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How Transparency, Presentation, and Task Type Impact the Processing of Compound Words

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By

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ABSTRACT

Compound words are words with multiple constituents that individually have their own meaning and that combine to make another meaning (e.g. dog + house = doghouse). When these constituents help us infer the meaning of the whole compound word, they are known as transparent constituents (e.g. doghouse, blueberry). In contrast, opaque constituents do not help us infer the meaning of the whole compound word (e.g. moonshine). Compound words can be fully transparent, fully opaque (not at all transparent), or partially transparent (e.g. strawberry, which is a berry, but not made of straw). Previous research has indicated that there is a processing advantage afforded to compound words when compared to monomorphemic words in lexical decision tasks (Ji, Gagné, & Spalding, 2011). When a space was added between constituents, which encourages the reader to process the word through decomposition, opaque compound words lost this advantage.

The current study investigated whether compound words are processed differently from monomorphemic words and whether their processing is influenced by transparency, task, or presentation effects. Consequently, this study uses four transparency groups (fully transparent, fully opaque, and opaque/transparent and transparent/opaque words), four types of tasks (lexical decision, letter detection, semantic categorization, and word relatedness), and two presentation conditions (intact presentation and spaced presentation). Dependant variables included reaction time, accuracy, and eye tracking data from 120 University of Windsor students. Every participant was exposed to each transparency word type, but only to one task and one presentation condition.

Data were analyzed using linear mixed effects modeling procedures. Overall, there was minimal evidence supporting the hypothesis of processing advantages being afforded to compound words as compared to monomorphemic words. However, the evidence supports that participants process compound words and monomorphemic differently. Further, pseudocompound words were found to be significantly different from monomorphemic words in all conditions that had semantic information embedded in the task requirements. Altogether, task requirements, transparency, and presentation condition all influenced how participants responded to the stimulus set with respect to reaction time, accuracy, and eye tracking results.

DEDICATION

To my advisor and friend, Lori Buchanan, for always having faith in me.

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CHAPTER I

INTRODUCTION

Overview of the Current Study

The fundamental goal of psycholinguistic research is to build an understanding of how language is read, processed, and comprehended. An area of interest that has garnered a lot of attention is whether multimorphemic words are processed in the same way as monomorphemic words. A morpheme is the smallest grammatical unit of language which cannot be broken up into any smaller meaningful components. For example, *breakable* is composed of two morphemes (*break* and *able*) which cannot be further segmented. Compound words are a type of multimorphemic word that are structurally composed of two pre-existing words, known as constituents (e.g. *blueberry* and its constituents *blue* and *berry)*. Monomorphemic words are, as the name suggests, words composed of a single morpheme, and consequently they cannot be broken down into any smaller units (e.g. *giraffe*). Ji, Gagné, and Spalding (2014) reported that compound words are processed more rapidly than monomorphemic words, prompting the question: What is it about compound words that affords this advantage?

This dissertation will begin with a broad overview of compound words and their processing to provide a useful framework for understanding how various semantic variables have been operationalized in psycholinguistics. Afterwards, I will review relevant literature, variables, and methodologies that will be addressed across this study. In particular, I will highlight the concept of transparency, which is one of the key variables explored in this dissertation.

General Principles of Compound Words

Compound words are found in virtually every language. It has been theorized that compounding was one of the first components of linguistics to emerge when languages were originally being developed (Semenza & Luzzatti, 2014). In fact, Jackendoff (2014) has argued that compound words are "protolinguistic fossils" from which more complex linguistic processes were derived. Compound words are also considered to be fundamental to the foundation of lexical productivity (Bauer, 2009). When looking across languages it becomes readily apparent that compounding fills an important niche—it allows one to quickly and easily increase the size of their vocabulary (Semenza & Luzzatti, 2014). Instead of developing novel terms for every item, compounding allows for an individual to develop variations of words by combining previously generated words, thus forming a whole new word that others can use. For example, *blue* and *berry* are words in their own right, and together they form *blueberry*, which creates a novel word with its own unique meaning. Of course, some languages have a greater proclivity towards linguistic productivity, which is to say that they develop novel compounded words more frequently than others.

In the case of non-Romance languages, such as German and Finnish, compound words are considered to be especially productive (Libben, 2014). Compound words are generated frequently and spontaneously, and this allows speakers to communicate with enhanced flexibility (Libben, 2014). If these speakers do not have a word in their vocabulary that describes their intended meaning, they are able to easily develop a new one and still have the listener comprehend. In English, compound words are comparably less flexible (and hence, less productive). While compound words are still fairly common in this language, they are rarely generated spontaneously. Instead, compound words are fixed. Even so, compound words are still valuable, because, despite the inability to be produced spontaneously, they still have the benefit of expanding the English vocabulary (Libben, 2014). Notably, English compound words can also contain spaces between each constituent (known as open compound words).

In English, compound words are constructed such that the second constituent is known as the head, whereas the first constituent is the modifier (Libben & Jarema, 2006). While this initially might seem counterintuitive, especially considering that the English language is read left-to-right, it makes sense if you consider how meaning (i.e. semantics) is embedded in compound words. For the most part, the head (second) constituent contains the semantic category of the word, whereas the modifier (first) constituent serves to modify the head (McGregor, Rost, Guo, & Sheng, 2008). In the case of the word *doghouse*, the head of the word is *house* and it indicates that the word *doghouse* is a type of house. The modifier, which is *dog*, allows readers to know that it is a house that a dog lives in. If you were to rotate these constituents and form the word *housedog*, this would transform the meaning of the word. Instead, *housedog* describes a dog that lives in a house.

The position of compound word headedness can vary according to language. For instance, English and German compound word heads are always the second constituent (Semenza & Luzzatti, 2014; Juhasz et al., 2003). In contrast, Hebrew compound words always position the head as the first constituent (Semenza & Luzzatti, 2014). In Italian, heads and modifiers are not positionally bound and can present in either order (Semenza & Luzzatti, 2014).

Constituent position is one of many factors that may influence how readers process compound words. Research by Juhasz, Starr, Inhoff, and Placke (2003) provides evidence that suggests the head constituent contains information of greater importance than the modifier. In their study, Juhasz and colleagues (2003) examined the processing of compound words by studying eye fixation, naming, and lexical decision tasks. The results of all three tasks found that processing favours the ending (head) constituent (Juhasz et al., 2003). This may suggest that readers primarily use the information provided in the head constituent to help determine the meaning of the full compound (Juhasz et al., 2003). Alternatively, it could indicate that the meaning of the head constituent is co-active with the meaning of the full compound (Juhasz et al., 2003). In any case, the readers appear to process a compound word with an emphasis on the head constituent, and this is likely because, at least in English, the head typically provides information about a word's semantic category.

Pseudocompound Words

Thus far this paper has detailed the structure and readability of monomorphemic words and compound words. However, we are still left with one unusual type of word: pseudocompound (PC) words. These are words that are read as if they are monomorphemic words, but are structured like compound words in that they appear to have two constituents (Christianson, Johnson, & Rayner, 2005). Some notable examples include *bravery* (*bra* and *very*), *accountant* (*account* and *ant*), and *carpet* (*car* and *pet*). Research concerning pseudocompound words is fairly sparse, and there is no conclusive definition as to what distinguishes a pseudocompound word from a regular compound word. However, this categorical distinction might have something to do with word boundaries. For instance, there are typically clear boundaries between the two constituents in compound words, and these boundaries are identified via rare bigram combinations (e.g. you don't often see "kb" as a bigram, except in compound words like blackberry) (Libben & Jerema, 2006). In contrast, pseudocompound words typically do not have the same sort of rare bigram frequencies between the pseudoconstituents and readers may not identify these letter combinations as boundaries while reading. As such, it may be that people read pseudocompound words more fluidly, which may make them seem more structurally similar to monomorphemic words than compound words. Some research supports this, such as eye movement research conducted by Inhoff (1989) that determined that no morpheme effects were present for pseudocompound words. Other research, however, leaves the question open. For example, Christianson, Johnson, and Rayner (2005) examined letter transpositions within and across morphemes to determine how they function in masked-priming lexical decisions. The results indicated that for compound words letter transpositions across morpheme boundaries were more disruptive to word naming than were transpositions within the morphemes, and that within morpheme transpositions facilitated naming as much as correctly spelled primes. When they applied this research to a pseudocompound word condition, the authors determined that pseudocompound words follow the same morpheme-bound translocation rules that compound words do. This is in agreement with research conducted by Rastle et al. (2004), who also found that word boundaries are relevant to the positional coding of letters.

Further, there has been evidence to support that people process pseudocompound words differently from compound words in word production tasks. In research by Gagné and Spalding (2016) participants were asked to complete a typing task meant to measure the written production of pseudocompound words, compound words, and monomorphemic words. The authors identified that embedded pseudoconstituents influence the production of pseudocompounds, but not in the same way that the embedded morphemes affect the production of compounds. The authors speculated that these differences might arise because there is a mismatch between the presence of pseudoconstituents, which may lead a participant to expect a compound word. When the participant realizes the target word is not a true compound word, they then have to reconceptualise the word during typing, which changes a participant's pattern of typing as compared to compound words (Gagné & Spalding, 2016).

Ultimately, what this conflicting research demonstrates is that pseudocompound words are a unique class of words that cannot be discounted when creating a stimulus set. While pseudocompound words are not the primary focus of this study, they will still be included in the stimulus set and analyzed separately from other words to determine whether any differences are present.

Main Theories of Processing

Generally speaking, when a word is processed or accessed, readers activate the word itself within their mental lexicon, as well as the semantic links associated with any number of related words (Coltheart, 1978; Coltheart, Curtis, Atkins, & Haller, 1993; Coltheart & Coltheart, 1997; Roediger & McDermott, 1995; Plaut, McClelland, Seidenberg, & Patterson, 1996). These words may be related phonologically, orthographically, or semantically (Coltheart, Curtis, Atkins, & Haller, 1993; Plaut, McClelland, Seidenberg, & Patterson, 1996). For example, semantic neighbours are words that share some degree of semantic relatedness with the target word. If the word *chair* was the activated target word, it is likely that other related words such as *couch*, *loveseat*, and *bench* will also be activated (Roediger & McDermott, 1995). From this point, readers proceed with word comprehension.

There are two main models of compound word comprehension: full-listing (whole word) and full-parsing (decomposition) (Libben & Jarema, 2006; Arcara, Semenza, & Bambini, 2014). Full-listing models (Butterworth, 1983) speculate that compound words are stored and accessed holistically (e.g. *blueberry* is stored in the mental lexicon as *blueberry*). In contrast, full-parsing models (Taft & Forster, 1979; Zwitserlood, 1994) hypothesize that compound words are decomposed into their constituents, which are then stored and accessed as separate entities in the mental lexicon (e.g. *blueberry* is stored as *blue* and *berry*) (Andrews, 1986; Andrews, Miller, & Rayner, 2004; Libben, 1998; Pollastek, Hyönä, & Bertram, 2000; Taft & Forster, 1975; Zwitserlood, 1994). See figure 1 for a visual representation of these two access pathways.

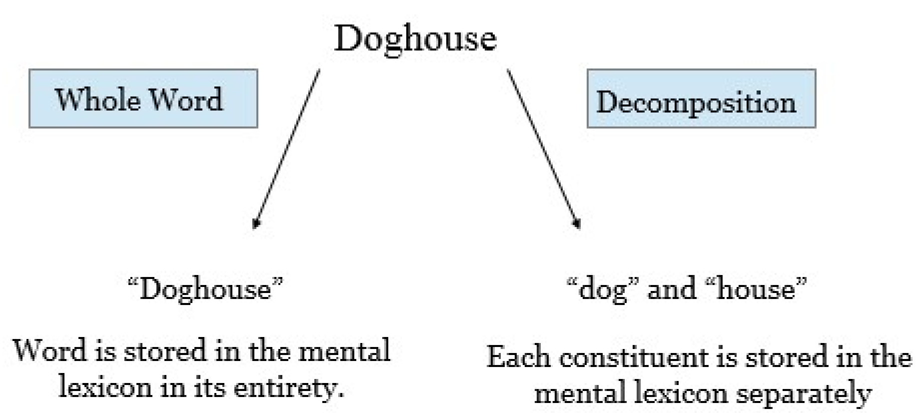

Figure 1. Representation of full-listing (whole word) and full-parsing (decomposition) models.

Initially, it was assumed that both access routes function independently (Baayen & Schreuder, 1999; Frauenfelder & Schreuder, 1992; Laudanna & Burani, 1985). More recently it has been proposed that these two routes proceed simultaneously through a dual route model (Baayen & Schreuder, 2000; Pollatsek, Hyönä, & Bertram, 2000). Ultimately, compound word processing is designed to maximize opportunity for activation, particularly with respect to semantic activation (Libben, 2014). By storing both holistic representations, as well as individual constituents, readers maximize their chances of either recognizing the word or being able to derive meaning from its components. The preference for one route over another may be influenced by a number of variables, such as frequency and transparency (Arcara, Semenza, & Bambini, 2014; Kuperman, Bertram, & Baayen, 2008; Kuperman, Schreuder, Bertram, & Baayen, 2009). These variables will be described in greater depth in the following section.

Evidence has demonstrated that compound words are processed differently from monomorphemic words (Semenza & Mondini, 2006; Arcara, Semenza, & Bambini, 2014; Ji et al., 2011). In a study by Mondini, Acara, and Semenza (2012) aphasic patients were shown to be differentially spared with respect to either compound word processing or monomorphemic word processing, indicating that compound and monomorphemic words are processed separately. In naming tasks, aphasic patients tend to substitute compound target words with other compound words rather than monomorphemic words (Semenza & Modini, 2010). Semenza and Modini (2010) have coined this phenomenon *the compound effect*, and they concluded that the morphological status of a word must be stored separately from its phonological counterpart.

Similarly, there has been data to support that constituent order switching does not occur as a common production error with aphasic patients (Badecker, 2001). Thus, modifier constituents generally do not replace head constituents and vice versa. For instance, an individual with aphasia may incorrectly say "redberry" instead of "blueberry," but they will never make an error like "berryblue." This demonstrates the importance of constituent order, and it supports the idea that the mental lexicon registers modifiers and heads as separate entities.

Libben's (2010) hypothesis of morphological transcendence describes that some constituent words can be used interchangeably as a head or modifier, whereas others remain fixed in their positions. For example, the word *berry* is always positioned as a head constituent in compound words (e.g. *blue<u>berry</u>, elder<u>berry</u>,* etc.). In contrast, a word like *key* can be found in either the head or modifier position (e.g. *<u>key</u>board*, *turn<u>key</u>*, etc.). This is not to be confused with changing a word's headedness itself; regardless of what order the constituent word itself is in, headedness as a quality of the second constituent would not change.

While *–key* differs from *key*—, these constituents are still semantically related and they remain connected in one's mental lexicon (Libben, 2014). Consequently, these words tend to co-activate each other during processing (Libben, 2014). With this in mind, researchers suspect that even partial activation of a compound word can activate families of compound words, which act as the driving force in the aforementioned compound effect (Semenza and Luzzatti, 2014; Libben, 2014). Essentially, because the compound constituent is associated with a morphological role and position, it serves to cue readers that they are dealing with a compound structure rather than a monomorphemic one

(Libben, 2014). This is similar to how “-ed” would serve as a cue to English readers that they are reading something that is in past tense (Libben, 2014).

Despite the complexities of compound word processing, people tend to be good at implicitly understanding compound words and how they are meant to be ordered in their native languages. When people experience language difficulties, however, compound word comprehension is just one of many components of linguistic awareness that are compromised. Research by McGregor, Rost, Guo, and Sheng (2010) investigated how compound words are processed by children who have a specific language impairment. They gathered sixteen child participants who have been previously diagnosed with a specific language impairment and matched them with two other groups: one group had children that were matched by age, and the other had children that were matched by vocabulary level. All participants were asked to complete tasks with compound words, such as ordering noun-noun compounds by semantic context, as well as asking them to explain the meaning of conventional compounds. Their results indicated that the children diagnosed with a language impairment had significantly more difficulty with ordering compound constituents according to semantic contextual cues, and they also had more difficulty explaining why compounds are structured as they are. Ultimately, the authors concluded that children diagnosed with a language impairment might have problems in the developmental links of their semantic lexicon (McGregor et al., 2010). This research is but one example that demonstrates that compound word research also has clinical implications. This research can assist those charged with the care of children with language impairments because it allows them to understand where and why children are struggling with certain words.

