SEMANTIC TRANSPARENCY AND CONTEXTUAL STRENGTH IN INCIDENTAL VOCABULARY ACQUISITION OF NOVEL COMPOUNDS DURING SILENT READING: EVIDENCE FROM EYE MOVEMENTS AND RECALL

A thesis submitted to Kent State University in partial fulfillment of the requirements for the degree of Master of Arts

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INTRODUCTION

Vocabulary knowledge has been linked to reading comprehension skill (National Reading Panel, 2000), and once children have learned to read, the acquisition of new words occurs primarily through exposure during reading (Carlisle, 2007). There are two main sources of information that readers utilize in word learning – information from the surrounding sentence context and the morphemes (word parts) of the to-be-learned word itself (Nagy & Scott, 2000). The process of using cues from the context to determine a meaning of an unfamiliar word is called incidental vocabulary acquisition and it is the primary way that people learn new words (Carlisle, Fleming, & Gudbrandsen, 2000). Using word parts to determine an unfamiliar word’s meaning can also be a very effective tool in incidental vocabulary acquisition during reading (Graves 2006). Once a reader can break down a word into its parts, (s)he can use that knowledge (including affixes and root words) to deduce the meaning of a new word.

An important question follows from these findings: Do readers benefit from combining contextual and morphemic information in the process of incidental vocabulary acquisition during reading? Studies that have set out to answer this question have done so using a variety of methods and have obtained mixed findings. The main goal of the present research was to reconcile these differences by monitoring skilled readers’ eye movements while they silently read sentences containing new vocabulary items (i.e., made-up words) and testing post-reading recall of the meanings of the new items.
These methods have been used previously and were chosen for the present study because they could provide both a measure of real-time processing during incidents of vocabulary acquisition and of word-learning success in the form of data about meaning retention.

Much of the previous research examining the role of context and morphemic information in incidental vocabulary acquisition has focused on the *product* of the acquisition in children. In one of the few studies to examine the combined influence of context and morphemic information, Wysocki and Jenkins (1987) investigated fourth, sixth, and eighth grade students' ability to use morphemic and contextual information to determine the meaning of unknown words. The authors assigned students to study a set of target words that were designated to be low frequency and unfamiliar, yet easily teachable. On a pretest of 24 words, the 12 words missed most frequently by all eighth-grade subjects were selected as the target words. The meanings of target words (e.g., *melancholic, clandestine*) were taught, and the performance on inferring related words (e.g., *melancholia, clandestineness*) was scored. Two sets of words were used such that *melancholic* and *clandestine* were never taught to the same group, creating a control group that saw the transfer word *melancholia* when trained with *clandestine*. As students were trained using one of two word sets, but tested on all words, this allowed the researchers to measure vocabulary scores obtained from the use of morphemic and contextual cues separately. Contextual strength was manipulated by varying how informative the context was concerning the meaning of the unfamiliar word; context was either weak in that it contained no information as to the meaning of the unfamiliar word or strong in that it contained information that could be used to determine the meaning of
the unfamiliar word. For example, three vocabulary tests were given, such that students either were tested on the 12 stimulus words in weak contexts (e.g., “The whole class was *melancholic*”), on the 12 transfer words in weak contexts, (e.g., “Her *melancholia* lasted seven days”) or on the 12 transfer words in strong contexts, (e.g., “After Jack's puppy died, his *melancholia* was so bad that he didn't want to play with his friends”). The authors used both a lenient and strict scoring criteria to assess the students’ success in using context and morphemic cues to determine the meaning of the unfamiliar word. Strict scorers only gave credit for definitions that “indicated students knew the transfer word's meaning and its correct grammatical form (Wysocki & Jenkins, 1987, p. 73).” Lenient scorers also gave credit for definitions that indicated students knew the general meaning of the transfer word. The results of this assessment suggested that students could infer the meaning of transfer words like *melancholia* after being taught the meaning of the word *melancholic*. Vocabulary scores were not significantly higher when students could combine sources of information (root word information and strong context) than scores obtained with either source by itself. Overall, the results suggested students’ success in deriving new word meanings did *not* benefit from combining contextual and morphemic cues. However, this finding was based on grading the product of vocabulary instruction in younger learners, not on a measure of incidental vocabulary acquisition with adult skilled readers. A measure that only looks at the retention of word meanings may not be sensitive enough to detect advantages to combining information that occur during the process of word learning itself, such as making acquiring a new word’s meaning less effortful.
In a related study, Mori and Nagy (1999) investigated the degree to which English-speaking students learning Japanese could combine word elements and context clues to infer the meanings of novel Kanji compounds in three conditions: words in isolation, words with context clues only, or both. Contrary to the findings of Wysocki and Jenkins (1987), Mori and Nagy found that students were most successful at interpreting the novel compounds when both sources of information were available. However, this finding was based on students reading in a second language, and as the authors pointed out, no studies have obtained evidence supporting the advantage of pooling sources of information during vocabulary acquisition for English-speaking students reading in their first language.

Most vocabulary acquisition strategies list using context and morphemic cues as the first of several steps to word learning (Sternberg, 1987; Sternberg & Powell, 1983), yet little is known about real-time processing of morphemic information during vocabulary acquisition. Eye movement studies have indicated that readers are successful at learning new words from informative context during a single reading session, with post-reading retention rates averaging 60% for new word meanings (Brusnighan, Morris, Folk, & Lowell, 2010; Williams & Morris, 2004). Still, it is unclear how successful readers are at learning new words from contextual and morphemic cues during reading, as no studies of on-line reading (e.g., eye movement studies) to date have addressed the topic. The present study will investigate how readers integrate available morphemic cues into sentence context as they read, and whether their success in acquiring vocabulary words is linked to the helpfulness of both contextual and morphemic cues. To measure
this in the current study, the semantic transparency of novel compound words and the helpfulness of context in which the words are embedded will be used as a test case.

Compound Processing and Semantic Transparency

A large body of literature exists on readers’ use of morphemes during the processing of morphemically complex words, with many studies focusing on compound words as a test case to investigate morphemic processing in English, Finnish, and Dutch (Bertram & Hyönä, 2003; Gagné & Spalding, 2004; Hyönä & Pollatsek, 1998; Hyönä & Pollatsek, 2000; Inhoff, Briihl, & Schwartz, 1996; Inhoff, Radach, & Heller, 2000; Inhoff, Starr, Solomon, & Placke, 2008; Jarema, 2006; Jarema, Busson, Nikolova, Tsapkini, & Libben, 1999; Juhasz, Inhoff, & Rayner, 2005; Juhasz, Starr, Inhoff, & Placke, 2003; Libben, 2006; Nicoladis, 2006; Pollatsek, Hyönä, & Bertram, 2000; Sandra, 1990). Compounding is productive in many languages and is commonly used to give names for new concepts or objects using known words. For example, a beginning language learner may know the concepts of floor and brush and refer to a broom as a floorbrush knowing that other words like toothbrush and hairbrush are compounded in this way (Carlisle, 2007). Compounding is not always this straightforward. English speakers learn that words like flapjack, ponytail, and hamstring mean something wholly different than the sum of their parts. Although etymology may shed light on how these words have been compounded to mean what they do, readers cannot always rely on deriving compound meanings from constituents.

A central question in compound processing regards whether compound words are represented in the mental lexicon under a whole-word entry, as word-parts only, or on
multiple levels. Sandra (1990) and Zwisterlood (1994) have both provided evidence that automatic activation of constituent meanings does not occur during compound processing, which suggests that compound words are represented on multiple levels. Consistent with this, Pollatsek and colleagues (2000) provided evidence for a dual-route model of compound processing in which readers, upon encountering a compound word, either directly access a whole-word meaning or arrive at this meaning by decomposing the compound into its constituent parts. Although evidence is mixed, Bertram and Hyönä (2003) suggested that the deciding factor in which route wins the parallel race is word length while others have speculated that it may be semantic transparency.

Much of the research on processing compound words has looked at the construct of semantic transparency (Dressler, 2006; Juhasz, 2007; Libben, 1998; Libben, Gibson, Yoon, & Sandra, 2003; Pollatsek & Hyönä, 2005; Underwood, Petley, & Clews, 1990; Zwisterlood, 1994), which refers to the relatedness of a compound’s overall meaning to its constituent parts. A word is considered fully semantically transparent if the overall meaning of the word is predictable from its constituent word parts (i.e., the meaning of cookbook can be derived from the words cook and book), and a word is fully opaque if the overall meaning is unpredictable (i.e., cocktail). ¹

Eye movement studies of familiar compound processing that compared reading times for words with varying degrees of semantic transparency, using neutral texts, found

¹ There are other combinations of what are known as partially opaque compounds, (such as butterfly for which the meaning of fly is helpful in deriving a whole-word meaning, but the meaning of butter is irrelevant) as well as compounds with more than two constituents, but discussion for this project was restricted to fully opaque and transparent bimorphemic compounds based on specific research questions. Also, the term “fully transparent” is relative, as the average transparency ratings for most compounds are between 1% and 99%. For a more in-depth review, see Frisson, Niswander-Klement, and Pollatsek (2008).
no evidence of transparency effects in reading time behavior (Frisson, Niswander-Klement, & Pollatsek, 2008; Pollatsek & Hyönä, 2005). This finding supports the conclusion that decomposition of compound words is not mediated by semantic transparency. Libben (1998) proposed a model in which compound word processing is sped up when there is a greater number of facilitatory links between a letter string and its representation in the mental lexicon. Semantically transparent compound letter strings are linked to their representations in the lexicon on a lexical and conceptual level while opaque letter strings are linked only on a lexical level. It would follow that semantically transparent words would be processed faster when preceded by conceptually congruent information. Underwood and colleagues (1990) tested this notion by looking at fixation times for opaque and transparent compounds in sentences with varied sentence frames, either priming the whole compound, the first constituent, the second constituent, or were neutral. They found that transparent compounds were read faster, but the authors did not control the sentence frames for predictability. In reading experiments, if some sentence contexts are highly predictable such that readers can guess an upcoming word, then reading time differences can be obscured by this unintentional facilitation for highly predictable sentences (Ehrlich & Rayner, 1981; Inhoff, 1984). It remains to be seen whether informative contexts that have been normed for predictability will continue to show this transparency effect for familiar words while neutral frames will continue to show the absence of such an effect.
Novel Compound Processing

Researchers have estimated that over half of the new words students read in school books have meanings that can be derived through morphemic analysis (Nagy & Anderson, 1984) and that 60% of new words encountered have a transparent morphemic structure (Nagy, Anderson, Schommer, Scott, & Stallman, 1989). Carlisle (2007) states that the success of incidental vocabulary acquisition is dependent on the extent to which context clues converge to suggest a clear meaning, the extent to which the word structure is transparent and the constituent morphemes are familiar, and the extent to which morphemes reinforce a known concept. What is unknown is how these sources of information interact during word learning. If readers rely on both contextual and morphemic sources of information, are new compound words processed differently based on the transparency of the word in context? Also, how would reading patterns for new compounds compare to reading for matched familiar compounds in context? When a reader encounters the word *cocktail* for the first time, does (s)he slow down for clarification if the surrounding text provides clues to its meaning (i.e., a mixed beverage and not a rooster’s tail)? In contrast, would a word like *milkshake* be read faster upon first encounter, provided similar clues? Aside from speed of processing, would either of these words be harder to learn?

Several studies have investigated the processing of new compounds in English using conceptual combinations (e.g., *chocolate lizard*) as a test case for memory-based versus algorithm-based processing (Gagné & Spalding 2006; Rawson & Middleton, 2009). While conceptual combinations are a good analog of new compounds for
measuring learning, Frisson and colleagues (2008) have demonstrated that spaced compounds are not processed analogously to unspaced compounds. Segmentation (cookbook → cook book) forces reassembly of constituent meanings. No studies to date have compared reading patterns for novel bimorphemic unspaced compounds (i.e., meatcan) with familiar words of the same ilk (i.e., cookbook) to identify the role semantic transparency plays in learning new compounds.

