sentence Condition 1: Context Sentence Condition 1				
b	-0.01	-0.05	-0.07	-0.05
SE	0.06	0.07	0.11	0.09
t	-0.18	-0.73	-0.58	-0.50
Sentence Condition 1: Context Sentence Condition 2				
b	-0.01	0.01	0.04	0.06
SE	0.04	0.05	0.07	0.06
t	-0.13	0.21	0.51	0.98

Table 60: Estimates, SEs, and t-Values of Fixed Effects for the Disambiguating Verb Region for L1 Readers (Experiment 3)

Variable	First Fixation Duration	Gaze Duration	Go-Past Time	Total Time
Sentence Condition 1				
b	-0.03	-0.02	-0.05	-0.06
SE	0.02	0.02	0.03	0.02
t	-1.98	-1.28	-1.58	-2.72
Context Sentence Condition 1				
b	0.04	0.02	-0.01	-0.01
SE	0.02	0.03	0.05	0.03
t	1.62	0.81	-0.13	-0.29
Context Sentence Condition 2				
b	0.02	-0.01	0.03	0.01
SE	0.02	0.02	0.04	0.03
t	0.87	-0.28	0.70	0.24
Sentence Condition 1: Context Sentence Condition 1				
b	-0.06	-0.02	-0.08	-0.02
SE	0.05	0.06	0.12	0.08
t	-1.27	-0.33	-0.66	-0.23
Sentence Condition 1: Context Sentence Condition 2				
b	-0.04	-0.03	0.03	0.00
SE	0.04	0.04	0.07	0.05
t	-1.24	-0.74	0.35	0.09

Table 61: Estimates, SEs, and t-Values of Fixed Effects for the Disambiguating Verb Region for L2 Readers (Experiment 3)

Variable	First Fixation Duration	Gaze Duration	Go-Past Time	Total Time
Sentence Condition 1				
b	0.02	0.02	0.07	-0.02
SE	0.02	0.02	0.04	0.03
t	1.07	1.00	1.81	-0.96
Context Sentence Condition 1				
b	-0.02	-0.02	-0.13	-0.03
SE	0.03	0.03	0.05	0.04
t	-0.60	-0.83	-2.44	-0.71
Context Sentence Condition 2				
b	0.03	0.02	0.08	0.03
SE	0.02	0.02	0.05	0.03
t	1.48	0.74	1.75	0.99
Sentence Condition 1: Context Sentence Condition 1				
b	-0.06	-0.01	-0.04	-0.01
SE	0.06	0.07	0.13	0.09
t	-1.08	-0.09	-0.27	-0.09
Sentence Condition 1: Context Sentence Condition 2				
b	0.04	0.08	0.19	0.09
SE	0.04	0.04	0.08	0.06
t	1.07	1.93	2.31	1.51

Table 62: Estimates, SEs, and t-Values of Fixed Effects for the Spillover Region for L1 Readers (Experiment 3)

Variable	First Fixation	Gaze Duration	Go-Past Time	Total Time
Sentence Condition 1				
b	0.01	0.06	-0.15	0.00
SE	0.04	0.05	0.07	0.05
t	0.36	1.25	-1.98	-0.01
Context Sentence Condition 1				
b	0.00	0.02	-0.03	-0.01
SE	0.01	0.01	0.02	0.02
t	0.35	1.46	-1.26	-0.52
Context Sentence Condition 2				
b	0.04	0.01	-0.02	0.04
SE	0.03	0.05	0.07	0.05
t	1.07	0.26	-0.24	0.85
Sentence Condition 1: Context Sentence Condition 1				
b	-0.02	-0.03	0.03	0.00
SE	0.04	0.05	0.08	0.06
t	-0.56	-0.58	0.44	0.02
Sentence Condition 1: Context Sentence Condition 2				
b	-0.05	-0.05	0.04	-0.06
SE	0.05	0.08	0.11	0.08
t	-1.03	-0.70	0.38	-0.71

Table 63: Estimates, SEs, and t-Values of Fixed Effects for the Spillover Region for L2 Readers (Experiment 3)

Variable	First Fixation	Gaze Duration	Go-Past Time	Total Time
Sentence Condition 1				
b	-0.02	0.04	-0.08	0.00
SE	0.04	0.06	0.07	0.06
t	-0.44	0.66	-1.03	-0.03
Context Sentence Condition 1				
b	-0.01	0.00	0.01	0.01
SE	0.01	0.02	0.02	0.02
t	-0.41	-0.16	0.33	0.46
Context Sentence Condition 2				
b	-0.09	-0.02	-0.02	-0.09
SE	0.04	0.06	0.07	0.05
t	-1.46	-0.39	-0.22	-1.58
Sentence Condition 1: Context Sentence Condition 1				
b	0.04	0.00	0.01	-0.01
SE	0.04	0.06	0.08	0.06
t	0.89	0.01	0.10	-0.14
Sentence Condition 1: Context Sentence Condition 2				
b	0.13	0.00	0.06	0.09
SE	0.05	0.09	0.11	0.09
t	2.40	-0.01	0.53	0.96

Table 64: Estimates, SEs, and t-Values of Fixed Effects for the Total Time on the Context Sentence for L1 and L2 Readers (Experiment 3)

Variable	L1 readers	L2 readers
Sentence Condition 1		
b	0.02	0.03
SE	0.01	0.01
t	3.62	4.10
Context Sentence Condition 1		
b	-0.01	0.00
SE	0.01	0.01
t	-1.23	-0.34
Context Sentence Condition 2		
b	0.08	0.10
SE	0.01	0.01
t	9.16	10.89
Sentence Condition 1: Context Sentence Condition 1		
b	0.15	0.03
SE	0.03	0.03
t	0.91	1.32
Sentence Condition 1: Context Sentence Condition 2		
b	0.05	0.07
SE	0.01	0.02
t	3.40	4.87

Table 65: Estimates, SEs, and t-Values of Fixed Effects for Accuracy for L1 and L2 Readers (Experiment 3)

Variable	L1 Accuracy	L2 Accuracy
Sentence Condition 1		
b	0.92	2.06
SE	0.09	0.14
z	10.22	14.96
p	$p < 0.001$	$p < 0.001$
Context Sentence Condition 1		
b	0.85	-0.66
SE	0.13	0.20
z	6.56	-3.28
p	$p < 0.001$	$p < 0.01$
Context Sentence Condition 2		
b	0.17	-0.19
SE	0.13	0.16
z	1.36	-1.18
p	0.17	0.24
Sentence Condition 1: Context Sentence Condition 1		
b	-0.41	1.22
SE	0.37	0.48
z	-1.11	2.57
p	0.27	$p < 0.05$
Sentence Condition 1: Context Sentence Condition 2		
b	-0.03	2.17
SE	0.20	0.29
z	-0.14	7.38
p	0.89	$p < 0.001$

Table 66: Estimates, SEs, and t-Values of Fixed Effects for the Reaction Time to the Comprehension Question for L1 and L2 Readers (Experiment 3)

Reaction time	L1	L2
Sentence Condition 1		
b	0.06	0.08
SE	0.01	0.01
t	7.66	10.24
Context Sentence Condition 1		
b	0.00	-0.03
SE	0.01	0.01
t	-0.09	-3.17
Context Sentence Condition 2		
b	-0.04	0.00
SE	0.01	0.01
t	-3.94	-0.27