Variables that Influence Processing

As previously noted, there are many variables that can influence how compound words are processed. See Table 1 for a chart of some of these values and their definitions. It should be noted that this is not an exhaustive list of all variables that have been found to impact compound word processing.

Frequency. Word frequency is measured by counting how often a word occurs in a corpus of text (Liversedge, Gilchrist, & Everling, 2011). Literature suggests that a word's frequency influences how words are processed (Arcara et al., 2014). It has been demonstrated that high frequency compound words are more likely to be accessed by whole word representations, whereas low frequency compound words are more likely to be accessed via their constituents (Kuperman et al., 2009; Arcara et al., 2014). Eye tracking studies have demonstrated that word frequency influences fixation durations (how long eyes fixate on a part of a target word) (Juhasz & Rayner, 2003; Andrews, Miller, & Rayner, 2004). While frequency is not one of the main variables considered in this study, it is vital to emphasize the importance of frequency, and hence the importance of controlling the variable of frequency when constructing a balanced stimulus set.

Transparency. The transparency of a compound describes the semantic content of its constituents (Libben & Jarema, 2006). A compound word can be fully transparent, partially transparent, or fully opaque (not transparent at all). When a constituent is transparent, this indicates that it contains semantic information related to the meaning of the whole word (Libben & Jarema, 2006). In the case of *blueberry*, both constituents *blue* and *berry* are transparent, because a *blueberry* is a *berry* that is *blue*. In contrast, when a constituent is opaque, this indicates that the constituent is semantically unrelated to the meaning of the whole word (Libben & Jarema, 2006). With a word like *moonshine*, *moon* and *shine* are both opaque constituents, because *moonshine* is a type of alcohol, which is unrelated to the *moon* or its *shine*. Compound words can also be partially transparent, by which only one of its constituents is transparent while the other is opaque. An example of an opaque-transparent (OT) word is *strawberry*, which is a *berry*, but it is not made of *straw*. Similarly, *jailbird* is a transparent-opaque (TO) word, because a *jailbird* is a *person* who is in *jail*, not a *bird*.

Historically it has been hypothesized that semantic transparency determines whether a compound word will be processed via whole word recognition or through decomposition (Laudana and Burani, 1995). Similarly, Schreuder and Baayen's (1995) meta-model of morphological processing postulated that semantic transparency determines whether a compound word has its own representation in the mental lexicon, or whether it is represented by its constituents. In this model, totally opaque compound words must be stored as a whole word, because decomposing the word into its constituents gives no information about the meaning of the word (Libben, Gibson, Yoon, & Sandra, 2003).

More recent literature supports the idea that early activation of constituents via morphological decomposition happens regardless of transparency, and the full impact of semantic transparency is seen somewhat later during processing (Brooks & Garcia, 2015). Moreover, Brooks and Garcia (2015) used magnetoencephalography (MEG) activity to identify that the processing of transparent compound words is related to activation in certain brain regions (Brooks & Garcia, 2015). Specifically, the authors identified that activation begins in the lateral anterior temporal lobe, which is responsible for composing the meaning of morphemes, and then transitions to the posterior temporal lobe, where retrieval of stored information is accessed.

Libben and colleagues (2003) examined how transparency influences the processing of compound words. The authors had participants complete a lexical decision task, which required them to decide whether a target word is a real word (e.g. *blueberry*) or a nonword (e.g. *hexipest*). Libben et al. (2003) had every type of transparency as part of the task: fully transparent, both types of partially transparent (OT and TO), and fully opaque words. The reaction time data indicated that words with transparent heads (fully transparent [TT] and OT words) were processed more rapidly than words with opaque heads (fully opaque [OO] and TO words). Evidently the transparency of the head appears to have more of an influence on processing than the transparency of the modifier. Additionally, this study provides evidence for the importance of transparency in compound word processing.

Presentation type. It is clear that processing of compound words differs depending on transparency. The question remains: are compound words processed differently than monomorphemic words? Ji et al. (2011) sought to answer this question. Through their research, they determined that compound words are afforded a processing advantage as compared to monomorphemic words. This means that compound words were reliably processed faster than monomorphemic words, regardless of constituent transparency.

Ji and colleagues (2011) took this a step further and added a new presentation type. Traditionally, compound words are presented in a concatenated manner. That is, they are presented holistically (e.g. *blueberry* is presented as *blueberry*). Another way of presenting compound words is by adding a space between each of the constituents and telling participants to ignore the space and read the word holistically (e.g. *blueberry* presented as *blue berry*). This presentation style serves the purpose of encouraging readers to access compound words via their constituents, which might prompt the use of full-parsing tactics (decomposition). When the authors used spaced presentation, they found that the processing advantage afforded to compound words disappeared for opaque words. The authors suggested that in opaque words there may be a conflict between the lexical representation of the word and the semantic information found in the constituents. Decomposition of an opaque compound word into its constituents does not help readers to reach conclusions about the semantic content of the word, so it is presumed that this delays processing because readers must access the whole word representation instead. This shift in processing strategy presumably takes time, which may explain why these words lose their processing advantage relative to monomorphemic words.

In a Master's thesis (Stathis, 2014), the author expanded Ji et al.'s (2011) lexical decision study to include all four types of transparencies: fully transparent, both types of partially transparent, and fully opaque words. Results were consistent with previous literature in that fully transparent words retained a processing advantage under spaced presentation, while opaque words did not. As in Libben's (2003) research described above, it was expected that transparent-head words (OT) would retain the processing advantage, because the head of the word provides the semantic categorization of the word, which is arguably more important to semantic comprehension than a modifier. Instead, results indicated that partially transparent words also lost their advantage and were responded to at approximately the same rate as monomorphemic words. Even though readers may be able to derive some semantic information from the one transparent constituent, this is not sufficient to generate a processing advantage.

Task type and semantic depth. Compound words have also been found to be processed differently according to task requirements. Janssen, Pajtas, and Caramazza (2014) found that while most tasks produced evidence of constituent effects (e.g. constituent frequency impacting processing), these effects were not found in a picture naming task. The authors speculated that there might be a difference in how readers handle word comprehension tasks (like lexical decision) as opposed to word production tasks (like picture naming). With this in mind, it is worth exploring how transparency influences processing across task types.

A dissertation by Danguecan (2015) examined how concreteness and semantic neighbourhood density influenced performance on tasks of varying semantic depth. This study was conducted using monomorphemic words rather than compound words, but the results suggested that the behavioural effects of a given semantic variable were differentially impacted by task demands.

Ultimately it becomes evident that there are several factors that can influence how readers process compound words. The goal of this study is to integrate three variables in particular: transparency, presentation type, and tasks of varying semantic depth. Factors such as compound frequency will be controlled via the creation of the stimulus set, as these variables are not of immediate interest in this research.

Table 1. Variables Known to Influence Compound Word Processing

Variable	**Brief Description and Findings**	**Associated Authors**
Age of Acquisition	Age of acquisition (AoA) refers to the age at which target words are acquired.	Juhasz, 2018

(AoA)	Compound words that are learned earlier in life are processed faster when read in sentences.	
Compound frequency	Frequency is how often a particular word is found in text. This refers to the frequency of the whole compound word. High frequency words are more likely accessed via whole word representation, whereas low frequency words are more likely to be accessed via their constituents.	Arcara et al., 2014; Kuperman et al., 2009; Janssen et al., 2014;
Constituent frequency	Frequency is how often a particular word is found in text. Compound words with high-frequency second constituents are recognized faster than the ones with low-frequency second constituents.	Vergara-Martinez et al., 2009; Arcara et al. , 2014; Pallastek et al., 2000; Kuperman et al., 2009; Janssen et al., 2014;
Entropy	The competition between potential meanings associated with the same complex word form.	Schmidtke, Kuperman, Gagné, & Spalding, 2015
Familiarity	Familiarity assesses the experience that a reader has with a particular word. Familiarity can be thought as an index of subjective frequency. Compounds that are more familiar are read more quickly in context (e.g. sentences).	Juhasz, 2018; Williams & Morris, 2004
Previous Reaction Time	Slower previous reaction times are related to slower current trial reaction times.	Kuperman et al., 2009
Reading ability	Previous literature has demonstrated that more proficient readers are less influenced by distributional biases in language (e.g. frequency) than poorer readers.	Falkauskas & Kuperman, 2015
Sensory Experience Rating (SER)	SER reflects the extent to which a word evokes a sensory and/or perceptual experience in the mind of a reader. SER was found to influence first fixations on compound words.	Juhasz, 2018; Juhasz & Yap, 2013; Kuperman, 2013
Sentence context	Sentences provide contextual cues for the meaning of a full word. It is thought that a sufficiently predictable sentence context may pre-activate the semantic representation for a compound word, particularly at the beginning of processing.	Juhasz, 2018; Juhasz, 2012; Gagné, Spalding, & Gorrie, 2005
Spelling	Compound words are sometimes able to be spelled two ways: concatenated (ex. Windowsill) or spaced (ex. Window sill). Some spellings are more common than others, and so these spellings have their	Falkauskas & Kuperman, 2015

	own probabilities of occurring. The more probable a representation, the stronger the faciliatory effect on compounds that occur more frequently (in any spelling), belonged to larger morphological families, or with more prolific readers.	
Transparency	The quality of semantic information that is derived from compound word constituents. Semantically opaque words (e.g. *moonshine*) are more likely accessed via whole word representation, whereas semantically transparent words (e.g., *sunset*) are more likely to be accessed via their constituents.	Arcara et al., 2014; Ji et al., 2011; Stathis & Buchanan, 2013

Methods of Studying Compound Words

The processes involved in compound word production and comprehension may be examined using a variety of techniques that provide a wealth of data. The majority of studies reviewed in this document used the following standard behavioural methods and neuroimaging techniques.

Response times. In behavioural experiments, reaction times are classically used as a dependent variable because they are meant to serve as a proxy for processing efficiency of the experimental stimuli (Danguecan, 2015). As such, psycholinguistic researchers are often interested in how variables impact changes in mean reaction times across various conditions (Pachella, 1974). With respect to compound words, it has been demonstrated that transparency and presentation type influence how quickly participants respond to stimuli (Ji et al., 2011; Stathis, 2014).

Accuracy. Accuracy is another measure that is commonly used in behavioural experiments with compound words. This variable is also considered to be a proxy for processing efficiency. There has been research to support that accuracy rates change as a function of transparency and presentation type in the recognition of compound words (Stathis, 2014; Ji et al., 2011).

Eye tracking. While accuracy and reaction time data are able to demonstrate how readers eventually processes compound words, eye tracking techniques provide temporal information about how readers behaviourally processes information. This means that eye tracking allows us to get a sense of how processing happens over time. Additionally, as previously noted there has been research to support that compound words, their constituents, and their frequencies influence eye tracking measures (Andrews, Miller, & Rayner, 2004; Hyönä & Pollastek, 1998). For example, Hyönä and Pollastek (1998) noted that the length of the initial constituent influenced the location of the second eye fixation on the target word and the pattern of fixation durations. Additionally, the frequency of the first constituent influenced the duration of the first fixation on the target word, the location of the first and second fixations on the target word, and how long gaze duration lasted (Hyönä & Pollastek, 1998). Ultimately, eye tracking provides another modality for assessing how and when compound words are processed. Eye tracking is especially useful in evaluation of how processing proceeds over time, whereas accuracy and reaction time data is more useful at noting the speed and ultimately the end result of compound word processing.

Event-related potential (ERP). ERP is an electrophysiological measure that represents the brain's response as a result of specific cognitive events (Vergara-Martinez, Dunabeitia, Laka, & Carreiras, 2009). In the case of compound words, ERPs are classically used to trace the time course of constituent processing. One of the most important components related to language processing is the N400, which is a negative peak with maximum amplitude around 400 ms after stimulus onset (Kutas & Hillyard, 1980). Additionally, the N400 has been found to correlate with semantic aspects of single word and compound word reading (Koester et al., 2007; Kutas & Federmeier, 2000). While the literature surrounding ERP data and compound words is relatively sparse, Vergara-Martinez and colleagues (2009) conducted a study using the ERP measure and determined that constituent order and frequency both influenced N400 amplitudes.

More recently, research by Davis, Libben, and Segalowitz (2019) has indicated that semantic access happens even earlier during processing than previously thought. Specifically, their findings demonstrate that some level of semantic access occurs as early as the P100. The authors posited that these results support the notion of a form-and-meaning approach to early processing, indicating that both morphological features and early semantic activation are important and accessible from the beginning. Furthermore, the authors suggest that this would allow readers to maximize their opportunity for meaning creation by using all processing cues available in compound words.

Overview of Proposed Study

The primary goal of this study was to investigate whether compound words are processed differently from monomorphemic words. Further, it was designed to examine whether compound word processing is influenced by task type, transparency, or presentation effects. This study sought evidence through four different tasks, all programmed to record eye tracking data (fixation count, first fixation duration, second fixation duration), reaction times, and accuracy rates. Most components of this research have already been examined by other researchers individually, but this study was the first to examine these variables in the same language (English) using the same stimulus set across tasks.

The selected tasks were also chosen to represent a continuum of semantic depth. Some tasks are semantically shallow, which means that the task does not require access to semantic content to successfully complete the task. For tasks that are semantically deep, the participant is required to access semantic information to optimally complete the task. Transparency and word presentation have been demonstrated to modify compound word processing at a semantic level, and thus it is worthwhile to explore how these factors vary across tasks. See Figure 2 below for a visual representation of tasks across semantic depth.

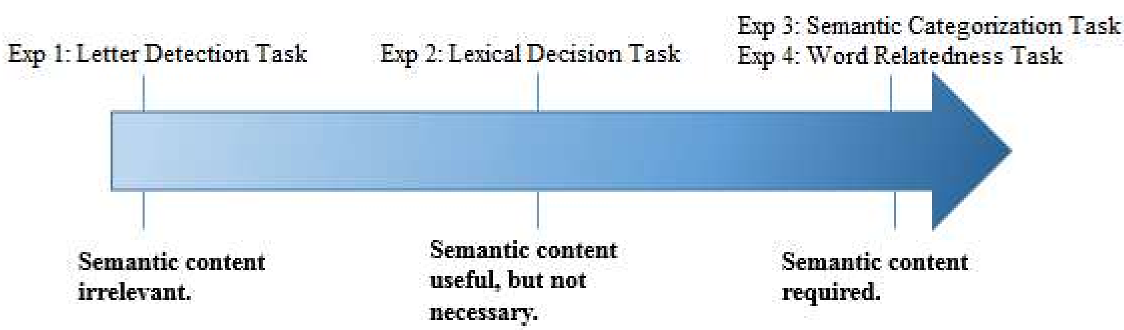

Figure 2. Experimental tasks as they map onto semantic depth.

Experiment 1: Letter detection task. For this task participants were asked to view a word and then indicate which of two letters is part of a target word. This task is considered to be semantically shallow, because additional semantic content provided by a word does not benefit the user at all (Danguecan, 2015). Instead, the participant must direct their attention to the morphological features of the word. Consequently, it is hypothesized that there will be no difference between compound words and monomorphemic words. Additionally, because semantic content is irrelevant for the purposes of this task, it is hypothesized that there will be no presentation or transparency effects.