On-Line Reading Patterns for Incidental Vocabulary Acquisition

Vocabulary acquisition studies using on-line measures of processing such as eyetracking (Brusnighan, et al., 2010; Chaffin, Morris, & Seely, 2001; Williams & Morris, 2004) have provided much of what is known about sentence level effects such as context use and inference generation as well as lexical level effects such as frequency, familiarity, phonology, and orthography in vocabulary acquisition during silent reading (see Morris & Williams, 2003 for a review). For example, previous eye movement studies have shown that readers spend more time processing words with low printed word frequencies than on high frequency words of equal length (Inhoff & Rayner, 1986; Rayner & Duffy, 1986; Rayner, Sereno, & Raney; 1996). Chaffin and colleagues (2001), using printed word frequency as an operational measure of word familiarity, found that readers spend more time processing novel words and words with low familiarity than highly familiar words, suggesting a continuum of familiarity. Williams and Morris (2004) noted that some words with equal written word frequency estimates, such as assay and pizza may have very different subjective familiarity ratings. Controlling for this, the authors supplied eye movement evidence that readers are sensitive to differences in
subjective familiarity ratings similar to estimates of printed word frequency, such that readers spend more time on words rated with low familiarity than words rated with high familiarity of equal length.

In two studies (Brusnighan, et al., 2010; Chaffin, et al., 2001) readers utilized context significantly more for novel words than familiar words, and processing time did not differ between anaphors of familiar and novel words. Similar to the findings of O’Brien, Shank, Myers, and Rayner (1988) and Garrod, O’Brien, Morris, and Rayner (1990), this suggests that readers generate meaning inferences on-line during reading of a single sentence, before moving on to later sentences. Directly after reading sessions in which readers encountered novel words (Brusnighan, et al., 2010; Williams & Morris, 2004) readers accurately recognized 60% of novel word meanings on average. Taken together, these findings suggest readers are able to retain newly learned word meanings after a single reading session.

Brusnighan and colleagues (2010) have also shown that phonology influences early processing of novel words during silent reading, extending the findings showing that phonological information is available early in the processing of familiar words (Coltheart, Patterson, & Leahy, 1994; Folk, 1999; Folk & Morris, 1995; Henderson, Dixon, Petersen, Twilley, & Ferreira, 1995; Inhoff & Topolski, 1994; Jared & Seidenberg, 1991; Lesch & Pollatsek, 1993, 1998; Lukatela & Turvey, 1991; Luo, 1996; Perfetti & Bell, 1991; Perfetti, Bell, & Delaney, 1988; Pollatsek, Lesch, Morris, & Rayner, 1992; Rayner, Pollatsek, & Binder, 1998; Rayner, Sereno, Lesch, & Pollatsek, 1995; Van Orden, 1987; Van Orden, Johnston, & Hale, 1988; see Morris & Folk, 2000.
for a review). An important detail to note is that these vocabulary acquisition studies (Brusnighan, et al., 2010; Chaffin, et al., 2001; Williams & Morris, 2004) have looked at processing monomorphemic words only. Gagné and Spalding (2006) have suggested that compounds are not processed analogously to matched monomorphemic words. Thus, it remains to be seen for novel compounds whether readers are sensitive to factors on the lexical and sentence levels such as familiarity and morphology as well as use of context and anaphors as they have in previous vocabulary acquisition studies.

Graves (2006) proposed that vocabulary acquisition occurs whenever readers construct a new definition for an unknown word, correct a definition of a misunderstood word, or expand a definition for a word that is being used in a new sense. When readers construct a new definition for an unknown word and this definition fits with the surrounding context, processing should be faster for these items than when the constructed definition conflicts with surrounding context. This would suggest that decomposition for novel semantically transparent compounds facilitates access to meaning. In contrast, if readers have to derive a new meaning based on the constituents and correct that definition based on the surrounding context, processing should be slower for these items. This would suggest that accessing constituent meanings for novel opaque compounds will slow readers down.

The Current Study

The present research was designed to investigate how the transparency of a word’s overall meaning, based on its constituent morphemes and the strength of the context in which a word is embedded, affect word recognition for both familiar words and new
vocabulary words during silent reading, focusing on the role these factors play in vocabulary acquisition. To do this, readers silently read sentences containing familiar and novel compound words that were designated as either semantically transparent or opaque. The target words were embedded in sentences in which the surrounding context was either informative or neutral as to the intended interpretation of the target word. The sentence frames for strong contexts had four areas of interest (see Table 1).

Table 1. Eyetracking regions of analysis for strong context frames.

<table>
<thead>
<tr>
<th>Informative Context Region</th>
<th>(Target Word)</th>
<th>Spillover Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>At breakfast the chef put butter on the (flapjack, pancake, bowcamp, flatcake) each time.</td>
<td>The flat, doughy cake has been a favorite among the customers for years.</td>
<td></td>
</tr>
</tbody>
</table>

In these strong sentence frames, target words appeared in the first of two sentences (in bold in example above), were preceded by informative context (italics), and were followed by a short, neutral spillover region (wavy underline). The second sentence of the pair included a synonymous anaphoric noun phrase (underline), intended to be the definition of each of the target words.

A set of neutral sentence frames served as a comparison control for any transparency effects that may emerge as a result of converging or diverging sources of information in strong sentence frames. As these sentence frames were neutral, there was no delimited synonym region for analysis, leaving three regions of interest for comparison (see Table 2).
Table 2. Eyetracking regions of analysis for neutral sentence frames.

<table>
<thead>
<tr>
<th>Neutral Context Region</th>
<th>(Target Word)</th>
<th>Spillover Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Every time Stephanie saw a (flapjack, pancake, bowcamp, flatcake) she was happy.&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The experience reminded her of growing up.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Predictions varied based on the regions of analysis as well as word and sentence conditions. Also, predictions were based on the assumption in eyetracking studies that inflated reading times and increased numbers of fixations are thought to reflect greater cognitive processing (i.e., these items are more difficult for readers to process) (e.g., Rayner, 1998).

One goal of this research is to determine how morphemic and contextual information interact during incidental word learning by investigating whether reading times on new English compound words vary with regard to transparency when the words are read in informative contexts. Another goal is to investigate whether there is a processing or retention advantage when context cues and morphemic cues agree, as well as whether there is a processing or retention disadvantage when the sources disagree. If it is the case that these advantages and disadvantages become apparent under these circumstances, it suggests that, contrary to the findings of Wysocki and Jenkins (1987), readers’ success in deriving new word meanings does benefit from combining contextual and morphemic cues. This pattern of results would demonstrate that readers can ultimately increase their vocabulary knowledge by combining available sources of information as they read.
Previous studies have utilized eye movements to determine how well readers are able to assign meanings to new letter strings in real time (Brusnighan, et al., 2010; Chaffin, et al., 2001; Williams & Morris, 2004). These studies have evidenced a robust familiarity effect, such that familiar words are read faster than unfamiliar or novel words. Although the studies have used new monomorphemic letter strings (generally two characters different than any known word, following all rules of written English) as the exemplar “novel word” stimuli, global main effects of familiarity are expected in both informative and neutral contexts because the “novel” compounds use known words combined in new ways.

Frisson and colleagues (2008) have demonstrated that in a neutral sentence, reading times do not differ between compounds based on semantic transparency. Thus, reading times on *honeymoon* and *moonlight* did not differ in the sentence “John thought the (honeymoon/ moonlight) was extremely romantic.” Similarly, in the current study, reading times on the familiar target words *flapjack* and *pancake* are not expected to differ in neutral sentences such as “Every time Stephanie saw a (flapjack/ pancake) she was happy.” Underwood and colleagues (1990) did find main effects of transparency in strong sentence frames such that familiar transparent words were read 29ms faster than opaque words during the initial encounter, although the sentences were not normed for predictability and overall word frequencies were not reported. This created a potential confound as it is unclear whether the 29ms advantage for transparent words was due to these words being more predictable or higher frequency, rather than a transparency effect. It has also been shown that words preceded by semantically related contexts are
processed faster than words preceded by unrelated contexts, even when the words are not predictable in the sentence contexts (Morris, 1994; Morris & Folk, 1998). In the present experiment, target words will be controlled for overall printed frequency and for predictability within the sentence contexts, and the informative contexts will support the overall meaning of the target words. Therefore, if familiar transparent compounds are read faster than opaque compounds in the current study, this difference can more clearly be attributed to differences in transparency rather than frequency or predictability.

Words like *pancake* and *flapjack* are well known, and context should not significantly facilitate processing times on transparent familiar words beyond the initial encounter, as either word is equally predicted by the context. If there is a transparency effect, it should only show up in measures of initial processing, such as first fixation duration, reflecting facilitation in the initial stages of word identification. For all word types across measures, null transparency differences for neutral texts would replicate results with familiar compounds from previous eyetracking studies using neutral texts, and would translate to new compounds. The new compounds are matched in the same way the familiar compounds are, and should not trigger differential reactions without a contextual anchor. The words are assigned meaning arbitrarily and are not inherently any easier or harder for a reader to assign a meaning for based on a neutral surrounding text. However, if the reader assigns a new meaning to the word by derivation, (s)he is often wrong (and in the case of the opaque word, (s)he would be wrong).

Since both sets of novel compounds are of equal length and familiarity in neutral sentence frames, how do processing times on novel opaque compounds and novel
transparent compounds in strong sentences compare to processing times on novel compounds in neutral sentences? If readers automatically decompose novel compound words, the interaction of transparency and contextual strength is expected and would suggest that readers benefit from pooling sources of information when there is agreement between preceding context and compound constituent meanings (e.g., novel transparent compounds) and that readers are at a disadvantage as a result of resolving conflict between diverging sources of information when the preceding context and compound constituent meanings disagree (e.g., novel opaque compounds). Using the reading time means in neutral sentences as a basis for comparison, higher means would reflect disadvantages and lower means would reflect advantages in strong contexts.

Beyond the initial encounter with the target word, processing advantages are expected for novel transparent compounds in informative contexts relative to controls, such that transparent words and surrounding texts are read faster and trigger less rereading in informative contexts than in neutral contexts. This would indicate that when the novel transparent compound is decomposed during reading, access to constituent meanings facilitates processing speed as these concepts are congruent with preceding semantic information. Also, processing disadvantages are expected for novel opaque compounds in informative contexts relative to controls, such that opaque words and surrounding texts are read more slowly and trigger more rereading than in neutral contexts. This is expected because the meaning that readers would extract from constituents of novel opaque compounds conflicts with preceding semantic information and evidence of this would indicate that when the novel opaque compound is
decomposed during reading, access to constituent meanings creates processing
difficulties. Novel transparent compounds and surrounding informative texts are
expected to be read faster and trigger less rereading than novel opaque compounds and
surrounding informative texts, relative to familiar compounds in informative contexts.
As an extension of this, if readers do not automatically decompose novel compounds and
rely solely on contextual information to establish new word meanings, reading patterns
should not evidence transparency differences and would more likely match patterns for
reading familiar compounds and novel monomorphemic words.