Experiment 2: Lexical decision task. Lexical decisions tasks require participants to decide whether a target letter-string is a real word or a (pronounceable) nonword. Lexical decision reaction times for individually presented compound words are a function of the word's lexical properties (Andrews, 1986; Juhasz et al., 2003; Taft & Forster, 1976). This task will thus allow a determination of whether there is a processing speed advantage present in partially transparent words. This task does benefit from the addition of semantic information (Danguecan, 2015), but it is not wholly necessary for task completion. For example, someone may be able to identify a word as a real word, but not know what the word means exactly. Previous research has determined the presence of transparency (Stathis, 2014; Ji et al., 2011) and presentation effects (Ji et al., 2011) in lexical decision tasks. It is hypothesized, as with other research, that compound words will be processed more rapidly than monomorphemic words when the words are presented holistically. When decomposition is encouraged via the addition of a space between constituents, it is hypothesized that compound words will only demonstrate their advantage under conditions of full transparency.

Experiment 3: Semantic categorization. Participants are instructed to decide whether a target word is abstract or concrete. In this way, participants are required to think about the semantic information of the word, as well as how the word is represented in the mental lexicon (Danguecan, 2015). For example, concrete words like *sunset* and *blueberry* have distinct representations that participants can construct. In contrast, abstract words like *bravery* and *honeymoon* do not have one clear mental representation.

Rather, there can be a number of mental representations that can be accessed for these words. This task was selected because it requires the participant to comprehend the semantic content of the word before they can respond. That is, this task is semantically deep. Consequently, it is hypothesized that there will be a processing advantage for compound words over monomorphemic words. As well, it is proposed that fully transparent and partially transparent words will retain their advantage, as semantic information can be derived from the constituents.

Experiment 4: Word relatedness task. For this task, participants are asked to view a target word, and then asked to view another word shortly after. They will decide whether the secondary word is related to the initial target word. This task requires that a participant know the meaning of not only the target word, but also how this word relates to the second word (which may or may not be related) (Danguecan, 2015). Given that semantic content is essential to comprehending the task, it can be said that this task is semantically deep (Danguecan, 2015). Consequently, it is hypothesized that the processing advantage afforded to compound words will be retained as compared to monomorphemic words. Similarly to Experiment 3, we also expect that fully and partially transparent words will retain their advantage, as semantic information can be derived from the constituents.

Summary of experimental tasks. A summary of all the experiments described above, along with their respective task requirements and hypotheses, is provided in Table 2. The specific task demands for all experiments are described further in the Design and Methodology section to follow.

Table 2. Summary of Task Instructions and Hypotheses for All Experiments

Experiment	Task Instructions	Hypotheses
Letter Detection Task	After viewing a word, indicate (with a key press) which of two letters (left or right) is part of the real word.	No differences between compound words and monomorphemic words.
Lexical Decision Task	Indicate (with a key press) whether the word is a real word or a nonword.	Faster RT and higher accuracy for compound words in intact presentation. Faster RT and higher accuracy for fully transparent words in spaced presentation.
Semantic Categorization Task	Indicate (with a key press) whether the word is a concrete or an abstract word.	Faster RT and higher accuracy for compound words in intact presentation. Faster RT and higher accuracy for fully and partially transparent words in spaced presentation.
Word Relatedness Task	Only respond (key press) when a word is related to the preceding word. Do not respond when a word is unrelated to the preceding word.	Faster RT and higher accuracy for compound words in intact presentation. Faster RT and higher accuracy for fully and partially transparent words in spaced presentation.

CHAPTER II

METHODOLOGY

Participant Recruitment and Exclusion Criteria

120 University of Windsor students participated in this study. Each participant was randomly assigned to one of the four experiments. They were also randomly assigned to either the intact presentation condition or the spaced presentation condition. All participants were registered in the Psychology Department Participant Pool and they were compensated with bonus points applied to eligible psychology courses. This study took approximately 30 minutes to complete and, consistent with Participant Pool Guidelines, the participants were awarded 1 bonus points for their contribution.

The exclusionary criteria associated with this study required that participants were first language English speakers. The purpose of this study is to examine how words and perceived and understood. If someone is not familiar with English words then it will be difficult for them to fulfill the task requirements. The second exclusionary criterion was the presence of a learning/language disability. As noted in the introductory section, there has been evidence to support that people with language impairments may process compound words differently than those without impairments (McGregor et al., 2010) and this study sought to examine how the average reader processes compound words.

No deception was used in this study. Additionally, the words selected for the stimulus set were not emotionally charged. Consequently, there was no expectation for any long-term risk associated with participation in this study.

Apparatus

Eye movements were recorded via an Eyelink 1000 (SR Research, Ltd.) eye-tracker. This system records eye movements every millisecond. Participants viewed each word binocularly, however only eye movements from their right eye were recorded.

Task Procedures

All tasks included the four types of transparency (fully transparent, both types of partial transparency, and fully opaque), as well as monomorphemic and pseudocompound words, and had two versions to encompass both presentation conditions (intact and spaced).

Before the task began, the participants answered a number of demographic questions. More specifically, participants were asked to identify their sex, age, whether English is their first language, and whether they have been diagnosed with a learning disability or language impairment. Participants would have still been awarded the participation point if they had answered that English was not their first language or they had a learning disability but their data would be excluded from the analyses.

Each participant sat in front of the computer with the eye tracking device. The participant was positioned using a chinrest before beginning the task. The participant was asked to follow the task instructions on the screen and to use the keyboard to respond accordingly. The eye tracker was then calibrated individually for each participant (by having them fixate on nine calibration points across the screen).

To ensure understanding of task instructions, participants completed a series of practice trials prior to each experiment. Correct/incorrect feedback was provided on all practice trials. If errors were made during the practice phase, the correct response was provided and task instructions were repeated. All participants received the same number of practice trials (5 trials), regardless of task. If the participant was randomly assigned to a spaced presentation condition, the participant was further instructed to ignore the space in between the constituents and to read the word holistically when making their decision.

Participants were encouraged to respond as quickly and as accurately as possible. For all tasks, reaction times, proportion of correct responses (also known in this study as accuracy), and eye tracking data were recorded for further analysis. The eye tracking variables gathered for this study were fixation count, first fixation duration, and second fixation duration for both heads and modifiers of each word.

Experiment 1: Letter detection task. For this task participants were asked to view a randomly presented word and then indicate which of two letters was part of the target word. Each target word appeared for 500ms. Participants made their response by pressing either the “Z” key if the letter on the left was in the target word, or the “?” key if the letter on the right was in the target word. The correct letter was on the right side of the screen for 50% of the trials and on the left side for the other 50% of the trails. The letters remained on the screen until a decision was made.

Experiment 2: Lexical decision task. In this task, carefully matched and pronounceable nonwords were intermixed with the experimental words and participants decided whether a target letter-string was a real word or a nonword. The target remained on the screen until the decision was made by pressing either the “Z” key if the target was a word, or the “?” key if the target was a nonword.

Experiment 3: Semantic categorization. Participants decided whether a target word was abstract or concrete. The target word remained on the screen until the participant made a decision. Participants indicated their response by pressing either the "Z" key if the target word was concrete, or the "?" key if the target word was abstract.

Experiment 4: Word relatedness task. For this task, participants were asked to view a target word, and then asked to view another word shortly thereafter. They were required to decide whether the second word was related to the initial target word. For this task, participants were presented with a single word for 500 ms, followed by an experimental or control word, which remained on the screen until participants made their decision. Participants were instructed to decide whether the two words within each trial were related by meaning or not. Participants indicated their response by pressing either the "Z" key if the two words were related, or the "?" key if the two words were not related.

Stimulus Development

First, the stimulus set was derived by compiling all compound words available in each transparency category. Given that fully opaque words are the least common type they acted as the limiting word type and were identified first. Afterwards, the same number of fully transparent and partially transparent words were matched according to number of letters, number of syllables, and compound frequency. All words and values were derived using WordMine2 (Durda & Buchanan, 2006).

Monomorphemic words were selected in such a way that when split into components (consistent with a spaced presentation), there was a mixture of constituent types. For instance, there were an equal proportion of monomorphemic words that had two real constituents (i.e. *plank ton*), words that had a real first constituent (i.e. *con clude*), words that had a real second constituent (i.e. *pron ounce*), and words where neither of the constituents were real (i.e *tourni quet*). During data analysis, the monomorphemic words with two real constituents were separated from other monomorphemic words and placed into their own group called pseudocompound words. These words share a similar structure to compound words in that they seem to have two constituents (e.g. *bravery, accountant, carpet*), but they are not identified as compound words by readers, as detailed in the introduction section.

An equal number of nonwords were created for the lexical decision task (Experiment 2). There were two types of nonwords: those that had characteristics of monomorphemic words (i.e., *mathir*), and those that had characteristics of compound words (i.e. *topdrug*). Compound nonwords were adapted from Taft and Forster (1976). These were constructed such that nonword constituent pairs used letter combinations that would rarely be seen together in monomorphemic words (such as k and b, which are rare consonant pairs). There were four types of compound nonwords. The first is a word-word pair, whereby both constituents are real words, but the total compound word is not found in the English language (i.e. *topdrug*). The second is a word-nonword pair, in which the first constituent is a real word, but the second constituent is a pronounceable nonword (i.e. *cleanmip*). The third is a nonword-word pair (i.e. *thernlow*) and the fourth is a nonword-nonword pair (i.e. *spilkwut*). Monomorphemic nonwords were taken from the Ji, Gagné, and Spalding (2011) study, and additional ones were also creating using Wuggy, the multilingual pseudoword generator (Keuleers & Brysbaert, 2010).

Additional words were also required for experiments 3 (semantic categorization task) and 4 (word relatedness task). For the compound words and monomorphemic words in experiment 3, half of the words were identified as abstract while the other half was identified as concrete. A pilot study of 10 raters identified whether a target word was abstract or concrete. Only words with 100% rater agreement were selected for the stimulus set. Similarly, for the compound words and monomorphemic words in experiment 4, half of the words were paired with semantically related words while the other half was paired with semantically unrelated words. A pilot study of 10 raters identified whether the words were related or not. Only words with 100% rater agreement were selected for the stimulus set.

In sum, each participant viewed 40 compound words (10 TT, OO, TO and OT words each), 80 monomorphemic words (20 of which were pseudocompounds). In the lexical decision task they also saw 40 compound-like nonwords, and 80 monomorpheme-like nonwords for a total of 240 words. There were more monomorphemic words than compound words and more monomorpheme-like nonwords than compound-like nonword because this strategy made controlling for compound words less pivotal. With more monomorphemic words, participants remain unaware that this was a study about compound words and would presumably be less inclined to quickly identify constituent nonwords and then reject the word based on the first constituent. The study items and their respective number of letters, syllables, and orthographic frequencies can be seen in the Appendices.

CHAPTER III

RESULTS

General Statistical Procedure

All analysis was conducted using R statistical software [version 3.5.0] and the lme4 [version 1.1.17] package. Additional packages used for analysis include effects [version 4.0.2], ggplot2 [version 2.2.1], lmertest [version 3.0.1], and lsmeans [version 2.27.62].

Prior to statistical analysis, extreme outliers were removed from the reaction time data. For the purposes of this study, an extreme value is operationalized as any value that exceeds 10 seconds or is less than 400 milliseconds. Incorrect responses were also removed from the reaction time data prior to analysis. No participants were removed from analysis for low accuracy (< 60%). No participants were removed due to exclusionary criteria. In terms of eye tracking data, trials with misreadings (i.e. trials in which no fixations were recorded by the eye tracking device, due to machine error) were removed.

Linear mixed effects multiple regression models were used for this study. Both participant and word served as random effects (with random intercepts) for each of the models. Number of letters, number of syllables, orthographic frequency of the whole word, concreteness category, age of acquisition, and the previous trial's reaction time were all evaluated as control variables. While the full random effect structure was tested, only effects that significantly improve the performance of the models were kept. An improvement was indicated by a significantly higher log likelihood estimate of the model when a given random effect was included as compared to when that random effect was not. Gaussian (for continuous response variables), binomial (for binary response variables), or Poisson (for count-based response variables) underlying distributions were used accordingly.

Orthographic frequency was selected rather than lemma frequency because the data for the orthographic frequency values were more current. Orthographic frequency values were acquired from WordMine2 (Durda & Buchanan, 2006). Age of acquisition ratings were acquired from Kuperman, Stadthagen-Gonzalez, and Brysbart (2012). Reaction time, previous trial reaction time, and orthographic frequency were log transformed for analysis to help minimize the influence of outliers. Word group (Opaque-Opaque [OO], Opaque-Transparent [OT], Transparent-Opaque [TO], Transparent-Transparent [TT], Pseudocompound [PC], and monomorphemic words) and presentation (intact or spaced) were the two primary variables of interest during model fitting. Monomorphemic words and the spaced presentation condition were used as the reference levels for analysis. Planned interactions between word group and presentation condition were also assessed. Each experiment (task type) was fitted to its own individual model for reaction time and accuracy rates. Further, each eye tracking measure (fixation count for head and modifier, first fixation duration for head and modifier, and second fixation duration for head and modifier) were all also fitted to their own models.

After model fitting, values that were greater or lesser than 2.5 standard deviations from the residual error of the model were identified and trimmed from Gaussian models. The model was then refitted to the trimmed data set. The model was then assessed using the summary function in R, which uses the Satterthwaite approximation to the degrees of freedom. This function subsequently computes t-values and p-values associated with the fixed effects.

Only statistically significant differences ($p < .05$) will be discussed below, unless otherwise specified. Further, additional control variables that were tested during eye tracking data were not included in the body of text to help keep the relevant information succinct. These values, however, can be found in Appendix C (Tables C1 through C4).

Tables and Charts

Throughout this section there are several tables and charts to illustrate the data for each experiment. It should be noted, however, that these values are before the data was aggregated and trimmed during the modeling process. This means that the only modification to the data will have been the removal of extreme outliers. This is to provide readers with a sense of what the data looks like from both presentation conditions. As a result, sometimes the visual aids might seem inconsistent with the results of the data analysis. Readers should keep in mind that the numbers embedded into the text represent the results after model fitting, trimming less extreme outliers, and refitting to the trimmed data set.

Experiment 1: Letter detection task.

Thirty University of Windsor undergraduate students participated in Experiment 1 (26 females, 4 males; mean age: 20.4 years). 15 participants were assigned to the intact presentation condition, and 15 were assigned to the spaced presentation condition. Outliers were identified using the previously described procedure, resulting in the removal of 2.8% of the data.

Reaction time. Participants responded to monomorphemic words more rapidly than TT ($b = 0.024$, $SE = .011$, $t = 2.276$ $p = .024$), OT ($b = 0.030$, $SE = .011$, $t = 2.824$, $p = .005$), and TO words ($b = 0.021$, $SE = .014$, $t = 1.973$, $p = .050$). Presentation condition did not influence reaction times in this task altogether. However, it was found that the current trial's reaction time was impacted by the previous trial's reaction time, which is consistent with previous research (Kupperman et al., 2009). Specifically, slower reaction times in the previous trial were linked to slower reaction times in the current trial (b = 0.105, SE = .013, t = 7.828, p < .001).

Post hoc analysis also revealed that PC words were processed more rapidly than OO words (b = 0.020, SE = .012, t = 2.368, p = .019), supporting the idea that these word types are distinct from one another. This difference held true even when bigram frequency was inserted as a control variable during modeling.

Table 3. Reaction times means and standard deviations for Experiment 1.