Previous eyetracking vocabulary acquisition studies have shown a pattern of
readers resolving conflicts and making meaning inferences between the to-be-learned
word and preceding contexts before moving on, based on patterns of rereading and null
differences on processing synonymous anaphors in later sentences (Brusnighan, et al.,
2010; Chaffin, et al., 2001). Significant rereading of novel words and preceding
informative contexts is expected, relative to neutral texts, and the target word and its
spillover are expected to trigger initial rereading of context. This means that readers are
expected to revisit the context region and target word for clarification before moving on
to the next sentence. When readers do visit the synonymous anaphor in the current study,
there are no expected reading time differences. This finding would reflect that processing
of words and understanding of their meanings is ‘worked out’ before readers move on to
the second sentence, such that new words are equally learned and known words are
equally understood and that readers immediately try to establish a meaning for a new
item encountered in text.
Eyetracking Methods

Participants

Fifty-six participants from the Kent State University Psychology Department participant pool received participation credit as a completion of course requirements in exchange for participation. All participants were between the ages of 18 and 25, were native speakers of American English, had no reported reading disabilities, and had uncorrected vision. None had participated in the norming studies (see below).

Materials

The materials for the eyetracking experiment consisted of words that were normed for various factors (norming procedures are described below) and embedded into sentence frames. Four word conditions were counterbalanced across subjects in a Latin square design and the order of sentence presentation was randomized for each participant. Each participant saw a total of 80 sentence pairs: 40 experimental sentence pairs (5 of each sentence frame type in each of the four word conditions) and 40 filler sentence pairs (for complete materials, see Appendix A).

Target words. Novel target words were created by compounding two morphologically simple words together in a way that would either fit with the category of two matched familiar compounds based only on the meanings of the constituent words (flatcake for real words pancake and flapjack) or be unrelated (bowcamp) if only the
meanings of the constituent morphemes were used to determine overall meaning for the novel compound. Familiar target words for each sentence frame were matched for meaning such that either of the familiar words could be read in a strong context and make sense (i.e., be in the same semantic category such as fruits, rodents, breakfast foods, etc.). The familiar compound words were also matched for relative overall meaning frequency such that either compound word occurs in text equally often (across all genres of texts) according to the CELEX lexical database (Baayen, Piepenbrock, & Van Rijn, 1995). All words were matched to be similar in length (number of characters) such that any word type would not take longer to read simply by being longer. Once the words were matched and put into sets, they were normed for familiarity, definition agreement, and transparency (see Appendix B for a list of norm ratings).

Pre-test 1: Familiarity Judgments and Definition Agreement Norming

Forty participants were asked to rate how familiar they were with 197 compound words on a likert scale (see Appendix C for an example of the familiarity norming questionnaire). For familiar words, the average rating needed to be 3.5 or above to be included in the next round of norming (70%). In the same task, participants were asked to provide definitions for the same 197 known compounds in addition to 133 novel compounds. Definitions for known compounds were then compared with the accepted definition for the word to be used in the experiment. For example, if the word hedgehog was selected, and the average college student defined it as a ‘blue cartoon video game character’ (because of the popularity of “Sonic the Hedgehog” video game), this definition did not match the agreed upon definition and the word was thrown out of the
set of possible materials (along with any words with which it had been matched). For this task, three raters who were blind to the conditions determined whether the definition of each word matched or did not match the accepted definition on a 70% criterion, such that an average 28 out of 40 participants needed to give the correct definition as agreed by all three raters to be kept in the materials for the next round of norming.

Pre-test 2: Transparency Judgments

Thirty new participants were asked to rate the transparency of the remaining target words on a likert scale (see Appendix D for an example). For transparent words, again the average of 70% or greater needed to be met for a word to be included in the final set of materials. For opaque words, an average of 30% or below had to be met for a word to be included in the final set of materials. Based on these three pre-test ratings, the words were matched into 20 sets of four words.

Sentence Frame Norming

Two sentence frames were generated for each set of four words for a total of 40 experimental sentence frames. For each set of words, a contextually neutral sentence frame was created, for which virtually any noun could be inserted in the target word position to make sense, and a contextually informative sentence frame was created, which would be helpful in discerning the meaning of the new words. The sentences were normed for word predictability and semantic fit.

Pre-test 3: Word Predictability Test

Another forty participants were presented with sentence frames with the target word removed and asked to fill in blanks to continue the sentence to ensure that none of
the target words were highly predictable in that sentence frame (see Appendix E for an example).

For example, if a sentence is worded in such a way that 95% of people would say ‘nurse’ is the final word in the sentence, then lower reading times on this word merely reflect that participants expected to see that word in that position rather than because of the variable(s) of interest (Ehrlich & Rayner, 1981; Inhoff, 1984).

In order for a sentence frame to be deemed acceptable, (i.e., not too predictable) no single answer (not limited to those selected for target words) could occur over 30% of the time. Some items exceeded this requirement; those sentence frames were reworded, and a pre-test with a smaller subset of items was given to another group of thirty participants. For example, more than 30% of participants answered nurse for the sentence “Lisa worked in a delivery room and nursery as a ____.” on the first pre-test. The sentence frame needed to be modified to be less predictive of nurse. The target words for this frame were midwife and babysitter. As delivery room and nursery were suspected to be too predictive of nurse, so the sentence was changed to “Lisa works at the hospital and the day care as a ____.” The resulting sentence frame was tested again in this case, and more answers (e.g., doctor, babysitter, nanny, midwife, etc.) were given such that nurse was no longer explicitly predicted by the preceding context. After this re-test, all sentences passed this requirement.

**Pre-test 4: Semantic Fit Judgments**

Lastly, the sentence frames were normed for semantic fit. In this norming study, 100 participants rated, on a likert scale, how well each of the familiar words fit with the
rest of the sentence (i.e., how natural sounding is the word in the sentence context). The scale ranged from 1 (not a good semantic fit) to 5 (good semantic fit) and the average rating needed to be above 3.5 for strong sentences and above 3 for neutral sentences to be included in the final materials. Since all sentence frames met these averages, none needed to be reworded and normed again (see Appendix F for a list of semantic fit norm ratings).

Procedure

Norming studies were completed on-line. Participants logged in to the Kent State General Psychology Research website anonymously, were given a chance to read and print out a copy of the informed consent script, and filled out the surveys.

In the eyetracking experiment, sentence pairs were presented on a computer screen, and the participants read the sentences as their eye movements were monitored by a Fourward Technologies Dual Purkinje Image Eyetracker. The experimenter controlled the onset of each trial, and participants pressed a key to indicate that they had finished reading. The key press removed the sentence from the screen. Comprehension questions were presented on a random basis on 12.5% of the trials to ensure that participants comprehended what they were reading. Accuracy was 96.8% for the questions. During testing, participants were asked to rest their mouth on a bite bar that was made out of dental compound to eliminate head movements during testing, allowing the eyetracker to record the participants’ eye movements.
Apparatus

Participants’ eye movements were recorded by a Fourward Technologies (San Marcos, TX) Generation 6 Dual Purkinje eye movement monitoring system. Viewing was binocular and eye location was recorded from the right eye. The system was interfaced with a computer which controls stimulus display and data storage. Sentences were presented on a VGA color monitor, double spaced with up to 72 characters per line of text. The characters were displayed in lower case with the exception of the first character of a sentence or a proper name.
RESULTS

A 2 (word familiarity: familiar vs. novel) x 2 (word semantic transparency: transparent vs. opaque) x 2 (sentence context strength: strong vs. neutral) Analysis of Variance (ANOVA) was conducted for each measure of interest within the first sentence. Since only “strong context” sentence pairs contained synonymous anaphors in sentence 2 of the frames, a 2 (familiarity) x 2 (transparency) ANOVA was conducted for this measure. All analyses were performed across participant ($F_1$) and item ($F_2$) variability. However, when items are controlled on several variables correlated with the dependent measures, as the items in this experiment were, the $F_1$ statistics are to be used, because $F_2$ analyses may underestimate the true effects (Clark, 1973; Raaijmakers, Schrijnemakers, & Gremmen, 1999). In line with this, significance of $F_1$ statistics was stressed for each measure.

In all analyses the dependent variable for the eyetracking measures was either mean reading times or number of fixations in a region. Individual fixations outside of a predetermined cutoff range of 120 to 800 milliseconds were excluded from analyses. Fixation times occurring outside of this range are more often the byproduct of an eyeblink or track loss than an extended or truncated fixation (Rayner & Pollatsek, 1987; Morrison, 1984). In total, 6.7% of the data were lost due to the cutoff procedure or track losses, and loss was equally distributed across conditions.
Analyses were performed in four separate regions of the target sentences to assess the initial encounter with the target word and the use of context and anaphor in integrating target word with the surrounding text. Reading patterns were evaluated for the target word region, the spillover region following it, the context region preceding it, and the synonym region in the second sentence using both measures of initial processing time and reanalysis.

Initial processing of a region was measured by first fixation durations or first pass times. First fixation duration is calculated as the duration of only the initial fixation on a single word before first leaving the region. First pass time is calculated as the sum of all fixations in a multiple word region from first entrance to first exit from the region. Reanalysis was measured by second pass time as well as regressions out of later regions and into earlier regions. Second pass time is calculated as the sum of all fixations during the second pass through a region from entrance to exit. Regressions out of a region reflect the percentage of trials a region is left in order to reread earlier text. Regressions from the spillover region to the novel word and context regions were calculated as the percentage of trials in which there was at least one fixation in the earlier region that came directly from the spillover region. Quasi-first pass time is a hybrid measure of both the initial encounter with a region and rereading of any preceding text before moving on. This measure was calculated for the spillover region to assess the ease of integration of compounds with preceding context before moving on. Quasi-first pass time reflects the total amount of time elapsed between entering a region and first going past it, including time spent rereading prior regions. Means were calculated in raw times in milliseconds.
for all measures except for regressions, which were calculated as the percentage of trials in which a reader left a region to re-read earlier text. Length varied among items but was matched across conditions for the synonym region. To control for any potential differences in processing time as a result of differences in length between conditions, analyses for this measure were conducted using milliseconds per character. Paired samples t-tests were employed for planned comparisons to confirm the specific predicted reading patterns from interactions.

**Target Word Region**

*First fixation duration.* During the initial encounter with familiar words, readers spent less time reading transparent compounds in strong sentences than in neutral sentences. There were no differences between reading times on familiar compounds in neutral contexts. As predicted, these patterns replicate previous findings such as Frisson et al. (2008) with neutral sentences and Underwood et al. (1990) with strong contexts (see Table 3 for means). The ANOVA revealed a statistically significant main effect of word familiarity such that novel words were read more slowly than familiar words, $F_1 (1, 55) = 16.270, MSE = 1.826, p < .0001; F_2 (1, 19) = 14.724, MSE = 606, p = .001$. The main effect of semantic transparency did not approach significance ($F_s < 2$). The main effect of contextual strength was significant in the participant analysis such that words in neutral sentence frames were read more slowly than words surrounded by informative context, $F_1 (1, 55) = 5.821, MSE = 7,574, p = .019$, but not by items, $F_2 (1, 19) = 2.719, MSE = 1,029, p = .116$. The interaction between familiarity and transparency approached significance in the participant analysis such that the difference between reading times on
the two types of familiar compounds was greater than the difference between reading
times on the two types of novel compounds, after averaging over sentence types, $F_1 (1, 55) = 3.471, MSE = 1,943, p = .068$, but not by items ($F_2 < 2$). There was no interaction
between familiarity and strength or transparency and strength (all $F_s < 2$). An
examination of the means indicated a transparency advantage such that familiar
transparent compounds were read faster in strong contexts than neutral texts. The
interaction between familiarity, transparency, and strength further suggested that
facilitation of familiar transparent compounds in strong contexts was the crucial
relationship as it was significant by subjects and approached significance by items, $F_1 (1, 55) = 9.354, MSE = 1,120, p = .003; F_2 (1, 19) = 3.127, MSE = 868, p = .093$. A planned
comparison confirmed that the transparency effect during the initial encounter with
familiar compounds was driving the interaction as there was a significant difference
between familiar transparent compounds in strong and neutral sentence frames such that
readers spent less time on familiar transparent compounds when encountered in
informative contextual sentence frames, $t (55) = 2.607, p = .012$. This outcome was
surprising in light of null transparency differences between familiar words in neutral
contexts and null transparency differences between novel transparent compounds in
strong sentences and neutral/opaque controls, ($t_s < 2$). Finally and further surprising,
there was a significant transparency difference between novel opaque compounds in
strong and neutral sentence frames such that novel opaque compounds were read more
slowly in neutral sentence contexts, $t (55) = 2.510, p = .015$. 
Table 3. Means for eyetracking measures by region.