	Intact Presentation		Spaced Presentation	
	Mean (ms)	SD	Mean (ms)	SD
Mono	1436.85	462.99	1385.96	396.35
PC	1392.95	445.71	1368.93	358.88
OO	1507.74	578.41	1496.98	599.85
OT	1521.99	545.27	1556.46	520.57
TO	1547.35	506.83	1533.09	558.07
TT	1554.30	549.94	1559.44	707.88

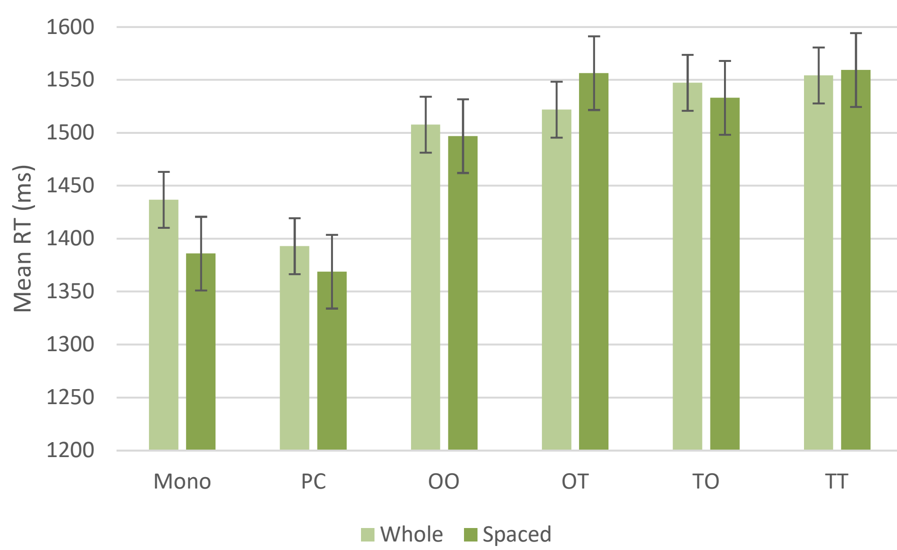

Figure 3. Visual representation of experiment 1 mean RTs. Error bars represent standard error.

Accuracy. No main effect for presentation condition or for transparency group was present, however an interaction effect between transparency group and word length was observed. Overall, as word length increased, participants were less accurate at identifying fully transparent words as compared to monomorphemic words (b = -.662, SE = .303, z = -2.186, p = .029).

Table 4. Proportion of correct responses and standard deviations for Experiment 1.

	Proportion of Correct Responses	
	Intact Presentation	Spaced Presentation
Mono	0.946	0.968
PC	0.943	0.956
OO	0.943	0.953
OT	0.879	0.980
TO	0.907	0.967
TT	0.929	0.920

Eye Tracking.

Modifier Fixation Count. Overall, participants had a tendency to fixate more frequently on monomorphemic modifiers than OO modifiers (b = -0.234, SE = .103, z = -2.264, p = .024). Further, participants fixated more frequently on PC modifiers than monomorphemic modifiers (b = 0.122, SE = .062, z = 1.971, p = .049). There was a significant interaction effect between transparency group and presentation condition, whereby PC words were differentially impacted by presentation condition. Specifically, participants looked at PC modifiers more frequently in the spaced condition and less frequently in the intact condition as compared to monomorphemic words (b = -.196, SE = .091, z = -2.157, p = .031).

Head Fixation Count. In terms of head fixation counts, participants fixated more often on OO heads than on monomorphemic heads (b = 0.299, SE = .127, z = 2.352, p = .019).

First Fixation Duration. With respect to the first fixation duration, there was no main or interaction effects for presentation condition or for transparency group when it came to either head or modifier constituents.

Modifier Second Fixation Duration. There was also no main or interaction effect for transparency group or presentation condition when it came to second fixation durations for modifier constituents.

Head Second Fixation Duration. Participants looked at head constituents longer in the spaced condition than in the intact condition (b = -143.630, SE = 60.773, t = -2.363, p = .024). Further, an interaction effect was identified between transparency group and presentation condition with respect to PC words. Specifically, PC heads were looked at for more time than monomorphemic heads in the spaced condition (b = 90.921, SE = 41.006, t = -0.022, p = .028).

Table 5. Fixation count, first fixation duration, and second fixation duration for both heads and modifiers in the intact presentation condition of Experiment 1**.**

	Fixation Count		First Fixation Duration		Second Fixation Duration	
	Modifier	Head	Modifier	Head	Modifier	Head
Mono	2.01	1.01	375.20	351.36	338.85	311.71
PC	1.84	1.11	390.28	342.22	337.61	365.95
OO	1.79	1.39	372.84	340.38	283.60	334.67
OT	2.15	1.22	371.97	326.72	293.51	313.51
TO	2.10	1.09	378.74	332.55	321.13	354.39
TT	2.08	0.99	366.96	321.26	347.39	317.97

Table 6. Fixation count, first fixation duration, and second fixation duration for both heads and modifiers in the spaced presentation condition of Experiment 1.

	Fixation Count		First Fixation Duration		Second Fixation Duration	
	Modifier	Head	Modifier	Head	Modifier	Head
Mono	1.93	1.32	413.89	351.35	411.82	449.99
PC	2.14	1.22	410.00	371.60	403.76	396.20
OO	1.74	1.35	358.64	355.14	422.39	451.00
OT	2.02	1.07	396.53	328.20	411.98	438.42
TO	2.33	1.24	413.99	325.14	367.23	415.94
TT	1.97	1.29	468.64	341.43	361.75	453.50

Discussion. The findings are not consistent with the hypothesis that there would be no differences between monomorphemic words and compound words. Rather, participants responded to monomorphemic words more rapidly than compound words, regardless of transparency. There were no differences when it came to accuracy (defined as proportion of correct responses). In terms of eye tracking results, was some evidence that monomorphemic words were looked at differently than OO words. For instance, participants looked at monmorphemic modifiers more often than OO modifiers, whereas the reverse was true for head constituents.

Another interesting result is that response times for PC words did not differ from those for monomorphemic words. However, eye tracking results indicated that PC words were differentially impacted by presentation condition, whereas monomorphemic words were not. While PC words and monomorphemic words are often used interchangeably, and there is evidence to support that they are processed at the same rate and with the same accuracy in this task, there appear to be functional differences in how we go about reading these words based on these eye tracking results. In addition, PC words were responded to at a faster rate than OO words, indicating that these two word types are also not interchangeable.

Experiment 2: Lexical decision task.

Twenty-nine University of Windsor undergraduate students participated in Experiment 2 (26 females, 3 males; mean age: 20.5 years). 15 participants were assigned to the intact presentation condition, and 14 were assigned to the spaced presentation condition. Outliers were identified using the previously described procedure, resulting in the removal of 2.7% of the data.

Reaction time. Participants responded more rapidly to monomorphemic words than to OO words in the spaced presentation condition ($b = .046$, $SE = .021$, $t = 2.226$, p = .027). No other differences were detected between compound words and monomorphemic words, even in the intact presentation condition. Other significant predictor variables were also identified during the modeling process, including the previous trial's reaction time ($b = .081$, $SE = .012$, $t = 6.837$, $p < .001$), orthographic frequency ($b = -.027$, $SE = .005$, $t = -5.004$, $p < .001$), and age of acquisition (AoA; $b = .009$, $SE = .001$, $t = 5.396$, $p < .001$).

It was anticipated that the intact condition would result in a processing advantage for all compound words, as has been demonstrated in previous research (Ji, Gagné, and Spalding, 2011). However, there were no conditions where compound words demonstrated a processing advantage over monomorphemic words.

Table 7. Reaction times means and standard deviations for Experiment 2.

	Intact Presentation		Spaced Presentation	
	Mean (ms)	SD	Mean (ms)	SD
Mono	883.69	442.41	881.66	437.86
PC	905.91	446.83	937.20	437.84

OO	1022.24	544.51	1116.91	627.15
OT	1049.12	604.97	998.00	530.42
TO	1025.97	641.54	1025.97	582.90
TT	919.38	669.73	912.78	445.36

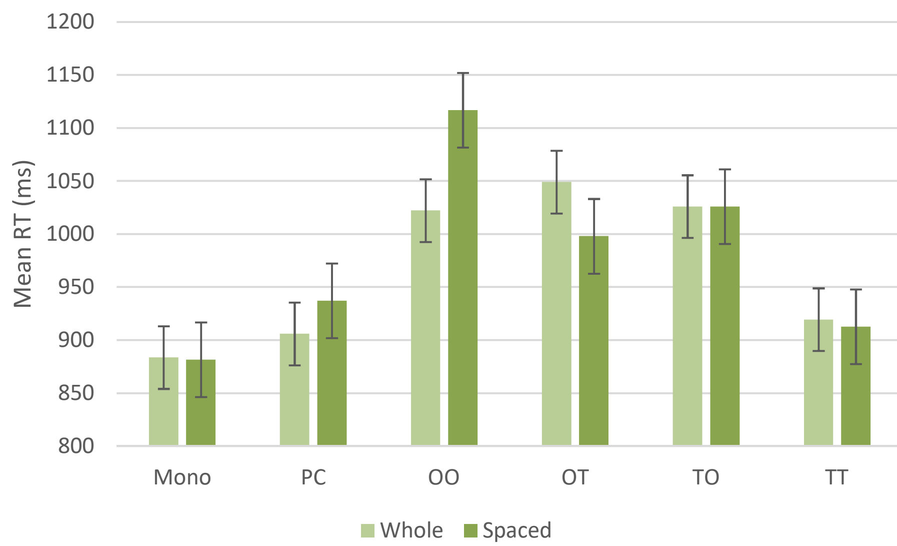

Figure 4. Visual representation of experiment 2 mean RTs. Error bars represent standard error

Accuracy. Overall, participant accuracy (defined as proportion of correct responses) was higher in the intact presentation condition than in the spaced presentation condition (*b* = .767, *SE* = .356, *z* = 2.156, *p* = .031). Further, participant accuracy was higher for monomorphemic words than for OO words (*b* = -1.630, *SE* = .467, *z* = -3.489, *p* < .001). Other significant predictor variables identified during the modeling were number of syllables (*b* = .970, *SE* = .317, *t* = 3.065, *p* = .002) and age of acquisition (*b* = -.284, *SE* = .074, *t* = -3.825, *p* < .001).

Table 8. Proportion of correct responses and standard deviations for Experiment 2

	Proportion of Correct Responses	
	Intact Presentation	Spaced Presentation
Mono	0.980	0.944
PC	0.954	0.929

OO	0.843	0.807
OT	0.907	0.885
TO	0.957	0.907
TT	0.979	0.957

Eye tracking.

Modifier Fixation Count. Altogether, participants fixated more often on modifiers in the intact presentation condition than modifiers in the spaced condition (b = 0.339, SE = .150, z = 2.26, p = .024).

Head Fixation Count. With respect to head fixation count, it was revealed that participants fixated more on TT heads than on monomorphemic heads (b = .298, SE = .150, z = 1.992, p = .046). It may be that when the task demands it, participants tend to look more often at the part of the word that will provide them with the most semantic information.

Modifier First Fixation Duration. When it comes to first fixation duration, participants looked at monomorphemic modifiers for a longer duration than PC modifiers (b = -21.622, SE = 10.793, t = -2.003, p = .045).

Head First Fixation Duration. No differences were detected amongst the head constituents during first fixation durations.

Modifier Second Fixation Duration. In terms of second fixation duration, participants spent more time looking at TO modifiers than monomorphemic modifiers (b = 38.268, SE = 16.403, t = 2.333, p = .021). In contrast, participants spent more time fixated on monomorphemic modifiers than OO (b = -41.610, SE = 16.795, t = -1.238, p = .014) and TT modifiers (b = -39.927, SE = 16.814, t = -2.375, p = .018).

Head Second Fixation Duration. In terms of head constituents, participants looked at OO heads for longer than monomorphemic heads (b = 46.769, SE = 17.309, t = 2.702, p = .007).

Table 9. Fixation count, first fixation duration, and second fixation duration for both heads and modifiers in the intact presentation condition of Experiment 2

	Fixation Count		First Fixation Duration		Second Fixation Duration	
	Modifier	Head	Modifier	Head	Modifier	Head
Mono	2.58	2.03	332.73	245.74	328.28	295.62
PC	2.67	1.99	320.57	239.17	339.62	296.55
OO	2.65	2.66	315.83	232.65	269.68	336.15
OT	3.16	2.10	350.00	229.59	284.65	319.02
TO	3.31	1.86	306.52	240.28	331.92	287.66
TT	2.76	2.09	319.32	250.69	286.89	325.524

Table 10. Fixation count, first fixation duration, and second fixation duration for both heads and modifiers in the spaced presentation condition of Experiment 2

	Fixation Count		First Fixation Duration		Second Fixation Duration	
	Modifier	Head	Modifier	Head	Modifier	Head
Mono	2.16	1.98	333.56	250.69	352.02	326.56
PC	2.08	1.96	317.60	258.32	382.32	338.51
OO	3.29	2.38	328.05	236.93	308.86	340.76
OT	1.75	2.18	334.11	218.08	333.27	326.45
TO	1.71	1.62	286.96	257.72	398.57	300.11
TT	2.74	2.89	333.55	250.92	324.56	296.81

Discussion. It was hypothesized that there would be a processing advantage afforded to all compound words in the intact presentation condition, and that this processing advantage would only remain for partially and fully transparent compounds in the spaced presentation condition. This hypothesis was not supported by the data; there was never a condition where compound words demonstrated a processing advantage. Further, presentation condition did not impact reaction times as robustly as it has in previous research. It did impact accuracy rate, whereby participants responded more accurately in the intact presentation condition than in the spaced one. This makes sense, given that participants see the words presented holistically more frequently than they see them with an artificial space in between. With respect to eye tracking data, participants fixated more frequently on TT heads than monomorphemic heads, which may indicate that participants sometimes intuitively know to look at the component of the word with the most meaning.

Experiment 3: Semantic categorization.

Thirty University of Windsor undergraduate students participated in Experiment 3 (29 females, 3 males; mean age: 20.5 years). 15 participants were assigned to the intact presentation condition, and 15 were assigned to the spaced presentation condition. Outliers were identified using the previously described procedure, resulting in the removal of 2.1% of the data.

Reaction time. Participants responded more rapidly to monomorphemic words than to TO (b = 0.055, SE = .018, t = 2.874, p = .004), OO (b = 0.060, SE = .025, t = 3.215, p = .002), and PC words (b = 0.047, SE = .012, t = 3.700, p < .001). Presentation condition did not present as a significant factor during the modeling process. Among the control variables age of acquisition was significant (b = .020, SE = .002, t = 7.952, p < .001).

Table 11. Reaction times means and standard deviations for Experiment 3

	Intact presentation		Spaced Presentation	
	Mean (ms)	SD	Mean (ms)	SD
Mono	1220.78	725.04	1288.68	817.01
PC	1430.92	935.89	1510.07	975.38
OO	1448.11	761.73	1436.44	617.26
OT	1279.75	665.71	1328.88	871.19

TO	1468.41	972.30	1340.52	714.84
TT	1227.35	712.73	1277.86	709.00

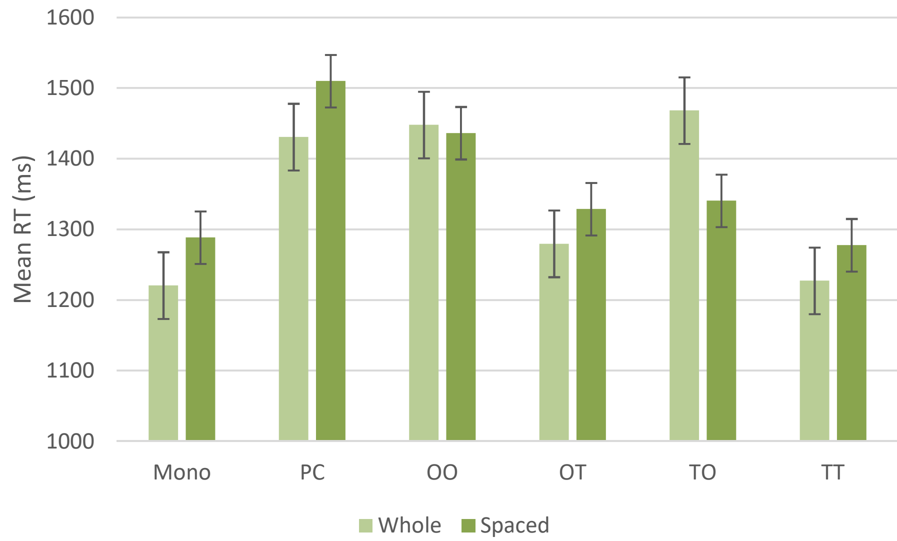

Figure 5. Visual representation of experiment 3 mean RTs. Error bars represent standard error

Accuracy. Participants gave a greater proportion of correct responses for monomorphemic words than for OO (b = -.913, SE = .374, z = -2.441, p = .015), TO (b = -1.654, SE = .363, z = - 4.546, p < .001), OT (b = -.860, SE = .379, z = - 2.226, p = .023), and PC words (b = -1.148, SE = .256, z = -4.491, p < .001). Age of acquisition was also indicated to be a significant variable during the modeling process (b = -3.827, SE = .947, t = 4.040, p < .001).