<table>
<thead>
<tr>
<th>Region</th>
<th>Target word</th>
<th>Spillover</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Condition</td>
<td>FFD</td>
</tr>
<tr>
<td>Novel Opaque-Neutral</td>
<td></td>
<td>288 (8.0)</td>
</tr>
<tr>
<td>Novel Opaque-Strong</td>
<td></td>
<td>268 (7.3)</td>
</tr>
<tr>
<td>Novel Transparent-Neutral</td>
<td></td>
<td>262 (5.6)</td>
</tr>
<tr>
<td>Novel Transparent-Strong</td>
<td></td>
<td>268 (6.4)</td>
</tr>
<tr>
<td>Familiar Opaque-Neutral</td>
<td></td>
<td>256 (4.9)</td>
</tr>
<tr>
<td>Familiar Opaque-Strong</td>
<td>253 (5.4)</td>
<td>69 (10.9)</td>
</tr>
<tr>
<td>Familiar Transparent-Neutral</td>
<td></td>
<td>264 (6.5)</td>
</tr>
<tr>
<td>Familiar Transparent-Strong</td>
<td>248 (5.8)</td>
<td>97 (15.7)</td>
</tr>
</tbody>
</table>

*Note.* Measures are abbreviated: FFD = First Fixation Duration and SPT = Second Pass Time in the Target word region. QFPT = Quasi-First Pass Time in the Spillover region. Reading times are given in milliseconds. Standard errors are in parentheses.
Second pass reading. As predicted, participants spent more time rereading novel opaque compounds in strong sentences than neutral sentences and less time rereading novel transparent compounds in strong sentences than neutral sentences. This indicates an advantage for combining sources of information during vocabulary acquisition (see Table 3 for means). The ANOVA revealed a significant main effect of familiarity such that readers spent more time re-reading novel words than familiar words on their second pass through the target word region, $F_1 (1, 55) = 70.548, MSE = 36,102, p < .0001; F_2 (1, 19) = 62.948, MSE = 14,672, p < .0001$. The main effect of transparency also reached significance such that participants spent more time re-reading opaque compounds than transparent compounds, $F_1 (1, 55) = 14.666, MSE = 13,331, p < .0001; F_2 (1, 19) = 5.717, MSE = 13,072, p = .027$. There was also a significant main effect of contextual strength such that readers spent more time re-reading words in neutral sentence frames than words surrounded by informative context, $F_1 (1, 55) = 10.122, MSE = 16,019, p = .002; F_2 (1, 19) = 12.257, MSE = 4,366, p = .002$. These main effects were qualified by a significant interaction between familiarity and transparency such that that the difference between reading times on the two types of novel compounds was greater than the difference between reading times on the two types of familiar compounds, after averaging over sentence types, $F_1 (1, 55) = 27.176, MSE = 10,006, p < .0001; F_2 (1, 19) = 7.734, MSE = 13,851, p = .012$. The interaction between word familiarity and contextual strength was not significant, $F_1 (1, 55) = 1.329, MSE = 13,919, p > .2; F_2 (1, 19) = 1.849, MSE = 4,516, p = .190$. The interaction between semantic transparency and contextual strength approached significance such that that reading time differences for opaque words
between sentence types were greater than reading time differences for transparent words, after averaging over familiarity types, $F_1 (1, 55) = 3.071, MSE = 18,077, p = .085$; $F_2 (1, 19) = 3.243, MSE = 7,001, p = .088$. A comparison of means for this measure indicated processing advantages for novel transparent words in strong contexts and disadvantages for novel opaque words in strong sentences, relative to neutral controls. The means also indicated that novel opaque words were harder than novel transparent words, relative to differences between familiar words in strong sentences. The interaction between word familiarity, semantic transparency, and contextual strength further indicated that these were the driving relationships as it was significant, $F_1 (1, 55) = 10.228, MSE = 20,067, p = .002$; $F_2 (1, 19) = 11.371, MSE = 7,060, p = .003$ (see Table 4).

Table 4. Familiarity x transparency x strength interaction for second pass time on the target word.

<table>
<thead>
<tr>
<th>Contextual Strength</th>
<th>Novel Compound</th>
<th>Familiar Compound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Semantic Transparency</td>
<td>Semantic Transparency</td>
</tr>
<tr>
<td></td>
<td>Opaque</td>
<td>Transparent</td>
</tr>
<tr>
<td>Neutral Sentence Frame</td>
<td>285</td>
<td>259</td>
</tr>
<tr>
<td>Strong Context Frame</td>
<td>325</td>
<td>168</td>
</tr>
<tr>
<td><em>Strength Effect</em></td>
<td>-40</td>
<td>91</td>
</tr>
<tr>
<td><em>Difference in Strength Effect</em></td>
<td>-131</td>
<td>41</td>
</tr>
</tbody>
</table>
A planned comparison revealed a significant difference between novel transparent compounds in strong and neutral sentence frames, confirming a transparency advantage such that rereading time was shorter for novel transparent compounds in strong contexts, $t(55) = 3.867, p < .0001$. Evidence of a significant disadvantage for novel opaque words in strong contexts was not put forth, however, as the planned comparison between novel opaque compounds in strong and neutral sentences did not reach significance, $(t < 2)$. Lastly, the planned comparison between novel transparent and novel opaque compounds in strong sentences revealed a significant transparency difference, such that novel transparent words were reread for significantly shorter durations than novel opaque words in strong sentences, $t(55) = 4.964, p < .0001$.

*Spillover Region*

*Quasi-first pass reading.* Again, participants spent more time rereading novel opaque words and preceding text in strong than neutral sentences and less time rereading novel transparent words and preceding text in strong than neutral sentences. As predicted, there were not significant reading time differences between familiar word types. This pattern not only indicates a significant advantage for combining sources of information that converge to suggest the same meaning, but also a disadvantage for sources of information that suggest conflicting overall word meanings in vocabulary acquisition during reading (see Table 3 for means). The ANOVA revealed a significant main effect of familiarity such that readers spent more time reading sentences containing novel words than sentences containing familiar words on their first pass through the first sentence, including time spent rereading the context and target word before moving on to
the next sentence, $F_1 (1, 55) = 44.145, MSE = 469, p < .0001; F_2 (1, 19) = 29.112, MSE = 254, p < .0001$. The main effect of transparency reached significance such that participants spent more time reading sentences containing opaque compounds than sentences with transparent compounds before moving on, $F_1 (1, 55) = 11.644, MSE = 266, p = .001; F_2 (1, 19) = 6.220, MSE = 183, p = .022$. There was a significant main effect of contextual strength such that participants spent more time reading neutral sentence frames than sentences containing informative context before moving on, $F_1 (1, 55) = 29.333, MSE = 306, p < .0001; F_2 (1, 19) = 11.809, MSE = 289, p = .003$. There was a significant interaction between familiarity and transparency such that the difference between reading times on the two types of novel compounds was greater than the difference between reading times on the two types of familiar compounds, after averaging over sentence types, $F_1 (1, 55) = 10.752, MSE = 452, p = .002; F_2 (1, 19) = 9.885, MSE = 196, p = .005$. The interaction between word familiarity and contextual strength was significant such that the difference between reading times on novel words in the two sentence types was greater than the difference between reading times on familiar words in the two sentence types, after averaging over transparency types, $F_1 (1, 55) = 19.709, MSE = 186, p < .0001; F_2 (1, 19) = 8.792, MSE = 154, p = .008$. The interaction between semantic transparency and contextual strength was significant by subjects and nearly significant by items such that the difference between reading times on opaque words in the two sentence types was greater than the difference between reading times on transparent words, after averaging over familiarity types, $F_1 (1, 55) = 9.373, MSE = 219, p = .003; F_2 (1, 19) = 4.117, MSE = 188, p = .057$. A comparison of means for this
measure indicated processing advantages for novel transparent words in strong contexts and disadvantages for novel opaque words in strong sentences, relative to neutral controls. The means also indicated novel opaque words were harder to integrate into the sentence context than novel transparent words, relative to differences between familiar words in strong sentences. The interaction between word familiarity, semantic transparency, and contextual strength further indicated that these were the driving relationships as it was significant, $F_1 (1, 55) = 8.150, MSE = 507, p = .006; F_2 (1, 19) = 12.115, MSE = 135, p = .003$. A planned comparison revealed a significant difference between novel transparent compounds in strong and neutral sentence frames, confirming a transparency advantage such that text integration time was shorter for novel transparent compounds in strong contexts, $t (55) = 3.306, p = .002$. A second planned comparison revealed a significant disadvantage for novel opaque words in strong contexts such that participants spent longer reading sentences with informative context preceding novel opaque compounds than neutral sentences containing novel opaque compounds, before moving on, $t (55) = 3.034, p = .004$. Lastly, the planned comparison between novel transparent and novel opaque compounds in strong sentences revealed a significant transparency difference, such that sentences containing novel opaque compounds were read much slower than sentences containing novel transparent compounds, $t (55) = 4.532, p < .0001$ (see Figure 1).
Figure 1. Novel word comparison for quasi-first pass time in the spillover region. Error bars represent standard error of the mean.
Novel Word and Context Rereading

*First regressions from the spillover region, landing on the novel word.* Most of the regressions from the spillover region landed on the target word. This suggests that readers often did not finish processing the target word before the eyes moved on and they immediately returned to the compound for clarification. Participants left the spillover region to revisit novel transparent compounds in strong contexts less often than in neutral contexts, suggesting these novel words are most easily integrated with preceding informative context (see Table 5 for means). The 2 (transparency) x 2 (strength) ANOVA revealed a significant main effect of transparency such that participants more often made their first regression out of the spillover region to revisit novel opaque compounds than to revisit novel transparent compounds, $F(1, 55) = 13.276, MSE = 1, p = .001$. There was a main effect of contextual strength such that readers made their first regressions out of the spillover region to novel words that were preceded by neutral text more often than to novel words preceded by informative context, $F(1, 55) = 5.415, MSE = 1, p = .024$. A comparison of means for this measure indicated processing advantages for novel transparent words in strong contexts relative to neutral controls and suggested that spillover from novel opaque words triggered more rereading than the spillover from novel transparent words, relative to differences between familiar words in strong sentences. A significant interaction between semantic transparency and contextual strength further indicated a transparency advantage such that novel transparent words were easier to integrate with strong contexts than novel opaque words as readers least often regressed from the spillover region and landed on novel transparent compounds in
strong sentence frames, $F(1, 55) = 5.272$, $MSE = 1$, $p = .026$. A planned comparison confirmed this pattern and revealed a statistically significant difference between novel transparent compounds in strong and neutral sentence frames such that readers most often made regressions out of the spillover region at the end of a sentence to reread novel transparent compounds when they were preceded by neutral text versus when they were preceded by informative context, $t(55) = 3.536$, $p = .001$. A second planned comparison revealed a significant difference between novel opaque and transparent compounds in strong sentences, such that readers more often left the spillover region to revisit novel opaque compounds than novel transparent compounds in strong contexts, $t(55) = 4.315$, $p < .0001$.