Table 12. Proportion of correct responses and standard deviations for Experiment 3

	Proportion of Correct Responses	
	Intact Presentation	Spaced Presentation
Mono	0.910	0.875
PC	0.767	0.709
OO	0.747	0.780
OT	0.747	0.773
TO	0.640	0.693
TT	0.827	0.853

Eye tracking.

Modifier Fixation Count. With respect to fixation count, participants fixated on monomorphemic modifiers more frequently than OO modifiers (b = -0.157, SE = .073, z = -2.146, p = .032).

Head Fixation Count. Participants fixated on OO heads more frequently than monomorphemic word constituents (b = 0.283, SE = .114, z = 2.486, p = .013).

Modifier First Fixation Duration. Overall, participants spent more time looking at modifiers in the spaced presentation condition than the intact presentation condition during their first fixation duration (b = -57.49, SE = 24.59, t = -2.339, p = .026).

Head First Fixation Duration. No main or interaction effect was shown for either presentation condition or transparency group for the first fixation duration of head constituents.

Modifier Second Fixation Duration. In terms of second fixation duration, participants fixated longer on modifier constituents in the intact presentation than the spaced presentation (b = 53.644, SE = 23.740, t = 2.260, p = .032).

Head Second Fixation Duration. Further, participants spent more time during their second fixation looking at monomorphemic heads than TT (b = -33.608, SE = 15.676, t = -2.144, p = .033) or TO heads (b = -39.776, SE = 15.545, t = -2.559, p = .012).

Table 13. Fixation count, first fixation duration, and second fixation duration for both heads and modifiers in the intact presentation condition of Experiment 3

	Fixation Count		First Fixation Duration		Second Fixation Duration	
	Modifier	Head	Modifier	Head	Modifier	Head
Mono	3.17	2.14	330.53	293.72	390.51	345.36

PC	3.44	2.48	347.02	280.42	379.80	343.85
OO	3.32	2.90	336.41	288.72	343.35	357.98
OT	3.77	2.28	340.38	266.05	373.28	313.88
TO	3.82	2.18	327.83	255.59	369.05	307.50
TT	3.44	2.24	346.63	305.70	347.42	322.25

Table 14. Fixation count, first fixation duration, and second fixation duration for both heads and modifiers in the spaced presentation condition of Experiment 3.

	Fixation Count		First Fixation Duration		Second Fixation Duration	
	Modifier	Head	Modifier	Head	Modifier	Head
Mono	3.29	1.88	392.48	288.21	331.72	351.34
PC	3.79	1.88	415.38	285.48	319.44	340.01
OO	3.41	2.34	350.67	298.93	292.40	341.73
OT	3.68	1.82	349.55	282.07	315.24	318.29
TO	3.82	2.11	401.50	271.62	320.38	306.59
TT	3.50	1.97	393.15	276.96	343.09	305.44

Discussion. As in Experiment 2, it was hypothesized there would be a processing advantage afforded to all compound words in the intact presentation condition, and that this processing advantage would only remain for partially and fully transparent compounds in the spaced presentation condition. Based on the results, this hypothesis is not supported. Overall, participants responded to monomorphemic words more rapidly and accurately than TO, OO, and PC words. With respect to eye tracking results it was noted that monomorphemic modifiers were looked at more often than OO modifiers, and that the opposite was true for OO heads. In terms of second fixation duration for head constituents, monomorphemic heads were looked at for a longer duration than TT and TO heads.

Experiment 4: Word relatedness task.

Thirty-one University of Windsor undergraduate students participated in Experiment 4 (28 females, 3 males; mean age: 20.5 years). 16 participants were assigned to the intact presentation condition and 15 were assigned to the spaced presentation condition. Outliers were identified using the previously described procedure, resulting in the removal of 2.3% of the data.

Reaction time. No main effects for presentation condition or transparency group were identified, but an interaction effect between the two was present. In particular, reaction times were faster for monomorphemic words than PC words in the intact presentation condition, whereas PC word reaction times were faster in the spaced condition (b = -0.0156, SE = .007, t = -2.332, p = .020). As with experiments 1 and 2, a slower reaction time in the previous trial was correlated to a slower reaction time for the current trial (b = 0.085, SE = .017, t = 6.232, $p < .001$). Age of acquisition also presented as a significant variable during the modeling process (b = .007, SE = .002, t = 3.442, $p <$ .001).

Table 15. Reaction times means and standard deviations for Experiment 4

	Intact Presentation		Spaced Presentation	
	Mean (ms)	SD	Mean (ms)	SD
Mono	1466.34	423.59	1549.84	541.095
PC	1459.67	448.64	1594.36	507.876
OO	1496.54	433.23	1616.70	493.612
OT	1539.19	468.10	1539.85	417.568
TO	1481.78	430.80	1622.49	566.580
TT	1473.26	513.70	1444.10	365.379

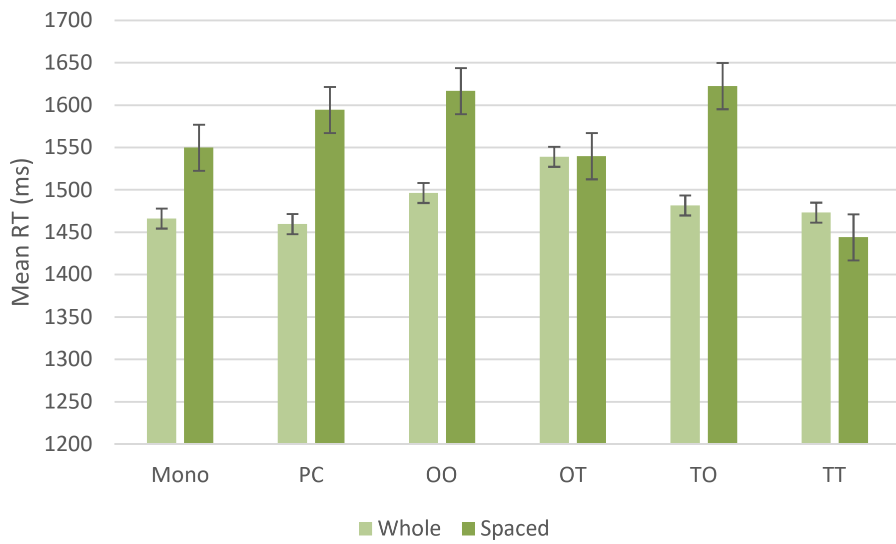

Figure 6. Visual representation of experiment 4 mean RTs. Error bars represent standard error

Accuracy. Overall, participant responses were less accurate for monomorphemic words than for TT (*b* = -1.877, *SE* = .846, *z* = -2.219, *p* = .026) and TO words (*b* = -1.681, *SE* = .768, *z* = -2.189, *p* = .029). Further, an interaction effect was identified between presentation condition and transparency group. Specifically, participant responses were more accurate for monomorphemic words than for OO words in the spaced presentation condition, whereas the opposite was true in the intact presentation condition (*b* = -.956, *SE* = .403, *z* = -2.373, *p* = .018). Reaction time (*b* = 1.703, *SE* = .592, *z* = 2.876, *p* = .004) and age of acquisition (*b* = 3.989, *SE* = 1.528, *z* = 2.610, *p* = .009) were also determined to be contributing variables during the modeling process.

Table 16. Proportion of correct responses and standard deviations for Experiment 4

	Proportion of Correct Responses	
	Intact Presentation	Spaced Presentation
Mono	0.864	0.860
PC	0.915	0.907
OO	0.840	0.733
OT	0.847	0.840

TO	0.960	0.973
TT	0.940	0.980

Eye Tracking.

Modifier Fixation Count. With respect to fixation count, participants looked at monomorphemic modifiers less frequently than OT modifiers (b = .337, SE = .076, z = 4.444, $p < .001$). There was also an interaction effect between transparency group and presentation condition, whereby OT and OO words were differentially impacted by presentation condition. In particular, participants looked at monomorphemic modifiers more frequently than OT modifiers in the spaced condition, while the opposite was true in the intact condition (b = -0.250, SE = .099, z = -2.535, p = .011). Further, participants looked at monomorphemic modifiers more frequently than OO modifiers in the intact presentation condition, while the opposite was true in the spaced condition (b = -0.283, SE = .077, z = -3.703, $p < .001$).

Head Fixation Count. When it comes to fixation counts on head constituents, participants looked at TO heads more frequently than monomorphemic heads (b = 0.297, SE = .119, z = 2.486, p = .013). There was also an interaction effect where TO and OO words were differentially impacted by presentation condition. Specifically, participants looked at TO heads more frequently than monomorphemic words in the intact presentation condition and less frequently in the spaced condition (b = -0.545, SE = .087, z = -6.240, $p < .001$). Further, participants looked at OO heads more frequently than monomorphemic words in intact condition, while the opposite held true for the spaced condition (b = 0.389, SE = .082, z = 4.737, $p < .001$).

Modifier First Fixation Duration. With respect to first fixation duration, no main or interaction effects for transparency group or presentation condition were revealed when it came to modifier constituents.

Head First Fixation Duration. For head constituents an interaction effect was identified and participants spent more time looking at monomorphemic heads than TT ($b = -66.983$, $SE = 33.321$, $t = -2.010$, $p = .045$) and OT heads ($b = -67.193$, $SE = 32.097$, $t = -2.093$, $p = .036$) in the intact presentation condition, while participants looked at TT and OT heads more in the spaced condition.

Modifier Second Fixation Duration. In terms of second fixation duration, while there was no main effect for either transparency group or presentation condition there was an interaction between the two. Participants looked at TO modifiers for a longer duration than monomorphemic modifiers in the intact condition ($b = 146.569$, $SE = 38.037$, $t = 3.853$, $p < .001$).

Head Second Fixation Duration. For head constituents there was also an interaction effect between transparency and presentation condition, whereby OO heads were fixated on for longer in the intact condition than in the spaced one ($b = 81.241$, $SE = 41.256$, $t = 1.969$, $p = .049$).

Table 17. Fixation count, first fixation duration, and second fixation duration for both heads and modifiers in the intact presentation condition of Experiment 4

	Fixation Count		First Fixation Duration		Second Fixation Duration	
	Modifier	Head	Modifier	Head	Modifier	Head
Mono	2.59	2.08	337.43	261.01	412.41	340.35
PC	2.59	2.14	311.32	248.02	414.43	351.26
OO	2.15	2.83	355.20	223.66	352.20	406.68

OT	2.90	2.22	375.05	228.11	392.74	344.26
TO	3.05	1.58	299.99	260.00	538.59	359.09
TT	2.74	1.91	355.15	226.20	367.51	335.71

Table 18. Fixation count, first fixation duration, and second fixation duration for both heads and modifiers in the spaced presentation condition of Experiment 4

	Fixation Count		First Fixation Duration		Second Fixation Duration	
	Modifier	Head	Modifier	Head	Modifier	Head
Mono	3.46	2.35	368.68	277.37	400.87	375.00
PC	3.20	2.53	368.81	289.41	407.58	355.42
OO	3.83	2.18	360.10	253.15	377.11	354.89
OT	2.76	2.58	375.45	310.53	409.04	399.47
TO	3.59	3.14	343.57	293.88	376.84	349.79
TT	3.43	2.36	402.85	310.46	394.63	370.26

Discussion. As with the previous two experiments, it was hypothesized there would be a processing advantage afforded to all compound words in the intact presentation condition, and that this processing advantage would only remain for partially and fully transparent compounds in the spaced presentation condition. The results indicate that the hypothesis is only partially supported. In particular, participants responded more accurately to TT and TO words than to monomorphemic words. However, no differences were detected between monomorphemic words and any other compound word category. There was an interaction effect, whereby PC words in the intact presentation condition were responded to more rapidly than PC words in the spaced presentation condition. This finding supports the idea that PC words are sometimes processed differently than monomorphemic words. With respect to eye tracking data, there was an interesting interaction effect between transparency group and presentation condition when it came to first fixation duration. In particular, participants spent more time looking at monomorphemic heads than TT and OT heads in the intact condition, whereas the opposite was true for the spaced condition. This may be evidence to support the idea that forced decomposition prompts the reader to look at the head of the word to obtain the most semantic information. That being said, this finding was not seen when it came to second fixation duration, nor has it been consistently seen consistently across experiments.

Table 19. Summary of hypotheses and outcome

Experiment	**Hypothesis**	**Hypothesis met?**
1: Letter Detection Task	No differences between compound words and monomorphemic words.	No. There were unexpected RT differences between monomorphemic words and compound words.
2: Lexical Decision Task	Faster RT and higher accuracy for compound words in intact presentation. Faster RT and higher accuracy for fully transparent words in spaced presentation.	No. There was never a situation where compound words were associated with any sort of improved performance.
3: Semantic Categorization Task	Faster RT and higher accuracy for compound words in intact presentation. Faster RT and higher accuracy for fully and partially transparent words in spaced presentation.	No. There was never a situation where compound words were associated with any sort of improved performance.
4: Word Relatedness Task	Faster RT and higher accuracy for compound words in intact presentation. Faster RT and higher accuracy for fully and partially transparent words in spaced presentation.	Partially. There was improved accuracy for TT and TO words relative to monomorphemic words.

CHAPTER IV

DISCUSSION

The main objective of this study was to examine how compound words are processed relative to monomorphemic words. Previous research (Ji et al., 2011; Libben et al., 2003; Libben, 1998) has demonstrated that compound words are processed more rapidly than monomorphemic words in lexical decision tasks. When processing through decomposition is encouraged via the addition of spaces between the constituents, Ji, Gagné, and Spalding (2011) found that opaque compound words lost their processing advantage relative to monomorphemic words. This study sought to expand this research by also considering partial transparency, presentation condition, and task type. Please see Table 19 for an overview of each hypothesis and general results.

Transparency. Research by Ji, Gagné, and Spalding (2011) focused on fully transparent (TT) and opaque (OO) compounds. This paper expanded transparency conditions to include partially transparent (transparent-opaque [TO] and opaque-transparent [OT]) compound words. It was hypothesized that there would be consistent processing advantages afforded to compound words, however this was generally not the case. Rather, there were many occasions where certain transparency conditions were processed slower and/or less accurately than their monomorphemic counterparts. In fact, the only advantage afforded to compound words was demonstrated in experiment 4, whereby TT and TO words were identified correctly more often than monomorphemic words. Compound words were never processed more rapidly than monomorphemic words. These findings are not consistent with previous literature concerning lexical decision tasks (Ji et al., 2011; Libben et al., 2003; Libben, 1998), which observed a consistent processing speed advantage for all compound words, including fully opaque words, in an intact presentation condition (Ji et al., 2011; Libben et al., 2003; Libben, 1998). The potential reasons for these differences will be considered more carefully in the overview section below.

Previous literature concerning the impact of transparency on eye tracking measures has been mixed (Schmidtke, Van Dyke, & Kuperman, 2018). In some studies, semantic transparency has been identified as having a facilitatory effect, whereby it helps to speed up processing during eye tracking (Schmidtke et al., 2018; Marelli & Luzzatti, 2012). Consequently, some studies have reported shorter gaze durations on transparent compounds as compared to opaque compounds (Underwood et al., 1990; Juhasz, 2007). In contrast, other studies have found no discernible influence of transparency on eye movement patterns (Juhasz, 2018; Pollatsek and Hyönä, 2005).

The current study has found some eye tracking differences between compound words and monomorphemic words. In experiment 1 (letter detection task) participants looked at monomorphemic modifiers more often than OO modifiers, whereas the reverse was true for head constituents. Curiously, this pattern was also seen in experiment 3 (semantic categorization task), but not experiments 2 (lexical decision task) and 4 (word relatedness task).

In experiment 2 (lexical decision task)**,** participants fixated more frequently on TT heads than monomorphemic heads, which may indicate that participants sometimes intuitively know to look at the component of the word with the most meaning. Similarly, in experiment 4 (word relatedness task), participants spent more time during their first fixation duration looking at monomorphemic heads than TT and OT heads in the intact condition, whereas the opposite was true for the spaced condition. This may indicate that forced decomposition prompts the reader to look at the head of the word for longer if semantic information is available. On the other hand, experiment 3 (semantic categorization) determined that during second fixation duration for head constituents, participants looked at monomorphemic heads for a longer duration than TT and TO heads, which is not consistent with experiments 2 and 4.

Overall, the eye tracking data did not demonstrate a consistent pattern of findings. There were some situations where participants seemed to look at the transparent portion of the word more frequently or for longer durations, and others where the opposite held true. It may be that most semantic processing occurs somewhat later than is captured by first and second fixation durations.

Altogether, the hypotheses concerning transparency were largely inaccurate. There is sometimes a processing advantage, but it seems to be limited to word relatedness tasks and accuracy rates. In any case, these results support the growing body of evidence that transparency can impact how compound words are processed as compared to monomorphemic words.

Presentation. This research determined that there were several instances where reaction time, accuracy, and eye tracking results were all impacted by presentation condition, either as a main effect or as an interaction effect with transparency group. That being said, presentation condition was not as robust an effect as anticipated. Research by Ji, Gagné, and Spalding (2011) demonstrated that all compound words maintained a processing advantage in the intact presentation condition, while opaque words lost this advantage under the spaced presentation condition. The current results indicate that compound words were largely identified at the same (or worse) rate and accuracy as monomorphemic words with rare exceptions. Altogether, the current findings indicate that presentation condition does sometimes impact the processing of compound words, but not to the extent as has been seen in previous literature.

Task Type. Previous literature has suggested (Hino & Lupker, 1996; Pexman et al., 2007; Yap et al., 2012) that semantic effects are more directly examined using tasks that explicitly require participants to process meaning as compared to those where the processing of semantics is not necessary. According to research by Danguecan (2015), semantic effects can be unveiled using a range of tasks varying in the degree of explicit semantic processing required. This study sought to replicate this concept by examining the processing of compound words using a variety of tasks.

In this study four different tasks were used: letter detection, lexical decision, semantic categorization, and word relatedness. Each task can be represented on a spectrum of semantic depth. A task such as letter detection is considered to be semantically shallow because one does not need to understand the meaning of a presented word to identify whether a target letter is in said word. In contrast, semantic categorization and word relatedness require a fundamental understanding of language to successfully engage in either of these tasks. With lexical decision tasks, the processing of semantics is not necessary, but it can be helpful as it serves as a proxy to word familiarity. If one knows what a word means, then the word is not novel and is thus more likely to be identified as being a real word.

The results indicate that task type does have an influence on how compound words are processed. Whether these differences can be explicitly attributed to differences in semantic depth is still unclear, given how inconsistent these results were. It was hypothesized that as the semantic demands of the task increased, then an improvement of reaction time and accuracy would be afforded to fully and partially transparent words. This hypothesis was partially met, in that experiment 4 demonstrated some aspects of improved accuracy, but there were no advantages afforded to any group in experiment 3 (semantic categorization task), which is also supposedly a semantically deep task. One caveat of this finding is that no direct statistical comparisons were made between tasks.

Altogether, task type did influence compound word processing as compared to monomorphemic word processing, but this finding is not necessarily linked to the semantic demands of a task.

Overview. Overall, support for the processing advantage hypothesis was limited. In fact, oftentimes it seemed as though there was a processing *disadvantage* for compound words, particularly when it came to fully opaque compound words. Rather than the anticipated rapid response time advantage afforded to compound words, participants in experiments 1, 2, and 3 demonstrated slower reaction times for one or more of the compound word conditions. Similarly, participant accuracy (defined as proportion of correct responses) was lower for one or more compound word group in experiments 2 and 3. Ultimately, participants only demonstrated improved accuracy in experiment 4, whereby TT and TO words were responded to correctly more often than monomorphemic words. Our results determined that transparency, presentation condition, and task type all influence compound word processing to some extent.

As previously stated, the results of this research are quite different from some of the previous literature. There may be a number of reasons for this. The first reason is that research concerning the influence of age of acquisition on the processing of compound words is fairly recent (Juhasz, 2018). Subsequently, previous authors may not have known to include it during their modeling processes or to control for it during stimulus set development. Age of acquisition was identified to be a robust factor during the current study's modeling process and its absence had the potential to heavily impact the results.

Another reason may be that current day readers are differentially impacted by presentation condition than their peers from a decade ago (when much of the previous research was conducted). The mean age of participants in this study was approximately 20 years, and therefore it is likely that these students have grown up with access to computers and texting. Indeed, texting has led to the creation of abbreviated words, known as Netspeak, which may impact how they respond to changes in punctuation. It may be that presentation condition was not as robust as a factor because the participants may be used to seeing atypical punctuation in their daily life.

Finally, it may be that individual variability is accounting for some of these differences. Research by Schmidtke, Van Dyke, and Kuperman (2018) reported that exposure to written language and vocabulary size influences one's ability to discriminate between meanings during compound word reading. Notably, having more exposure to printed language allowed participants to reap the facilitatory rewards associated with semantic transparency, whereas less experienced readers were effectively inhibited by their inability to effectively discriminate between two competing definitions (i.e. whole word meaning vs. constituent meaning) (Schmidtke, Van Dyke, and Kuperman, 2018). Future research should be mindful to include a measure of reading ability to help mitigate the influence of individual variability.

Pseudocompound Words.

One additional component that this study considered was the processing of pseudocompound words. Pseudocompound words are words that share a structure to compound words, but are read as though they are monomorphemic words (e.g. bra**very**, account**ant**). Overall the findings indicate that in conditions where semantic integration is necessary, there is a processing difference between monomorphemic words and pseudocompound words. The only experiment where participants responded comparably to monomorphemic words and pseudocompound words was experiment 1 (letter detection task), which required no semantic understanding of the target word in order to be successful at the task. Curiously, the first experiment was also the only one where there was a difference between PC and OO words. Otherwise, PC words and OO words were identified by participants at the same rate. It seems that, at least in some cases, PC words are processed differently from both monomorphemic words and compound words, depending on the task requirements. Altogether, this indicates that researchers need to be careful during analysis. It is important not to assume that pseudocompound words and monomorphemic words are sufficiently similar that they can be merged into one condition.

Limitations

One limitation of this study is that only early fixation durations were examined, which only provides an early perspective of processing. Previous research has indicated that participants can differentiate a compound word from a monomorphemic word based on morphological elements early in processing (Diependaele et al., 2005; Diependaele, Sandra & Grainger, 2009; Libben, 2014). Moreover, recent literature (Davis, Libben, & Segalowitz, 2019; Schmidtke & Kuperman, 2018) supports the idea that the processing of both morphology and early semantic activation occur simultaneously. It has been estimated that this process occurs within the first 120 milliseconds post-stimulus (Davis, Libben, & Segalowitz, 2019). With that in mind, it is reasonable to consider looking at early fixations to assess early semantic effects.

That being said, during first and second fixation durations it may be that only partial semantic information is available, as the reader has not necessarily had the opportunity to examine the entire word (Marelli & Luzzatti, 2012). Research by Marelli and Luzzatti (2012) indicated that the head constituent does not play a significant role during first fixation duration, signifying that information concerning the whole compound structure is not accessed until later processing stages. These authors posited that during early activation, when only partial semantic information is available, the combination of constituent meanings has begun (either successfully or unsuccessfully, depending on transparency), but a full processing of the second constituent is still required in order to access the whole compound structure. Overall, in order to get a full representation of how compound words are accessed semantically, later fixation durations should also be included.

Another limitation is the fact that this study exclusively used University of Windsor students who were enrolled in a psychology or business class and who were mostly females in their late teens or early 20s. As a result, these findings may not be generalizable to other populations.

Future Directions

Future research could include other sorts of tasks, such as picture naming tasks, to further aid in determining processing differences between monomorphemic words and compound words. Within psycholinguistics lexical decision tasks are very common, but as demonstrated through this research task type does differentially impact how words are processed. Further research should also attempt to parse out the influence of semantic requirements on compound word processing, as the results of this study were inconclusive in that regard.

Clinical Applications. Researchers could also expand on the clinical implications of compound word research. As previously noted, research by McGregor et al. (2010) concluded that children with language impairments may have problems in the developmental links of their semantic lexicon. Similarly, children with autism and co-morbid language impairment were indicated to have less difficulty recognizing the compound constituents, but showed a significant deficit in deriving the compound meaning (Kambanaro, Christou, & Grohmann, 2019). It appears that children with language impairments struggle to acquire an understanding about the nuanced facets of compounding more than typically-developing peers. As such, an appropriate intervention might be to explicitly teach these linguistic rules to children who are experiencing difficulties.

Research by Tsesmeli (2017) has evaluated the usefulness of a training program to help first and second grade students understand compound words through the use of classroom games. For the training program, the students completed five two-hour sessions aimed at offering instruction about morphological decomposition and the meaning of compound words. The results indicated that training was effective in improving the spelling and the semantic understanding of compounds. This research supports the idea that direct interventions may be one way to help children who have not acquired an understanding of compound words. This research was conducted in Greek with first and second grade children. Consequently, future research could examine whether these findings are generalizable to other languages and age ranges.

Conclusions

In conclusion, there was minimal evidence supporting the hypotheses of processing advantages being afforded to compound words as compared to monomorphemic words. However, the evidence still does support that participants process compound words and monomorphemic differently. Further, pseudocompound words, which are commonly assumed to be similar to monomorphemic words, were responded to differently in half of the experiments. Finally, transparency, presentation, and task requirements all influenced how participants responded to the stimulus set to varying extents. In summary, compound words are processed differently from monomorphemic words, and pseudocompound words are processed differently from both, depending on task requirements.

REFERENCES

Acara, G., Semenza, C., & Bambini, V. (2014). Word structure and decomposition effects in reading. *Cognitive Neuropsychology, 31*, 184-218, doi:10.1080/02643294.2014.903915

Andrews, S. (1986). Morphological influences on lexical access: Lexical or nonlexical effects? *Journal of Memory and Language, 25*, 726–740.

Andrews, S., Miller, B., & Rayner, K. (2004). Eye movements and morphological segmentation of compound words: There is a mouse in mousetrap. *European Journal of Cognitive Psychology, 16*, 285–311.

Baayen, R. H., Dijkstra, T., & Schreuder, R. (1997). Singulars and plurals in Dutch: Evidence for a parallel dual-route model. *Journal of Memory and Language, 37*, 94–117.

Baayen, R. H., & Schreuder, R. (1999). War and peace: Morphemes and full forms in a non-interactive activation parallel dual-route model. *Brain and Language, 68*, 27–32.

Baayen, R. H., & Schreuder, R. (2000). Towards a psycholinguistic computational model for morphological parsing. *Philosophical Transactions of the Royal Society, Series A: Mathematical, Physical and Engineering Sciences, 358*, 1–13.

Baayen, R. H. (2008). *Analyzing linguistic data: A practical introduction to statistics using R*. New York: Cambridge University Press.

Badecker, W. (2001). Lexical composition and the production of compounds: Evidence from errors in naming. *Language and Cognitive Processes, 16*, 337– 366.

Bauer, L. (2009). Typology of compounds. In R. Lieber & P. Stekauer (Eds.), The

Oxford handbook of compounding (pp. 343 – 356). Oxford: Oxford University Press.

Binder, J. R., McKiernan, K. A., Parsons, M. E., Westbury, C. F., Possing, E. T., Kaufman, J. N., & Buchanan, L. (2003). Neural correlates of lexical access during visual word recognition. *Journal of Cognitive Neuroscience, 15*(3), 372-393. doi:10.1162/089892903321593108

Bertram, R., Laine, M., & Karvinen, K. (1999). The interplay of word formation type, affixal homonymy, and productivity in lexical processing: Evidence from a morphologically rich language. *Journal of Psycholinguistic Research*, *28*, 213–226.

Brooks, T. L., & Garcia, D. C. (2015). Evidence for morphological composition in compound words using MEG. *Frontiers in Human Neuroscience*. doi: 10.3389/fnhum.2015.00215

Butterworth, B. (1983). Lexical representation. *Language production, 2*, 257-294.

Christianson, K., Johnson, R. L., & Rayner, K. (2005). Letter transpositions within and across morphemes. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31*(6), 1327-1339.

Coltheart, M. (1978). Lexical access in simple reading tasks. In G. Underwood (Ed.), *Strategies of Information Processing*, 151–216. New York: Academic Press.

Coltheart, M., Curtis, B., Atkins, P., & Haller, M. (1993). Models of reading aloud: Dual-route and parallel distributed processing approaches. *Psychological Review*, *100*, 589–608.

Coltheart, M., & Coltheart, V. (1997). Reading comprehension is not exclusively reliant upon phonological representation. *Cognitive Neuropsychology, 14*(1), 167-175, DOI: 10.1080/026432997381655

Danguecan, A. (2015). *Towards a new model of semantic processing: Task-specific effects of concreteness and semantic neighbourhood density in visual word recognition* (Doctoral dissertation). Retrieved from Electronic Theses and Dissertations (5632).

Davis, C. P., Libben, G., Segalowitz, S. J. (2019). Compounding matters: Event-related potential evidence for early semantic access to compound words. *Cognition, 184*, 44-52.

Diependaele, K., Sandra, D., & Grainger, J. (2005). Masked cross-modal morphological priming: Unravelling morpho-orthographic and morpho-semantic influences in early word recognition. *Language and Cognitive Processes, 20*(1–2),75–114.

Diependaele, K., Sandra, D., & Grainger, J. (2009). Semantic transparency and masked morphological priming: The case of prefixed words. *Memory & Cognition, 37*(6), 895–908.

Durda, K., & Buchanan, L. (2006). WordMine2 [Online] Available: http://web2.uwindsor.ca/wordmine

Falkauskas, K., & Kuperman, V. (2015). When experience meets language statistics: Individual variability in processing English compound words.

Frauenfelder, U. H., & Schreuder, R. (1991). Constraining psycholinguistic models of morphological processing and representation: The role of productivity. In G. Booji & J.van Marle (Eds.), *Yearbook of morphology* (pp. 165–183). Kluwer: Dordrecht.

Frisson, S., Niswander-Klement, E., & Pollatsek, A. (2008). The role of semantic transparency in the processing of English compound words. *British Journal of Psychology, 99*(1), 87– 107.

Gagné, C. L., & Spalding, T. L. (2016). Effects of morphology and semantic transparency on typing latencies in English compound and pseudocompound words. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 42*, 1489-1495.

Hino, Y., & Lupker, S. J. (1996). Effects of polysemy in lexical decision and naming: An alternative to lexical access. *Journal of Experimental Psychology: Human Perception and Performance, 22*(6), 1331-1356. doi:10.1037/0096-1523.22.6.1331

Hyönä, J., & Pollastek, A. (1998). Reading Finnish compound words: Eye fixations are affected by compound morphemes. *Journal of Experimental Psychology: Human Perception and Performance*, *24*(6), 1612-1627.

Jackendoff, R. (2002). Foundations of knowledge. Oxford: Oxford University Press.

Janssen, N., Yanchao, B., & Caramazza, A. (2008). A tale of two frequencies: Determining the speed of lexical access for Mandarin Chinese and English compounds. *Language and Cognitive Processes*, *23*, 1191-1223. DOI: 10.1080/01690960802250900.

Ji, H., Gagné, C. L., & Spalding, T. L. (2011) Benefits and costs of lexical decomposition and semantic integration during the processing of transparent and opaque English compounds. *Journal of Memory and Language, 65*, 406-430.