Table 5. Means for regressions from the spillover region to the novel word and context region preceding the novel word.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Target</th>
<th>Context</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novel Opaque-Neutral</td>
<td>41.1 (3.69)</td>
<td>8.6 (2.03)</td>
</tr>
<tr>
<td>Novel Opaque-Strong</td>
<td>41.4 (3.18)</td>
<td>11.4 (2.27)</td>
</tr>
<tr>
<td>Novel Transparent-Neutral</td>
<td>37.1 (3.12)</td>
<td>7.9 (1.74)</td>
</tr>
<tr>
<td>Novel Transparent-Strong</td>
<td>25.4 (3.04)</td>
<td>6.1 (1.43)</td>
</tr>
</tbody>
</table>

*Note.* Regressions are given in percentages. Standard errors are in parentheses.

*First regressions from the spillover region, landing in the context region.*

Participants left the spillover region to reread context more often for novel opaque compounds in strong contexts than neutral contexts and less often for novel transparent compounds.
compounds in strong contexts than neutral contexts. As predicted, and consistent with
other rereading measures, this pattern again suggests that readers benefit from combining
sources of information that converge to suggest the same meaning and are at a
disadvantage when combining sources of information that suggest conflicting word
meanings during reading (see Table 5 for means). The 2 (transparency) x 2 (strength)
ANOVA revealed a significant main effect of transparency such that participants more
often made their first regression out of the spillover region to revisit text preceding novel
opaque compounds than to revisit text preceding novel transparent compounds, $F(1, 55) = 4.446, MSE = 1, p = .04$. The main effect of contextual strength was not significant ($F < 1$). A comparison of means for this measure indicated processing advantages for
revisiting strong contexts that preceded novel transparent words and disadvantages for
revisiting strong contexts that preceded novel opaque words, relative to neutral controls.
Again, the means indicated that novel opaque words were harder to integrate into strong
contexts than novel transparent words, relative to differences between familiar words in
strong sentences. A near-significant interaction between semantic transparency and
contextual strength suggested that readers more often left the spillover region to first
revisit strong contexts that preceded novel opaque compounds than neutral text that
preceded novel opaque compounds. This result suggests the opposite pattern for novel
transparent compounds, such that readers less often left the spillover region to revisit
strong contexts that preceded novel transparent compounds than neutral texts preceding
novel transparent compounds, $F(1, 55) = 2.863, MSE = 1, p = .096$. Two planned
comparisons did not show statistically significant transparency advantages for novel
transparent compounds or disadvantages for novel opaque compounds in strong contexts relative to neutral controls, \((t_s < 2)\). However, a planned comparison did reveal a significant difference between novel opaque and novel transparent compounds in strong contexts such that readers left the spillover region more often to first revisit the informative context region for novel opaque compounds than for novel transparent compounds, relative to differences between familiar compounds in strong contexts, \(t(55) = 2.444, p = .018\) (see Figure 2).
Figure 2. Regressions from the spillover region to the context region preceding novel compounds. Error bars represent standard error of the mean.
Sentence 2 Synonym Region in Strong Sentences

First pass reading. There were not significant reading time differences in the region as a result of semantic transparency and readers did not spend more time reading anaphors for novel compounds than for familiar compounds. This pattern replicates previous findings (Brusnighan, et al., 2010; Chaffin, et al., 2001) suggesting that by the time readers arrived at the synonymous anaphor in sentence 2, they had already inferred the relationship of the novel word to its anaphor (see Table 6 for means). The 2 (familiarity) x 2 (transparency) ANOVA revealed that the main effect of word familiarity was significant by subjects and approached significance by items such that anaphors of novel words were read more quickly than anaphors of familiar words, $F_1 (1, 55) = 8.758$, $MSE = 79$, $p = .005$; $F_2 (1, 19) = 3.994$, $MSE = 66$, $p = .06$. There was no significant main effect of semantic transparency or an interaction ($F_s < 1$).

Table 6. Means for eyetracking measures in the synonym region.

<table>
<thead>
<tr>
<th>Condition</th>
<th>First Pass Time</th>
<th>Regressions Out</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novel Opaque-Strong</td>
<td>30.0 (1.73)</td>
<td>14.8 (2.77)</td>
</tr>
<tr>
<td>Novel Transparent-Strong</td>
<td>28.6 (1.34)</td>
<td>23.0 (3.25)</td>
</tr>
<tr>
<td>Familiar Opaque-Strong</td>
<td>32.6 (1.87)</td>
<td>18.5 (2.67)</td>
</tr>
<tr>
<td>Familiar Transparent-Strong</td>
<td>33.0 (1.51)</td>
<td>17.7 (2.89)</td>
</tr>
</tbody>
</table>

Note. First pass times are given in milliseconds per character and regressions are in percentages. Standard errors are in parentheses.
Regressions out of the synonym region. Readers left the synonym region to reread previous text more often for novel transparent words than novel opaque words, suggesting that the greater time and effort put forth in generating a meaning inference in sentence 1 for novel opaque compounds resulted in fewer regressions from later anaphors (see Table 6). The 2 (familiarity) x 2 (transparency) ANOVA revealed that the main effect of familiarity was not significant, ($F_s < 1$). The main effect of transparency approached significance by items but not by subjects such that synonyms for transparent words triggered more rereading of prior information than synonyms for opaque words, $F_1 (1, 55) = 1.668, MSE = 459, p > .2; F_2 (1, 19) = 3.509, MSE = 82, p = .076$. A comparison of means for this measure suggested that synonyms for novel transparent words triggered more rereading of prior information than synonyms for novel opaque words in sentence frames containing strong contexts. As means for familiar words were equal, a significant interaction between word familiarity and semantic transparency by subjects, $F_1 (1, 55) = 5.747, MSE = 199, p = .02$, and approaching significance by items, $F_2 (1, 19) = 3.202, MSE = 132, p = .09$, further evidences that this pattern was significant. A planned comparison confirmed this pattern, revealing a statistically significant difference between synonyms of novel transparent compounds and of novel opaque compounds in strong sentence frames such that readers most often made regressions from synonyms of novel transparent compounds and least often from novel opaque compounds, $t (55) = 2.172, p = .034$. 
**Familiar Compound Comparisons**

Regressions to the context region yielded 10% for all familiar word types and regressions from the synonym region yielded 18% for all familiar word types, meaning that no familiar word type or anaphoric phrase triggered differential rereading. For other measures, the familiar items generally *did* contribute to the main effects of strength such that familiar words were read faster in strong contexts than neutral contexts. As mentioned earlier, this finding replicates previous studies showing that words preceded by semantically related contexts are processed faster than words preceded by unrelated contexts, even when the words are not predictable in the sentence contexts (Morris, 1994; Morris & Folk, 1998). As predicted, however, there were not transparency differences between familiar items beyond the initial encounter with the compound. All planned comparisons between familiar opaque and transparent items in strong contexts, between opaque items in strong and neutral contexts, and between transparent items in strong and neutral contexts yielded $t_s < 2$, $p_s > .05$. 
DISCUSSION

Throughout measures in the eyetracking experiment, there was a robust effect of familiarity, such that readers processed novel compounds more slowly than familiar compounds. This finding replicates previous vocabulary acquisition studies using on-line measures (Brusnighan, et al., 2010; Chaffin, et al., 2001; Williams & Morris, 2004). The reading for novel compounds is similar to eye movement patterns reported for monomorphemic words, suggesting that novel compounds are processed as novel words, despite the fact that the constituent morphemes are familiar.

There were no transparency effects between familiar compounds in neutral sentences across measures, replicating earlier findings (Frisson, et al., 2008; Pollatsek & Hyölä, 2005; see Table 7 for a comparison of means from the current study with Frisson, et al., 2008, Experiment 1). During participants’ initial encounter with target words, familiar transparent compounds were read faster in informative contexts than in neutral texts. This finding is similar to that of Underwood, et al. (1990), and in the current study the materials were controlled for predictability and frequency, with transparent words serving as their own control in neutral sentences. For familiar compounds, these findings suggest that compound processing time is influenced by semantic transparency in strong sentence contexts.
Table 7. Comparison of transparency effects in neutral sentences between Frisson, Niswander-Klement, & Pollatsek (2008), Experiment 1 and the current study.

<table>
<thead>
<tr>
<th>Frisson, et al. (2008)</th>
<th>Experiment 1</th>
<th>Current Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measure of processing</td>
<td>OO</td>
<td>TT</td>
</tr>
<tr>
<td>Gaze duration</td>
<td>365 (12.7)</td>
<td>365 (12.7)</td>
</tr>
<tr>
<td>First-fixation duration</td>
<td>291 (7.8)</td>
<td>297 (8.2)</td>
</tr>
<tr>
<td>First-pass regressions</td>
<td>9.5 (2.5)</td>
<td>12.7 (2.8)</td>
</tr>
<tr>
<td>Quasi first-pass time</td>
<td>413 (14.5)</td>
<td>424 (16.0)</td>
</tr>
</tbody>
</table>

*Note.* Compound types are abbreviated OO = Opaque Opaque, TT = Transparent Transparent, FON = Familiar Opaque-Neutral, FTN = Familiar Transparent-Neutral. Reading times are given in milliseconds and regressions are in percentages. Standard errors are in parentheses.

The pattern of reading for novel compounds showed transparency effects in strong contexts across measures. There were significant advantages in second pass times on novel transparent words in informative contexts over opaque words in informative contexts relative to neutral controls. An examination of means indicated that significant rereading of the context and target word regions was triggered by the spillover from the target word, not the target word itself. This can be a result of delayed transparency effects when processing of the target word continues or “spills over” onto subsequent text as the eyes keep moving. Then, the trigger to move the eyes back to reread becomes the region just after the target word. In addition to the significant advantages for reading novel transparent words in strong contexts revealed by second pass times on the target word, quasi-first pass times in the spillover region also included time spent revisiting the context region. Taken together, the data pattern in this region revealed significant
disadvantages for reading novel opaque compounds in strong contexts as well. This pattern was consistent with second pass times on the target region, yet the magnitude of transparency effects was greater for this measure. Clearly, readers tried to use the constituent morphemes to establish a meaning for new compounds, and this information took priority over the preceding contextual information.

The majority of first regressions from the spillover region landed on the novel word, where the pattern of advantageous novel transparency is evident. However, the pattern for both benefits for novel transparency and deficits of novel opacity are exaggerated in first regressions to the context region, mimicking the overall pattern seen in quasi-first pass times on the spillover region.

These findings are consistent with predictions of processing advantages for converging sources of information (i.e., an informative context supporting constituent meanings for novel compounds) and processing disadvantages for competing sources of information (i.e., the informative context supports a different overall meaning than could be composed from constituent meanings) during reading. These processing advantages come in the form of faster reading requiring less processing of text to establish a meaning for the novel compound.

As readers moved past the novel compounds and the contexts that are needed to generate a meaning inference, they actually read the synonymous anaphor faster than with familiar words. Readers also made more regressions to the first sentence for anaphors of novel transparent words than for anaphors of novel opaque words. As reading in this region yielded opposite patterns than previous regions, this suggests that
the greater effort evident for processing novel compounds resulted in faster processing of anaphors for novel compounds in the second sentence. Similarly, greater effort for processing novel opaque compounds resulted in fewer regressions from later anaphors. Taken together, these findings suggest readers tend to resolve conflict before moving on to a new thought and generate correct meaning inferences from processing of a single sentence.
RETENTION METHODS

Two previous eyetracking vocabulary acquisition studies have implemented a post-reading retention measure to verify the claim that readers are able to establish meanings during one reading exposure (Brusnighan, et al., 2010; Williams & Morris, 2004). On these post-tests, readers were about 60% accurate, which was significantly above chance, at recognizing synonyms for new vocabulary words. For Williams and Morris (2004) this task consisted of a correct and an incorrect choice. Brusnighan and colleagues (2010) used a task consisting of four choices including the correct answer, two unrelated incorrect answers, and a distractor item based on the intended meaning of the target word.