Juhasz, B. J. (2018). Experience with compound words influences their processing: An eye movement investigation with English compound words. *Quarterly Journal of Experimental Psychology*, *71*(1), 103-112.

Juhasz, B. J. (2012). Sentence context modifies compound word recognition: Evidence from eye movements. *Journal of Cognitive Psychology, 7*, 855-870. DOI: 10.1080/20445911.2012.706602.

Juhasz, B.J., & Rayner, K. (2003). Investigating the effects of a set of intercorrelated variables on eye fixation durations in reading. *Journal of Experimental Psychology: Learning, Memory & Cognition*, *29*, 1312-1318.

Juhasz, B. J., & Yap, M. (2013). Sensory experience ratings for over 5,000 mono- and disyllabic words. *Behavioural Research Methods, 45*, 160-168.

Inhoff, A. W. (1989). Lexical access during eye fixations in reading: Are word access codes used to integrate lexical information across interword fixations? *Journal of Memory & Language, 28*, 441-461.

Kambanaros, M., Christou, N., & Grohmann. K. K. (2019) Interpretation of compound words by Greek-speaking children with autism spectrum disorder plus language impairment (ASD–LI). *Clinical Linguistics & Phonetics*, 33, 135- 174, DOI: 10.1080/02699206.2018.1495766.

Koester, D., Gunter, T.C., & Wagner, S. (2007). The morphosyntactic decomposition and semantic composition of German compound words investigated by ERPs. *Brain Language, 102* (1), 64–79.

Kuperman, V. (2013). Accentuate the positive: Semantic access in English compounds. *Frontiers in Psychology, 4*, 1-10.

Kuperman, V., Bertram, R., & Baayen, R. H. (2008).Morphological dynamics in compound processing. *Language and Cognitive Processes, 23*, 1089-1132.

Kuperman, V., Schrueder, R., Bertram, R., & Baayen, R. H. (2009). Reading polymorphemic Dutch compounds: Toward a multiple route model of lexical processing. *Journal of Experimental Psychology: Human Perception and Performance*, *35*, 876-895.

Kuperman, V., Stadthagen-Gonzalez, H., & Brysbaert, M. (2012). Age-of-acquisition ratings for 30,000 English words. *Behavior Research Methods, 44*(4), 970-990. DOI: 10.3758/s13428-012-0210-4.

Kutas, M., & Hillyard, S.A. (1980). Reading senseless sentences: brain potentials reflect semantic incongruity. *Science, 207*, 203–205.

Kutas, M., & Federmeier, K.D. (2000). Electrophysiology reveals semantic memory use in language comprehension. *Trends in Cognitive Science, 4*, 463–470.

Laine, M., Vainio, S., & Hyönä, J. (1999). Lexical access routes to nouns in a morphologically rich language. *Journal of Memory and Language, 40*, 109–135.

Laudanna, A., & Burani, C. (1985). Address mechanisms to decomposed lexical entries. *Linguistics, 23*, 775–792.

Libben, G. (1998). Semantic transparency in the processing of compounds: Consequences for representation, processing, and impairment. *Brain and Language, 61*, 30–44.

Libben, G., Gibson, M., Yoon, Y. B., & Sandra, D. (2003). Compound fracture: The role of semantic transparency and morphological headedness. *Brain and Language, 84*, 50 - 64

Libben, G. (2010). Compounds, semantic transparency, and morphological transcendence. In S. Olson (Ed.), New impulses in word-formation (Linguistische Berichte Sonderheft 17) (pp. 212–232). Hamburg: Buske.

Libben, G. (2014). The nature of compounds: A psychocentric approach. *Cognitive Neuropsychology, 31,* 8 – 25.

Libben, G., & Jerema, G. (2006). *The Representation and Processing of Compound Words*. Oxford University Press Inc: New York.

Liversedge, S., Gilchrist, I., & Everling, S. (2011). *The Oxford Handbook of Eye Movements*. Oxford University Press Inc, New York.

Marelli, M., & Luzzatti, C. (2012). Frequency effects in the processing of Italian nominal compounds: Modulation of headedness and semantic transparency. *Journal of Memory and Language, 66*(4), 644–664.

Mondini, S., Arcara, G., & Semenza, C. (2012). Lexical and buffer effects in reading and in writing Noun- Noun compound nouns. *Behavioural Neurology, 25*, 245–253.

McGregor, K. K., Rost, G. C., Guo, L. Y., & Sheng, L. (2010). What compound words mean to children with specific language impairment. *Applied Psycholinguistics, 31*, 463-487. doi:10.1017/S014271641000007X

Pachella, R.G. (1974) An interpretation of reaction time in information processing research. In: B. Kantowitz (Ed.), *Human Information Processing: Tutorials in Performance and Cognition*. Hillsdale, NJ: Erlbaum.

Pexman, P. M., Hargreaves, I. S., Edwards, J. D., Henry, L. C., & Goodyear, B. G. (2007). Neural correlates of concreteness in semantic categorization. *Journal of Cognitive Neuroscience, 19*(8), 1407-1419. doi:10.1162/jocn.2007.19.8.1407

Plaut, D.C., McClelland, J.L., Seidenberg, M.S., & Patterson, K. (1996). Understanding normal and impaired word reading: Computational principles in quasi-regular domains. *Psychological Review, 103*, 56–115.

Pollatsek, A., & Hyönä, J. (2005). The role of semantic transparency in the processing of Finnish compound words. *Language and Cognitive Processes, 20*(1-2), 261–290.

Pollatsek, A., Hyönä, J., & Bertram, R. (2000). The role of morphological constituents in reading Finnish compound words. *Journal of Experimental Psychology: Human Perception and Performance*, 26, 820–833.

Rastle, K., Davis, M. H.m & New, B. (2004). The broth in my brother's brothel: Morpho-orthographic segmentation in visual word recognition. *Psychological Bulletin & Review 11*, 1090-1098.

Roediger, H. L. & McDermott, K. B. (1995). Creating false memories: Remembering words not present in lists. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 21*, 803-814.

R Core Team. (2015). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Retrieved from http://www.R-project.org/.

Schmidtke, D., & Kuperman, V. (2018). A paradox of apparent brainless behavior: The time-course of compound word recognition, *Cortex*. doi: 10.1016/j.cortex.2018.07.003

Schmidtke, D., Kuperman, V., Gagné, C. L., & Spalding, T. L. (2015). Competition between conceptual relations affects compound recognition: The role of entropy. *Psychonomic Bulletin & Review*, 1-15.

Schmidtke, D., Van Dyke, J. A., & Kuperman, V. (2018). Individual variability in the semantic processing of English compound words. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 44* (3), 421–439.

Schreuder, R. and Baayen, R. (1995) Modeling morphological processing. In Feldman, L. B. (ed), Morphological Aspects of Language Processing. Lawrence Erlbaum, Hillsdale, New Jersey, 131–154.

Semenza C., & Luzzatti C. (2014). Combining words in the brain: the processing of compound words. introduction to the special issue. *Cognitive Neuropsychology, 31*, 1–7. doi: 10.1080/02643294.2014.898922.

Semenza, C., & Mondini, S. (2010). Compound words in neuropsychology. *Linguistische Berichte, 17*, 331–348.

Stathis, A. (2014). *How partial transparency influences the processing of compound words.* (Master's project). Retrieved from Electronic Theses and Dissertations. (5056).

Taft, M., & Forster, K. I. (1975). Lexical storage and retrieval of prefixed words. *Journal of Verbal Learning and Verbal Behavior, 14*, 638–647.

Tsesmeli, S. N. (2017). Spelling and meaning of compound words in early school years through classroom games: An intervention study. *Frontiers in Psychology.* doi: 10.3389/fpsyg.2017.02071

Yap, M., Pexman, P. M., Wellsby, M., Hargreaves, I. S., & Huff, M. J. (2012). An abundance of riches: Cross-task comparisons of semantic richness effects in visual word recognition. *Frontiers in Human Neuroscience, 6*, 72. doi:10.3389/fnhum.2012.00072

Williams, R. S. & Morris, R. K. (2004). Eye movements, word familiarity, and vocabulary acquisition. *European Journal of Cognitive Psychology, 16*, 312-339.

Zwitserlood, P. (1994). The role of semantic transparency in the processing and representation of Dutch compounds. *Language and Cognitive Processes, 9,* 341–368.

APPENDICES

Appendix A: Word Stimulus Set

Stimulus Set Words with their Lengths, Syllables, and Orthographic Neighbourhood Frequencies

				Orthographic Neighbourhood Frequencies		
Condition	Word	Letters	Syllables	Whole Word	First Constituent	Second Constituent
Compound TT	PAYDAY	6	2	0.138174	194.769	986.051
Compound TT	PEANUT	6	2	1.15394	3.82779	9.20538
Compound TT	HAIRPIN	7	2	0.821575	196.797	16.6556
Compound TT	HANDBAG	7	2	2.80083	665.741	50.3476
Compound TT	SUNDIAL	7	2	0.698339	193.896	5.28422
Compound TT	SANDBAR	7	2	0.119502	52.3605	64.2173
Compound TT	KEYHOLE	7	2	1.88215	92.416	56.6775
Compound TT	ROWBOAT	7	2	0.36224	46.2846	99.5525
Compound TT	ANTEATER	8	3	0.175518	6.0087	2.69626
Compound TT	BARNYARD	8	2	0.855185	18.9224	45.2725
Compound TT	SILKWORM	8	2	0.317427	33.8228	10.1875
Compound TT	SUITCASE	8	2	3.1556	55.419	388.265
Compound TT	BEDSPREAD	9	2	0.399584	212.919	76.3169
Compound TT	COASTLINE	9	2	1.95684	53.085	240.695
Compound TT	SPACESHIP	9	2	0.7917	112.507	86.0712
Compound TT	TOOTHPICK	9	2	0.616182	9.34355	50.1945
Compound TT	NOTEPAPER	9	3	0.843982	156.611	172.195
Compound TT	EARTHQUAKE	10	2	6.86389	200.121	1.21369
Compound TT	BASKETBALL	10	3	1.41162	23.2095	64.4713

				Orthographic Neighbourhood Frequencies		
Condition	Word	Letters	Syllables	Whole Word	Condition	Word
Compound TT	SCATTERBRAIN	12	3	0.0336099	4.66057	72.2576
Compound TO	CATNIP	6	2	0.253941	45.5452	2.60663
Compound TO	SAWHORSE	8	2	0.343568	514.594	158.291
Compound TO	POTLUCK	7	2	0.0485476	24.7817	46.1091
Compound TO	COPYCAT	7	3	0.160581	95.1086	45.5452
Compound TO	WEDLOCK	7	2	1.00456	8.6116	28.3966
Compound TO	PAYROLL	7	2	1.75518	194.769	34.8572
Compound TO	AIRLINE	7	2	4.01825	282.57	240.695
Compound TO	TYPEFACE	8	2	0.675932	139.022	629.861
Compound TO	SEAHORSE	8	2	0.0784231	224.712	158.291
Compound TO	CUPBOARD	8	2	10.7589	82.897	118.856
Compound TO	JAILBIRD	8	2	0.130705	12.2191	70.2036
Compound TO	UNDERDOG	8	3	0.250207	706.166	110.498
Compound TO	HOPSCOTCH	9	2	0.10083	6.06845	12.9622
Compound TO	STALEMATE	9	2	0.85892	5.16846	25.2037
Compound TO	SNAPSHOT	8	2	1.18755	10.5498	100.68
Compound TO	LITTERBUG	9	3	0.0112033	7.93941	10.7253
Compound TO	DAREDEVIL	9	3	0.321161	54.4779	50.4261
Compound TO	PEPPERCORN	10	3	0.179253	12.7419	34.1103
Compound TO	LUMBERJACK	10	3	0.175518	4.86597	82.7476
Compound TO	QUICKSILVER	11	3	1.04564	91.8783	78.8078
Compound OT	GODSON	6	2	0.593775	390.864	390.864
Compound OT	COBWEB	6	2	0.899998	1.56846	22.4402

				Orthographic Neighbourhood Frequencies		
Condition	Word	Letters	Syllables	Whole Word	Condition	Word
Compound OT	BULLDOG	7	2	1.49377	29.7186	110.498
Compound OT	CATFISH	7	2	1.09419	45.5452	106.166
Compound OT	CROWBAR	7	2	0.814107	8.58173	64.2173
Compound OT	LADYBUG	7	3	0.0186722	272.812	10.7253
Compound OT	SHEEPDOG	7	2	0.257676	42.2103	110.498
Compound OT	CHESTNUT	8	2	6.68837	41.807	9.20538
Compound OT	DEADLINE	8	2	4.02198	238.346	240.695
Compound OT	FORKLIFT	8	2	0.13444	10.6431	39.5962
Compound OT	FOLKLORE	8	2	2.22946	36.9186	5.97509
Compound OT	JOYSTICK	8	2	0.492945	84.9472	52.9841
Compound OT	BLACKLIST	9	2	0.194191	307.09	108.952
Compound OT	DASHBOARD	9	2	0.92614	11.6925	118.856
Compound OT	LIMELIGHT	9	2	1.09419	8.89542	377.058
Compound OT	QUICKSAND	9	2	0.746887	91.8783	52.3605
Compound OT	DRAGONFLY	9	3	0.343568	14.4821	53.3389
Compound OT	JELLYFISH	9	3	0.478007	5.45601	106.166
Compound OT	GREENHOUSE	10	2	4.76514	166.563	670.615
Compound OT	RINGLEADER	10	3	0.466804	76.7538	58.892
Compound OO	EARWIG	6	2	0.115767	62.3688	4.87344
Compound OO	HUMBUG	6	2	3.05103	9.57135	10.7253
Compound OO	BELLHOP	7	2	0.0634854	58.0443	6.06845
Compound OO	DOGWOOD	7	2	0.440663	110.498	106.663
Compound OO	HAYWIRE	7	2	0.130705	21.1817	27.478

				Orthographic Neighbourhood Frequencies		
Condition	Word	Letters	Syllables	Whole Word	Condition	Word
Compound OO	HOGWASH	7	2	0.130705	3.49916	28.6132
Compound OO	LAYOVER	7	3	0.0112033	219.45	1414.08
Compound OO	OFFHAND	7	2	1.22489	732.898	665.741
Compound OO	DUMBBELL	8	2	0.0485476	17.9514	58.0443
Compound OO	FLAPJACK	8	2	0.0672198	4.33568	82.7476
Compound OO	HONEYDEW	8	3	0.145643	23.0228	10.3518
Compound OO	TURNPIKE	8	2	1.74771	227.296	6.47551
Compound OO	HONEYMOON	9	3	4.64564	23.0228	68.2244
Compound OO	MOONSHINE	9	2	1.4639	68.2244	15.3298
Compound OO	OFFSPRING	9	2	12.5477	732.898	97.5434
Compound OO	PANHANDLE	9	3	0.313692	21.3647	43.2074
Compound OO	PINEAPPLE	9	3	1.56846	23.6016	34.4501
Compound OO	SLAPSTICK	9	2	0.231535	5.37758	52.9841
Compound OO	SNAPDRAGON	10	3	0.145643	10.5498	14.4821
Compound OO	BLOCKBUSTER	11	3	0.481742	39.2414	1.01577
Monomorpheme	TOURNIQUET	10	3	0.246473	-	-
Monomorpheme	MANNEQUIN	9	3	0.26141	-	-
Monomorpheme	DANDRUFF	8	2	0.339833	-	-
Monomorpheme	ZEALOT	6	2	0.358506	-	177.587
Monomorpheme	SCALLOP	7	2	0.36224	-	-
Monomorpheme	HIBISCUS	8	3	0.399584	-	-
Monomorpheme	SNUGGLE	7	2	0.418257	4.4253	-
Monomorpheme	MONGOOSE	8	2	0.425725	-	9.53401