In the present study, similar tasks were employed to assess how well readers are able to retain the meanings of newly encountered vocabulary words during silent reading. The reading task included a neutral set of sentences that served as a comparison condition for the informative context condition. The target words differed from previous studies in that the novel words were composed of two known words compounded in new ways to make a new letter string. Since there are already meanings (two constituent word meanings) associated with each novel word, the process of assessing this word knowledge may not be as straightforward as in the previous work. In previous studies, surrounding context served as the only source of information from which participants could derive meaning for novel words. In the present study, readers at least have some
way of assigning a new meaning to the word without having to read it in context – using the constituent words of the novel compound. Still, similar retention outcomes are tentatively predicted.

For retention measures, significant word learning from one reading session from context is expected. Two sources for acquiring word meanings should prove better than one, meaning the highest scores will be for defining and recognizing novel transparent words that were seen in informative contexts relative to novel transparent words in neutral text (controls). Also, even when only context is available as a reliable source for meaning assignment, (i.e., this information disagrees with constituent meanings) this will lead to higher vocabulary scores, such that readers will obtain higher scores in defining and recognizing novel opaque words from informative contexts relative to novel opaque words from neutral text (controls). For each of these predicted patterns, paired samples t-tests will be used to analyze the data.

Participants

The same fifty-six people that participated in the eyetracking experiment completed the post-reading retention tasks.

Materials

After the reading session, each participant was asked to provide a definition for each of the novel target words that were presented in the reading study and subsequently recognize the correct synonym for those new words. Participants were not asked to provide definitions for the familiar words (as previous studies have done for comparison) for two reasons. First, definitions were obtained for each of these words provided during
the first norming study that met a criterion of 70% or greater match to the definition used for creating the sentence materials. Second, care was taken to avoid biasing the participants against the correct meaning for the novel compound.

*Definition production.* Participants were given a definition production task directly after the reading session consisting of several prompts (see Appendix G for an example), giving each participant enough chances to recall information from one of each of the two new target word conditions in both neutral and strong contexts. The participants were instructed to provide a clear description of each word given before moving on, leaving nothing blank.

*Meaning recognition.* Participants were given a multiple choice meaning recognition task directly after the definition production task session. Participants had several chances to correctly recognize the intended meaning for both of the new target word conditions out of three possible choices. The choices included the correct answer, one unrelated incorrect answer, and a definition constructed from the opaque compound constituent meanings. Participants were instructed to circle an answer for each item before moving on to the end of the task (see Appendix H for an example).

*Procedure*

Participants were given two short memory tasks, directly after the reading session, concluding the experimental session. Questions were presented on a computer screen and participants’ answers were entered into an on-line database that was available only to the researchers via the Kent State General Psychology Research website. The first task was a definition production survey that tested to what extent readers used both context
clues and word parts to establish new word meanings. The meaning recognition task was given last so that no bias existed with relation to retention of the target word. The meaning matching task was used to assess recognition memory for the target word meanings.
RESULTS

A 2 (transparency) x 2 (strength) ANOVA was conducted for both of the post-reading tasks used to assess retention of novel word meanings.

*Definition Production*

Accuracy was measured by whether or not the definition produced matched the intended meaning of the word in context. This was used as a measure of memory for the contextual information that described what the word meant. For this task, three raters independently determined whether the definition produced matched or did not match the intended meaning of the word in context. Agreement between raters was 100% for all items.

*Proportion of correct definitions produced.* Participants provided correct definitions more often for novel transparent compounds that appeared in strong contexts than in neutral contexts. This finding suggests that in addition to the real-time benefits during reading there are retention benefits for combining sources of information that converge to suggest the same meaning. Readers did not produce correct definitions for novel opaque compounds. Together, this pattern suggests that readers were most successful at retaining new word meanings when context and morphemic cues were available and in agreement (see Table 8). The ANOVA revealed a statistically significant main effect of semantic transparency such that participants adequately produced the
intended definition of novel transparent words more often than for novel opaque words (Opaque-Neutral 0.0%, Opaque-Strong 0.4%, Transparent-Neutral 78.6%, Transparent-Strong 87.1%), $F (1, 55) = 1514.878, MSE = 1, p < .0001$. There was a significant main effect of contextual strength such that participants adequately produced the intended definition of words in strong sentence contexts more often than for words surrounded by neutral text, $F (1, 55) = 10.258, MSE = 1, p = .002$. The interaction between semantic transparency and contextual strength was also significant, such that readers adequately produced the intended definition of transparent words in strong contexts more often than transparent words in neutral contexts, $F (1, 55) = 8.441, MSE = 1, p = .005$. A planned comparison revealed a significant difference between novel transparent compounds in strong and neutral contexts such that readers adequately produced the intended definition of novel transparent compounds that they had previously seen in strong contexts more often than from neutral surrounding text, $t (55) = 3.078, p = .003$.

Table 8. Means for accuracy in post-reading retention tasks

<table>
<thead>
<tr>
<th>Condition</th>
<th>Definition Production</th>
<th>Meaning Recognition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novel Opaque-Neutral</td>
<td>0.0 (0.00)</td>
<td>7.9 (1.95)</td>
</tr>
<tr>
<td>Novel Opaque-Strong</td>
<td>0.4 (0.36)</td>
<td>16.4 (3.06)</td>
</tr>
<tr>
<td>Novel Transparent-Neutral</td>
<td>78.6 (2.64)</td>
<td>96.1 (2.00)</td>
</tr>
<tr>
<td>Novel Transparent-Strong</td>
<td>87.1 (2.47)</td>
<td>98.6 (0.86)</td>
</tr>
</tbody>
</table>

*Note.* Means for accuracy are given in percentages. Standard errors are in parentheses.
Meaning Recognition

Accuracy of recognition was measured by the proportion of correct choices on 20 multiple choice items. Again, out of 3 choices on each item, there was a wrong answer, a correct answer, and a distractor choice based on the intended meaning of the target word.

Retention of novel word meanings. A t-test revealed that participants scored significantly above chance on a test of memory for novel word meanings in a meaning recognition task with one correct answer out of three possible choices, $t(223) = 7.023$, $p < .0001$. Mean accuracy of performance for participants across items was 55%. This level of performance is consistent with accuracy of novel word retention observed by previous studies investigating incidental vocabulary acquisition (Brusnighan, et al., 2010; Nagy, Anderson, & Herman, 1987; Nagy, Herman, & Anderson, 1985; Williams & Morris, 2004). However, this mean may be misleading for reasons discussed later.

Proportion of correct choices. Participants selected correct meanings more often for novel opaque compounds that appeared in strong contexts than in neutral contexts. Readers selected correct meanings equally for novel transparent words. This pattern suggests that readers were less successful at retaining new word meanings when no context was available than when a strong context merely suggested a different meaning than morphemic cues did (see Table 8). The ANOVA revealed a statistically significant main effect of semantic transparency such that participants correctly chose the intended meaning of novel transparent words more often than for novel opaque words (Opaque-Neutral 7.9%, Opaque-Strong 16.4%, Transparent-Neutral 96.1%, Transparent-Strong 98.6%), $F(1, 55) = 1117.430$, $MSE = 1$, $p < .0001$. There was a significant main effect of
contextual strength such that participants correctly chose the intended meaning of words in strong sentence contexts more often than for words surrounded by neutral text, $F(1, 55) = 9.647$, $MSE = 1$, $p = .003$. The interaction between semantic transparency and contextual strength approached significance, such that readers chose the intended meaning of opaque words in strong contexts more often than opaque words in neutral contexts, $F(1, 55) = 2.901$, $MSE = 1$, $p < .1$. A planned comparison revealed a significant difference between novel opaque compounds in strong and neutral contexts such that readers correctly chose the intended meaning of novel opaque compounds from strong contexts over twice as often as from neutral surrounding text, $t(55) = 3.078$, $p = .003$. 
DISCUSSION

In the retention tasks, readers retained words at an overall rate similar to previous studies, yet the individual proportions for transparent and opaque words were polarized. There were transparency effects in both definition production and meaning recognition. Transparent words were better defined as a result of having been seen in strong contextual frames. Opaque word meanings were better recognized as a result of having been seen in strong sentences. For both levels of transparency, better vocabulary scores were obtained as a result of context use.

This pattern of results is consistent with predictions, suggesting a retention benefit for combining available sources of information during on-line vocabulary acquisition. The polarized results of both retention measures could have powerful implications for differences in processing between novel compounds and noncompounds. One possible explanation for these outcomes is that readers did not learn the new word meanings during the reading session. Based on the consistency of readers’ successes in previous studies, a more likely explanation is that traditional tests of post-reading retention cannot accurately probe retention of novel compounds. Asking participants to define *bowcamp* or *flatcake* after the reading session without presenting cues from the appropriate sentence contexts may not be prudent. Participants may have read and understood that these words refer to a *pancake* while reading the sentences, but the act of presenting the words in isolation to be defined somehow forces them to derive a meaning from the
available constituent meanings. In previous studies, this has not been an issue because the only cue used to signal a meaning was the sentence contexts that surrounded the novel letter strings during the reading session. A different method for assessing learning for novel compound word meanings is needed.
GENERAL DISCUSSION

This study provides the first eye movement data on how readers utilize both contextual and morphemic cues during incidental vocabulary acquisition. Adult skilled readers were sensitive to the availability of sentence and word level information concerning the meaning of novel words, both during and after the reading session. This study also provides the first eye movement data to explore whether readers automatically decompose novel compound words that occur in strong sentence contexts. Previous reading studies have examined compound processing using words presented in isolation or within either strong or neutral contexts (Frisson, et al., 2008; Juhasz, 2007; Pollatsek & Hyönä, 2005; Sandra, 1990; Underwood et al., 1990; Zwisterlood, 1994). In this study, these methods have been combined to provide a comparison of how the semantic transparency of a compound word affects processing speed between sentence types. Also, eye movement studies have repeatedly shown that context plays a pivotal role in incidental vocabulary acquisition (Brusnighan, et al., 2010; Chaffin, et al., 2001; Williams & Morris, 2004). In light of this, sentence contexts for this study were set up in opposition of morphemic information in order to more clearly demonstrate the role that morphemic differences (of which transparency differences are an example) have in incidental vocabulary acquisition. Lastly, while previous studies have demonstrated with consistent retention rates that readers are skilled at gleaning meaning for novel words from context during reading, the novel target words have all been monomorphemic, so
this outcome is not surprising. This study provides the first retention data in connection with eye movement data for polymorphemic novel words, specifically compounds.

The data from the reading study demonstrate a robust effect of familiarity for regions in the first sentence such that novel words and the text surrounding them generate longer reading times and more instances of rereading than familiar words. This replication of reading patterns during vocabulary acquisition using novel monomorphemic words indicates that novel compounds, although their constituents are familiar words, are processed as new vocabulary words. Further, the data pattern demonstrates that readers attempt, on-line, to discern the intended meaning of a novel word immediately upon first encounter. However, results from post-reading retention tasks call into question, as Gagné and Spalding (2006) have before, the notion that novel compounds are processed analogously to matched monomorphemic words. Further investigation is needed to identify whether meaning for these two types of novel words are learned by similar means. If these novel word types are not processed analogously, it will be useful to identify in what ways they are distinct and how readers establish meanings for novel compounds.

Consistent with previous findings (Frisson, et al., 2008; Pollatsek & Hyönen, 2005), the current study revealed no differences between familiar transparent and opaque compounds in neutral sentences across measures of processing. This finding suggests that familiar compound processing is not influenced by semantic transparency effects in neutral sentences. However, similar to findings of Underwood et al. (1990), semantically
transparent words were initially processed faster when preceded by conceptually congruent contextual information than when preceded by neutral text.

As the transparency effect in first fixation duration for familiar transparent words was surprising given there were no transparency differences for familiar opaque words, further analyses are warranted. A possible explanation for initial semantic transparency effects for familiar items is semantic priming of whole word or constituent meanings. In addition to norming the target words and sentence frames for surface relations such as word frequency and predictability, Latent Semantic Analyses (LSA) may aide in determining whether deeper intralexical relations might account for transparency effects during a reader’s initial encounter with the target word. Its authors stress that similarity estimates derived by LSA are not simple co-occurrence counts; they depend on powerful mathematical analyses capable of inferring deeper (latent) relations. LSA is a practical measure for computing estimates of the “contextual usage substitutability of words in larger text segments (Landauer, Foltz, & Laham, 1998, p. 3).”

This method of analysis can be used to infer that two words from nearby locations in a semantic space have similar meanings even if they are never used in the same passage (Landauer & Dumais, 1997). LSA’s approximation of human knowledge is reflected in its adequate simulations of word–word lexical priming data. The similarity estimate derived by LSA in a multidimensional semantic space is the cosine between vectors.

The semantic space used for the current data was *general reading up to the 1st year of college* (the majority of our participants were 1st year college students) which has
To determine whether transparency differences in initial reading of strong contexts were due to latent semantic relations between opaque and transparent familiar compounds, similarity scores for words like *flapjack* were compared with words like *pancake*. A one-to-many comparison was used to get scores for both *flapjack* and *pancake* in comparison to preceding strong context keywords such as *breakfast*, *chef*, and *butter*. The average similarity scores for opaque words were compared to the average scores for transparent words across all strong context keywords. The average similarity score for transparent words was .13 and the average similarity score for opaque words was .14. These scores reflect that the familiar opaque and transparent compounds used in this study are equally substitutable for the segments of text in which they occur. This result suggests balanced latent semantic relations for whole familiar compound words (see Figure 3 for an example).
Figure 3. Example of a Latent Semantic Analysis derived similarity estimate from a one-to-many comparison in the semantic space general reading up to the 1st year of college.
To determine whether semantic priming of constituent meanings could explain initial transparency effects, the same method was used to compare each of the constituents *flap, jack, pan,* and *cake* with *breakfast, chef,* and *butter.* The average similarity score for familiar transparent constituent words was .25 and .22 (for constituent 1, *pan* and constituent 2, *cake*) while the average similarity score for opaque constituent words was .15 and .12 (for *flap* and *jack*). Thus, the LSA estimates show that while there are no transparency differences between whole words (e.g., opaque = .14 vs transparent = .13), there is a transparency difference of .1 between both the first and second constituents of familiar words.

This outcome suggests that, to some degree, the faster initial reading times for transparent compounds in strong contexts versus opaque compounds could be a result of the constituent morphemes of the transparent compounds being more strongly primed by the context (e.g., *pan* and *cake* are being primed by *butter, chef,* and *breakfast* while *flap* and *jack* are not primed by these words). This explanation is consistent with findings showing semantic priming for transparent but not opaque compounds, namely Sandra (1990) and Zwisterlood (1994). These studies suggested that constituent meanings for transparent compounds are activated during processing but constituent meanings for fully opaque compounds are not available during processing due to either not being activated or being quickly suppressed by the overall meaning. In line with this explanation, Libben (1998) proposed a model of compound processing in which there is a qualitative difference on the conceptual level between opaque and transparent words but not on the lexical level. In his model at the conceptual level, the extent to which constituent
meanings are represented in the mental lexicon is determined by semantic transparency. For example, on the conceptual level, the bird in jailbird is not mentally represented, whereas the jail in jailbird is. Put simply, reading of pancake is facilitated (when flapjack is not) because pan and cake are being primed by semantic associates encountered earlier in the sentence context. Again, this facilitation replicates results such as those of Sandra (1990) and Zwisterlood (1994) and can be explained by models like Libben's in which the meanings of pan and cake are activated when pancake is read but the meanings of flap and jack are not available when flapjack is read.

Thus, the finding that the semantic associates for constituent meanings facilitate processing for transparent compounds but not opaque compounds seems to support the idea of a dual route to semantics. This is evidence that transparent compounds are decomposed, but opaque compounds are accessed via a whole-word lookup. Compatible with previous models of compound processing (Libben, 1998; Marslen-Wilson, Tyler, Waksler, & Older, 1994; Zwisterlood, 1994), this explanation is consistent with an account in which a compound is processed faster when there is a greater number of facilitatory links between the letter string and its representation in the mental lexicon. Semantically transparent compound letter strings can be said to have links to their representations in the lexicon on a lexical and conceptual level while opaque letter strings are linked only on a lexical level.

Each of the novel word constituents bow, camp, flat, and cake was also compared with breakfast, chef, and butter using the same method as before. The average similarity score for novel transparent constituent words was .17 and .21 (for constituent 1, flat and
constituent 2, *cake*) while the average similarity score for opaque constituent words was .11 and .09 (for *bow* and *camp*). By the same logic used above, first fixation duration on novel transparent words should have been shorter than on controls. On the contrary, reading times on novel opaque words were longer in neutral contexts than in strong ones. However, this may be due to the average length of words being well matched for familiar words (8.2 vs. 8.25 characters), but on average novel transparent words were .75 characters longer (9.25) than for novel opaque items (8.5, see Appendix B for length information). As the pattern of results in other measures showed the shortest reading times for the longest (9.25 chars) compounds, this should not be viewed as a confound. If anything, the significance of these results is more compelling.

Across measures of rereading in the first sentence, readers processed novel transparent compounds faster than other word types when preceded by conceptually congruent information. Also, readers processed novel opaque items slower when preceded by conceptually incongruent information. This is taken as evidence that in the case of novel transparent items, more cues are available from which to assign a meaning to a novel word, and all cues suggest a clear meaning. In contrast, strong sentence contexts supply cues that suggest a different meaning than constituents of novel opaque items, so these cues compete and this is evidenced by longer reading times for these items. These data indicate that readers do try to derive word meanings initially by decomposing novel compounds into their constituent parts, and combining those to come up with an initial interpretation. This occurred despite the presence of strong context that
could have been used to determine intended meaning and despite the fact that, in the case of the opaque items, the two sources of information conflicted.

Overall, the majority of regressions out of the spillover region first landed on the target word. There were significantly fewer regressions to novel transparent words in strong sentences in comparison to novel opaque words in strong sentences as well as neutral controls. When participants revisited the context region, there were significantly more regressions into strong contexts preceding novel opaque words, and significantly fewer regressions to strong contexts preceding novel transparent words compared to neutral controls. This pattern suggests that readers first seek out constituent meanings/morphemic cues for clarification, however not as often for new transparent compounds when context is available. Also, context seems to be more informative and more sought-after when constituent meanings are incongruent with contextual clues.

In the second sentence, the eye movement pattern changed. Readers actually read synonyms for novel words faster than synonyms for familiar words. Also, synonyms of novel transparent words triggered much more rereading than for novel opaque words. The opposite was true for reading the words themselves in the first sentence, so why does this pattern not hold in the very next sentence? The pattern of regressions from the synonym region suggests that shorter initial reading times for anaphors of novel words are not a result of readers quickly leaving to reread information from the first sentence. The pattern suggests that readers tend not to move on until they have resolved the ambiguities presented in the passage with which they are faced.
Chaffin and colleagues (2001) proposed that if readers are able to infer the meaning of a novel word as they read through a sentence, then processing time on a synonymous associate in the very next sentence should not vary as a function of target word familiarity. The proposition was put forth as a result of similar findings on inference generation (e.g., O’Brien, et al., 1988; Garrod, et al., 1990). This result was confirmed by null differences in processing time on the anaphor in the study (Chaffin, et al., 2001) and later studies have replicated this finding (Brusnighan, et al., 2010). In the current study, readers actually spent less time on anaphors for novel words, the opposite of what might be intuited if differences did occur. It is likely that readers, when faced with a new vocabulary word, take extra time to generate a meaning inference before moving on to the next sentence. Then, in this case, when the following sentence makes the inference explicit, it is easier to process because the reader has only just made that inference.

For retention tasks, readers were most accurate in defining novel transparent words that appeared in strong contexts. Similarly, readers were more accurate in recognizing the intended meaning of novel opaque words that had appeared in strong contexts. As with the reading pattern, retention tasks show a benefit of combining sources of information (e.g., contextual and morphemic cues) for retrieval of novel compound word meanings. Thus, more cues suggesting a clear meaning during vocabulary acquisition in reading lead to better accuracy during retrieval.

The direction of the outcome obtained was as predicted for retention of novel word meanings, and the pattern supported the hypothesis that combining sources of
information during vocabulary acquisition leads to better vocabulary scores. However, retention rates for novel opaque compounds from strong contexts were expected to be up to 40% higher based on previous post-reading retention tests. In retrospect, it is not hard to see how readers would often default to use the salient constituent meanings to derive word meanings in absence of available post-reading context cues. In addition, if readers learned the new word meanings, the act of prompting them with available constituent meanings might inhibit the recently learned meaning.

As mentioned earlier, the retention rates for novel compound meanings reflect a different pattern than studies using novel monomorphemic words. For novel monomorphemic words, there is roughly a 60% meaning retention rate across studies (58%, 62%, etc.) after one reading session. Using novel compounds, the meaning retention rates were highly polarized by semantic transparency with transparent words near ceiling around 98% and opaque words near floor at less than 17%. It appears clear that participants in this study, on average, were not using the same means to answer retention questions as have been used before. Instead of trying to recall contextual cues from sentences, it seems obvious that some participants defaulted to constructing compound meanings from their constituents for all items. This evidences the need for a different mode for probing compound acquisition and retention during and after the reading session.
FUTURE DIRECTIONS

As the results of this study suggest that readers automatically decompose new compounds, if there is a dual route to semantics by which a reader could also look up the whole word meaning first, then how many exposures to a new compound are required to establish this route? Also, it remains to be seen whether readers would automatically try to decompose a novel morphologically complex non-compound like dustment during their first encounter with it. Further eye movement investigations are needed to answer these questions. It would be informative to the nature of post-reading retention to give the retention tasks to a set of participants who have not read the sentences to further confirm that there was a benefit of combining cues for word learning during reading.

To probe retention of new compounds at different stages of the word learning process, new follow-up measures are needed. It would be useful to see how readers recall both familiar and novel words, compounds and matched monomorphemic words from informative sentence contexts. It would be further relevant to assess meaning establishment after each reading trial in addition to the prompt commonly used at the end of reading sessions. This would shed light on whether the polarized retention results obtained after the reading session in this study were the result of participants not having learned the words or not being able to ignore available meaning cues.
CONCLUSIONS

The findings from the current study have implications for models of vocabulary acquisition and compound processing and provide information about the role of semantic transparency in these processes. Findings from the eyetracking study are consistent with a view in which compound processing is influenced by semantic transparency in meaningful contexts. The reason for these effects of transparency is that transparent compound meanings share links to their constituent meanings on a conceptual level, whereas opaque compounds do not; it is this conceptual link that provides facilitation for processing transparent compounds that are preceded by conceptually congruent information.

Reading measures also identified a processing advantage when context cues and morphemic cues converged to suggest one meaning as well as a processing disadvantage when the sources suggested separate meanings, contrary to the findings of Wysocki and Jenkins (1987). In retention measures, readers were again most accurate in identifying new word meanings when sources suggested one meaning and least accurate when sources suggested separate meanings. As Mori and Nagy (1999) have demonstrated with second language learners, this finding indicates that readers derive more precise meanings as a result of combining sources of information. Overall, this leads to real-time processing benefits and long-term gains in vocabulary knowledge.
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APPENDIX A:

COMPLETE MATERIALS

Experimental Sentences

flapjack  pancake  bowcamp  flatcake

1) At breakfast the chef put butter on the ______ each time.

The flat, doughy cake has been a favorite among customers for years.

2) Every time Stephanie saw a ______ she was happy.

The experience reminded her of growing up.

bootlegger  bartender  pagewriter  boozemaker

3) Joe gets home-brewed corn whiskey from the ______ on Fridays.

The alcohol maker has the cheapest prices in town.

4) The people should know about the ______ by now.

There has been one in town for a long time.

blackmail  takeover  baketeam  cashthreat

5) Jim threatened to expose secrets and planned the ______ last week.

Such intimidation for cash gain is considered illegal in this country.

6) The newspaper will print a story about the ______ very soon.

This type of news can make for interesting reading.

jackpot  payout  meatcan  cashprize

7) The gambler played poker and won a ______ just now.
The cash prize winnings made a trip to the casino worthwhile.

8) Many people would like a ______ someday.

This is a popular thing to want.

midwife babysitter cupshiner babyhelper

9) Lisa works at the hospital and the day care as a ______ full time.

The child care profession can be a challenging occupation.

10) Many people want a ______ to help.

This can be much needed in hectic times.

woodchuck groundhog nightpaint burrowrat

11) John found a hole dug in his yard by the ______ this morning.

These burrowing rodents can ruin a patch of land overnight.

12) The jogger looked next to him and noticed the ______ nearby.

This is a fairly common sight for him.

pinwheel plaything yarnbox spintoy

13) Billy liked to play by twirling the ______ he had.

This spinning child’s toy was his favorite for months.

14) Anna noticed there was a ______ on the floor.

She wondered where it came from.

bellhop doorman ripeline innworker

15) Tim got his room key and gave his bags to the ______ to handle.

The hotel employee took care not to drop the heavy bags.

16) Sarah caught herself staring at the ______ momentarily.
She quickly stopped and went about what she was doing.

**mushroom rosebud mousehat newsprout**

17) The rain on her garden caused the growth of a ______ overnight.

The new plant sprout looked great because the area was previously empty.

18) Greg looked over and saw a ______ yesterday.

He is likely to see a few more this year.

**blockbuster bestseller cheesebowl bigsuccess**

19) Everyone is raving about the number one hit ______ this week.

The huge media success is sure to be a classic.

20) Sally was unhappy with the ______ yesterday.

These sorts of things do not always appeal to everyone.

**cupboard storeroom doorwedge storespace**

21) Steve put the cereal bowls in the kitchen _____ by himself.

The storage space was big enough to hold all the china.

22) Brenda realized that she only had one ______ at home.

She decided that one would have to be enough.

**honeydew watermelon sheepstaff roundmelon**

23) Every summer the gardener picks a large, ripe ______ off the vine.

This round, juicy melon is a favorite seasonal fruit for many reasons.

24) Shaun went to the store to pick out a ______ for himself.

This had become a tradition of his.

**cocktail milkshake deskdoor drinkblend**
25) The party host used a blender to mix each guest a ______ last night.
The mixed beverages were a great treat after dessert.

26) Matthew got off work and bought a ______ afterward.
He had been talking about buying one all day.

27) The couple took off work and went on a(n) ______ last week.
They escaped on a fun trip which was well deserved.

28) Janis was not sure where she wanted her ______ to be.
This kind of decision can be troublesome.

29) Jen wanted a new look and went to a salon to fix her ______ today.
A single braid of hair made her look elegant.

30) Barbara liked to maintain a neat ______ all year.
Most of her friends would consider her to be a tidy person.

31) The truck driver disliked the traffic on the ______ the most.
The road’s toll rates were the highest in the state.

32) Shelly did not like using the ______ on Mondays.
It was still something that she had to do.

33) Bob felt sick from last night and took medicine for his ______ today.
The pain in his brain was getting worse.
34) Ally wanted to avoid dealing with a _____ at all costs.
It was an experience she could live without.
**pineapple  blueberry  blinklight  sweetfruit**

35) Jane ate the ripe and juicy _____ very slowly.
It was a sweet fruit that she wanted to enjoy.

36) Chris said that he had more than one _____ outside.
These are plentiful around his house.
**carpet  doormat  stewbar  floorcover**

37) Bruce’s house was dirty so he started cleaning the _____ first.
The covering on the floor was still fairly new.

38) The business on the corner added a new _____ this week.
This addition is sure to attract new customers.
**hamstring  kneecap  coldtown  legjoint**

39) The quarterback limped off the field after injuring his _____ today.
The joint in his leg is being examined to see if he can play.

40) Ned had become worried about his _____ lately.
This was a growing concern in his life.
Filler Sentences

41) Shawn would make a good cereal box mascot. He is always smiling and wearing bright colors.

42) Santa Claus is a very important character to children. He is far more exciting than the Easter Bunny.

43) Richard started balding at a very early age. He shaves his head often to cover it up.

44) The orchard is a beautiful sight in the spring time. The grape vines span as far as the eye can see.

45) Jason has issues with anger management. He gets mad and takes it out on his dog.

46) The icons on my computer desktop are arranged by color. I like to keep the background neat.

47) Dale likes to play online video games with his friends. He spends most of his free time on the computer.

48) The movie did not live up to Sandy’s expectations. She wanted her money back.

49) Julia liked to walk her dogs at the national park. There was a lot of room for animals to roam there.

50) The old ghost town was a popular setting for western movies. The saloon was a good atmosphere for scenes.
51) Nathan liked using pencils more than pens.
He liked having the option of erasing stray marks.

52) Robert collected baseball cards and comic books as a child.
He made a fortune selling them twenty years later.

53) The university general store was shut down last week.
The store owner had been selling cigarettes to underage buyers.

54) John’s grandmother refuses to buy a computer.
She has lived without one for eighty years.

55) Cigars should be kept in humidors to retain freshness.
The taste is more enjoyable after a long time.

56) Even small earthquakes in California can break unrestrained China.
Many Californians glue valuables to surfaces in their household.

57) Violence on television is a major concern for many parents.
Most televisions now come with parental controls for censorship.

58) Tom just received his master’s degree from a reputable university.
He is confident he can get a job wherever he wants.

59) George recently found out that his wife was pregnant.
He immediately called his buddies to celebrate the good news.

60) Roger is the owner of the local microbrewery downtown.
The brewery has been in his family for generations.

61) The astronomer looked up and saw stars shining in the sky.
It was a brilliant night to gaze in the cosmos.
62) Bill was late paying his rent so he called a consolidator on the phone. He thought it was his best option.

63) The family’s dog went outside and was bitten by a rat today. He had to be rushed to the veterinarian.

64) The farmer was hoping for a rich harvest of grain crops. This was his main source of income.

65) The gumbo recipe called for spices and potatoes. This was a favorite family dish.

66) The policemen stopped at the bar after work to get a drink today. They heard it was the best bar in town.

67) The coffee shop is becoming famous for its new blend of mocha. The customers love this tasty brew.

68) The president of the company ate the sandwich with mustard on it. It was a popular catered lunch item.

69) It was raining outside, so Paul put on a jacket and braved the weather. It kept him warm in the freezing conditions.

70) In the winter time, the beautiful snowflakes fall from the sky. They cover the ground like a white powdery dust.
71) Samuel likes being a student at a small university.  
His class size allows him more teacher interaction.  

**QUESTION:**  
Does Samuel attend a large university?  
Yes No  

72) The men went bowling to take the edge off after work.  
The work environment made them very tense.  

**QUESTION:**  
Did the men go bowling after work?  
Yes No  

73) Susan likes to fly airplanes and sail boats.  
She is getting licenses for both activities.  

**QUESTION:**  
Does Susan hate flying?  
Yes No  

74) Wendy likes to jump on the bed in her room.  
She feels so young by playing that way.  

**QUESTION:**  
Does Wendy jump on the bed?  
Yes No
75) Phillipe does not trust the bank with his money at all.
He feels like they steal money from him.

QUESTION:
Does Phillipe trust the bank?
Yes   No

76) Marsha has six cats and two dogs to play with.
She enjoys having pets to keep her company.

QUESTION:
Does Marsha own any cats?
Yes   No

77) Stephanie decided that she wanted to be a policewoman.
She was always interested in criminal justice.

QUESTION:
Did Stephanie decide to be a firefighter?
Yes   No

78) Penelope decided to put her stuffed animals in the closet today.
She just turned sixteen and decided they appeared juvenile.

QUESTION:
Does Penelope have stuffed animals?
Yes   No

79) Fletcher just got a large unexpected bonus from the firm.
He has decided to buy his family a big screen television.
QUESTION:
Did Fletcher decide to buy a new car?

Yes  No

80) The football team is very superstitious at away games.
Each player wears their socks inside out for good luck.

QUESTION:
Is the football team superstitious?

Yes  No
APPENDIX B:

WORD NORMING STATISTICS

Familiar Opaque Compounds

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<th>Familiar Opaque</th>
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AVERAGE 8.25 5.70 93.00% 89.19% 10.83%

*Note. Words and frequency estimates were generated according to the CELEX lexical database (Baayen, Piepenbrock, & Van Rijn, 1995).*
## Familiar Transparent Compounds

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APPENDIX C:

WORD FAMILIARITY NORMING QUESTIONNAIRE EXAMPLE

Instructions: For each word presented, please rate how familiar you are with the word.

1. bartender
-How familiar is this word?
1 (very unfamiliar) 2 (somewhat unfamiliar) 3 (neither very unfamiliar nor familiar)
4 (somewhat familiar) 5 (very familiar)
APPENDIX D:

SEMANTIC TRANSPARENCY NORMING QUESTIONNAIRE EXAMPLE

Instructions: You will now see some existing English compound words and some new compound words. For each item you will be provided with a word and a definition. Based on the definition, you are to rate how predictable the compound’s meaning is from its constituent word parts.

Examples:
Cook = 100% book =100%, cookbook = 100% predictable
Butter= 0% fly = 100%, butterfly = 50% predictable
Pocket= 0% book=0%, pocketbook=0% predictable
Cow=100% boy= 50%, cowboy=75% predictable

1. pancake – flat cake made from dough in a frying pan

How predictable is the overall meaning of this word based on its word parts?
0% 25% 50% 75% 100%
APPENDIX E:

WORD PREDICTABILITY NORMING QUESTIONNAIRE EXAMPLE

Instructions: You will now see sentences one at a time with one word missing and you will be asked to fill in the blanks with the word that best fits with the rest of the sentence.

1. Lisa worked in a delivery room and nursery as a _______.
APPENDIX F:

SEMANTIC FIT MEANS

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<td>3.26</td>
</tr>
<tr>
<td>19</td>
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</tr>
<tr>
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<td>20</td>
<td>3.80</td>
</tr>
<tr>
<td><strong>AVERAGE</strong></td>
<td><strong>4.17</strong></td>
<td><strong>AVERAGE</strong></td>
<td><strong>3.71</strong></td>
</tr>
</tbody>
</table>
APPENDIX G:

POST-READING DEFINITION PRODUCTION TASK EXAMPLE

Instructions: You will now be asked to provide a definition for new words that you have seen during the reading experiment. Please write a clear description of what you think each word means. Please do not leave any items blank or give "N/A" or "do not remember" type answers.

1. barncart

_____________________________ .
APPENDIX H:

POST-READING MEANING RECOGNITION TASK EXAMPLE

Instructions: You will now be asked to choose the best meaning for new words that you have seen during the reading experiment. Please choose an answer for each item. If you are not sure, guess.

1. doorwedge

A) a room used for storage space
B) a wedge for propping doors open
C) a piece of construction equipment