				Orthographic Neighbourhood Frequencies		
Condition	Word	Letters	Syllables	Whole Word	Condition	Word
Monomorpheme	PLANKTON	8	2	0.436929	5.79211	7.75642
Monomorpheme	TUNGSTEN	8	2	0.485476	-	-
Monomorpheme	SOPHOMORE	9	2	0.541493	-	2148.61
Monomorpheme	RACCOON	7	2	0.586306	-	-
Monomorpheme	HOROSCOPE	9	3	0.687136	-	20.2854
Monomorpheme	LARYNX	6	2	0.743152	-	-
Monomorpheme	TROMBONE	8	2	0.746887	-	25.9058
Monomorpheme	MALLARD	7	2	0.761824	4.33941	-
Monomorpheme	POLLUTE	7	2	0.765559	-	3.24896
Monomorpheme	MANDOLIN	8	3	0.7917	1429.09	-
Monomorpheme	BROCCOLI	8	3	0.821575	-	-
Monomorpheme	PANCREAS	8	3	0.843982	21.3647	-
Monomorpheme	CHIPMUNK	8	2	0.881326	11.1099	-
Monomorpheme	GIRAFFE	7	2	0.997094	-	-
Monomorpheme	INTIMIDATE	10	4	1.0195	-	151.084
Monomorpheme	PHARMACY	8	3	1.04938	-	-
Monomorpheme	CACKLE	6	2	1.07178	-	-
Monomorpheme	WARLOCK	7	2	1.11286	268.875	28.3966
Monomorpheme	LIMERICK	8	2	1.1278	8.89542	3.9473
Monomorpheme	LEAKAGE	7	2	1.19875	4.08174	204.337
Monomorpheme	CASHMERE	8	2	1.20622	52.3642	-
Monomorpheme	SUMMARIZE	10	3	1.22489	49.2833	-
Monomorpheme	MOTIVATE	8	2	1.23236	-	30.2564

				Orthographic Neighbourhood Frequencies		
Condition	Word	Letters	Syllables	Whole Word	Condition	Word
Monomorpheme	SYRINGE	7	2	1.35186	-	-
Monomorpheme	SAPLING	7	2	1.38921	4.62696	-
Monomorpheme	GAZELLE	7	2	1.48257	39.2228	-
Monomorpheme	SHRAPNEL	8	2	1.52365	-	-
Monomorpheme	PORCUPINE	9	3	1.57967	-	23.6016
Monomorpheme	THROTTLE	8	2	1.85975	-	-
Monomorpheme	CATALOG	7	2	1.92323	-	21.9809
Monomorpheme	TATTOO	6	2	2.039	-	850.502
Monomorpheme	BANTER	6	2	2.06514	13.668	-
Monomorpheme	ANTHEM	6	2	2.1361	6.0087	4.59709
Monomorpheme	OSTRICH	7	2	2.20332	-	108.205
Monomorpheme	WITHER	6	2	2.39377	20.741	5760.61
Monomorpheme	BAYONET	7	3	2.41244	-	69.5688
Monomorpheme	CARROT	6	2	2.44232	161.316	7.05434
Monomorpheme	BRACELET	8	2	2.56556	5.27675	510.378
Monomorpheme	VIBRANT	7	2	2.61784	-	0.687136
Monomorpheme	ADDICTION	9	3	2.71867	0.870123	3.08838
Monomorpheme	CARBONATE	9	3	2.75601	14.9377	30.2564
Monomorpheme	BUCKLE	6	2	2.97634	-	-
Monomorpheme	CRIPPLE	7	2	2.97634	-	-
Monomorpheme	VANTAGE	7	2	3.14813	-	204.337
Monomorpheme	TRESPASS	8	2	3.24149	-	131.837
Monomorpheme	CANARY	6	3	3.24522	1735.33	-

				Orthographic Neighbourhood Frequencies		
Condition	Word	Letters	Syllables	Whole Word	Condition	Word
Monomorpheme	SEWAGE	6	2	3.54024	2.99502	204.337
Monomorpheme	TAPESTRY	8	3	3.65228	15.117	-
Monomorpheme	ECLIPSE	7	2	3.66348	-	-
Monomorpheme	STADIUM	7	3	3.839	-	-
Monomorpheme	BARROW	6	2	3.96223	64.2173	46.2846
Monomorpheme	ACCOUNTANT	10	3	4.23858	169.315	6.0087
Monomorpheme	JASMINE	7	2	4.33568	-	134.634
Monomorpheme	PATERNAL	8	3	5.03402	15.8191	-
Monomorpheme	PHOENIX	7	2	5.11991	-	-
Monomorpheme	MALICIOUS	9	3	5.33277	-	-
Monomorpheme	PIRATE	6	2	5.35891	-	30.2564
Monomorpheme	PRONOUNCE	9	2	5.40746	-	4.99667
Monomorpheme	DRAINAGE	8	2	5.45227	7.7975	204.337
Monomorpheme	STOCKING	8	2	5.45974	68.3775	-
Monomorpheme	CONSOLE	7	2	5.64646	9.4892	25.6593
Monomorpheme	BITTEN	6	2	5.7585	202.037	228.962
Monomorpheme	SYNTHESIS	8	3	6.38215	-	7.62198
Monomorpheme	GINGER	6	2	6.69584	7.90953	-
Monomorpheme	TEXTURE	7	2	6.69957	100.18	-
Monomorpheme	EXPLORING	9	3	7.56223	-	76.7538
Monomorpheme	FANTASY	7	3	8.17467	16.6593	-
Monomorpheme	TEMPEST	7	2	8.2531	-	3.36472
Monomorpheme	AMBULANCE	9	3	8.35393	-	6.34107

				Orthographic Neighbourhood Frequencies		
Condition	Word	Letters	Syllables	Whole Word	Condition	Word
Monomorpheme	GENETIC	7	3	9.07467	11.3153	0.567634
Monomorpheme	ATTRIBUTE	9	3	9.80289	-	-
Monomorpheme	WARRIOR	7	3	11.3938	268.875	-
Monomorpheme	PATHETIC	8	3	13.1826	89.9924	-
Monomorpheme	TROPICAL	8	3	13.2012	-	-
Monomorpheme	CONCLUDE	8	2	13.2199	9.4892	-
Monomorpheme	BALLOON	7	2	13.6531	-	1.18008
Monomorpheme	TURKEY	6	2	14.7249	-	92.416
Monomorpheme	AUTOMATIC	9	4	14.863	4.57095	-
Monomorpheme	ADMIRE	6	2	15.5464	32.3663	3.39087
Monomorpheme	RANDOM	6	2	16.7713	146.304	-
Monomorpheme	DEFINE	6	2	17.4585	-	-
Monomorpheme	ULTIMATE	8	3	19.251	-	25.2037
Monomorpheme	CHAMPION	8	3	19.4415	1.62448	3.08838
Monomorpheme	SCARLET	7	2	19.8448	4.71659	510.378
Monomorpheme	ACCURATE	8	3	19.9157	-	132.557
Monomorpheme	CATHEDRAL	9	3	20.2966	-	-
Monomorpheme	MINIMUM	7	3	23.8705	7.85351	30.2489
Monomorpheme	BRIEFLY	7	2	24.9572	0.380912	53.3389
Monomorpheme	EARNEST	7	2	25.958	62.3688	25.3307
Monomorpheme	ILLNESS	7	2	26.4062	111.04	-
Monomorpheme	OBSERVE	7	2	27.0373	-	-
Monomorpheme	REALIZE	7	3	32.1908	221.698	-

				Orthographic Neighbourhood Frequencies		
Condition	Word	Letters	Syllables	Whole Word	Condition	Word
Monomorpheme	ASHAMED	7	2	32.2319	12.0062	-
Monomorpheme	DIGNITY	7	3	33.9871	-	-
Monomorpheme	CONSENT	7	2	35.1933	9.4892	213.722
Monomorpheme	TRAFFIC	7	2	35.2829	-	-
Monomorpheme	TARGET	6	2	36.6049	5.54937	961.706
Monomorpheme	MANAGE	6	2	38.2891	1429.09	204.337
Monomorpheme	PROVISION	9	3	42.4344	24.6958	55.5385
Monomorpheme	TENDER	6	2	43.7302	228.962	-
Monomorpheme	CAPABLE	7	3	48.4319	36.0335	258.905
Monomorpheme	FOUNDATION	10	3	56.4348	630.847	-
Monomorpheme	FORTUNE	7	2	59.075	8722.1	
Monomorpheme	PRESSURE	8	2	68.2318	-	321.938
Monomorpheme	ACCEPT	6	2	84.1704	-	-
Monomorpheme	BEAUTY	6	3	108.086	-	-
Monomorpheme	SUCCESS	7	2	114.009	-	-
Monomorpheme	WONDER	6	2	114.345	80.2007	-
Monomorpheme	PLEASURE	8	2	114.513	9.53401	321.938
Monomorpheme	AFRAID	6	2	122.306	-	9.74314
Monomorpheme	WINDOW	6	2	168.64	71.1335	-
Monomorpheme	SUPPOSE	7	2	181.796	3.18174	9.48173

Appendix B: Nonword Stimulus Set

Stimulus Set Nonwords with their Lengths and Syllables

Condition	Word	Letters	Syllables
Compound	BRIEFTAX	8	2
Compound	CLEANMIP	8	2
Compound	THERNLOW	8	2
Compound	SPILKWUT	8	2
Compound	TOPDRUG	8	2
Compound	REDBLIN	7	2
Compound	HOMRANK	7	2
Compound	RADMOSH	7	2
Compound	HEARFEW	7	2
Compound	HALLWUB	7	2
Compound	GURMDAY	7	2
Compound	VASHPON	7	2
Compound	FLOWGUN	7	2
Compound	FLATBEW	7	2
Compound	BELFHIT	7	2
Compound	HALDNEG	7	2
Compound	LOTCOOL	7	2
Compound	ASKTARP	7	2
Compound	NASFUND	7	2
Compound	ERKFAND	7	2
Compound	ODDHARD	7	2
Compound	SUNWOLL	7	2
Compound	ORKTYPE	7	2
Compound	BIXMOOK	7	2
Compound	TOASTPULL	9	2
Compound	SPELLCUNG	9	2
Compound	FLURBPAIR	9	2
Compound	THRIMNADE	9	2
Compound	FORMMIND	8	2
Compound	BESTPILT	8	2
Compound	TOOPCASE	8	2
Compound	GINDTREM	8	2
Compound	DUSTWORTH	9	2

Condition	Word	Letters	Syllables
Compound	FOOTMILGE	9	2
Compound	TROWBREAK	9	2
Compound	MOWDFLISK	9	2
Compound	GASBAY	6	2
Compound	OILRAD	6	2
Compound	LISFAT	6	2
Compound	ROGCHY	6	2
Monomorpheme	FOSTEN	6	2
Monomorpheme	BANGUL	6	2
Monomorpheme	TEAREN	6	2
Monomorpheme	ROFFLE	6	2
Monomorpheme	GRENCH	6	2
Monomorpheme	HELPRE	6	2
Monomorpheme	DEBUINE	7	2
Monomorpheme	MIDMER	6	2
Monomorpheme	CONCOVER	8	3
Monomorpheme	MASTION	7	3
Monomorpheme	IMPECULATE	10	4
Monomorpheme	AUTHEBRIATE	11	4
Monomorpheme	ATHORATE	8	3
Monomorpheme	NANTOCK	7	2
Monomorpheme	RUNCOWL	7	2
Monomorpheme	PARLEEN	7	2
Monomorpheme	TEMBLE	6	2
Monomorpheme	TOTTLE	6	2
Monomorpheme	WANBASH	7	2
Monomorpheme	HETTOM	6	2
Monomorpheme	LISTOP	6	2
Monomorpheme	SONTARE	7	2
Monomorpheme	DEBAND	6	2
Monomorpheme	MESMIER	7	2
Monomorpheme	RUTSINIC	8	3
Monomorpheme	ANPIRE	6	2
Monomorpheme	MENNISE	7	2
Monomorpheme	PANCOR	6	2
Monomorpheme	REDUOUS	7	3
Monomorpheme	HASSURE	7	2

Condition	Word	Letters	Syllables
Monomorpheme	STRUCE	6	2
Monomorpheme	ARBAND	6	2
Monomorpheme	ERUSANT	7	3
Monomorpheme	COSEER	6	2
Monomorpheme	WOUGHT	6	2
Monomorpheme	STROPE	6	2
Monomorpheme	PENFRAND	8	2
Monomorpheme	BISHION	7	2
Monomorpheme	EVERPOL	7	3
Monomorpheme	TORROW	6	2
Monomorpheme	BROMUS	6	2
Monomorpheme	LARBET	6	2
Monomorpheme	CORAND	6	2
Monomorpheme	BENALK	6	2
Monomorpheme	SUMBTION	8	2
Monomorpheme	DRATSICAL	9	3
Monomorpheme	TUNILOUS	8	3
Monomorpheme	LOMPLE	6	2
Monomorpheme	DEBORN	6	2
Monomorpheme	SUNCHEL	7	2
Monomorpheme	MOTUSE	6	2
Monomorpheme	NOMETY	6	3
Monomorpheme	RETOFT	6	2
Monomorpheme	FOLLAP	6	2
Monomorpheme	TELLOW	6	2
Monomorpheme	ORNEEL	6	2
Monomorpheme	AIRUST	6	2
Monomorpheme	FOMAND	6	2
Monomorpheme	HOSENT	6	2
Monomorpheme	TURPOD	6	2
Monomorpheme	TORWAD	6	2
Monomorpheme	TOSSERATE	9	3
Monomorpheme	FALINRAN	8	3
Monomorpheme	ANGEST	6	2
Monomorpheme	ARBIST	6	2
Monomorpheme	SPESTIC	7	2
Monomorpheme	FLOUCH	6	2

Condition	Word	Letters	Syllables
Monomorpheme	ALSAVE	6	2
Monomorpheme	INSANCE	7	2
Monomorpheme	RUSSAGE	7	2
Monomorpheme	EXPLOM	6	2
Monomorpheme	WASTLE	6	2
Monomorpheme	HOUPER	6	2
Monomorpheme	TONALL	6	2
Monomorpheme	SPERANE	6	2
Monomorpheme	BODDLE	6	2
Monomorpheme	RUNSTER	7	2
Monomorpheme	SWAGMITE	8	2
Monomorpheme	HEISNER	7	2

Appendix C: Linear Mixed Effects Model Structures

Table C1. Experiment 1 Model Structures

Experiment 1: Letter Detection Task
Reaction time
RT_1 ~ transparency + previous_trial_RT + (1|subjects) + (1|items) + random error
Accuracy
ACC_1 ~ transparency*word_length + (1|subjects) + (1|items) + random error
Eye Tracking: Modifier Fixation Count
MFC_1 ~ transparency + presentation + word_length + orthographic_frequency + (1|subjects) + (1|items) + random error
Eye Tracking: Head Fixation Count
HFC_1 ~ transparency + orthographic_frequency + (1|subjects) + (1|items) + random error
Eye Tracking: Modifier First Fixation Duration
$MFFD_1$ ~ word_length + (1|subjects) + (1|items) + random error
Eye Tracking: Head First Fixation Duration
$HFFD_1$ ~ word_length + previous_trial_RT + (1|subjects) + (1|items) + random error
Eye Tracking: Modifier Second Fixation Duration
$MSFD_1$ ~ word_length + (1|subjects) + (1|items) + random error
Eye Tracking: Head Second Fixation Duration
$HSFD_1$ ~ transparency*presentation + (1|subjects) + (1|items) + random error

Table C2. Experiment 2 Model Structures

Experiment 2: Lexical Decision Task
Reaction time
RT_2 ~ transparency*presentation + previous_trial_RT + orthographic_frequency + age_of_acquisition + (1|subjects) + (1|items) + random error

Accuracy

ACC_2 ~ transparency*presentation + syllables + age_of_acquisition + (1|subjects) + (1|items) + random error

Eye Tracking: Modifier Fixation Count

MFC_2 ~ presentation + RT + orthographic_frequency + (1|subjects) + (1|items) + random error

Eye Tracking: Head Fixation Count

HFC_2 ~ transparency + RT + (1|subjects) + (1|items) + random error

Eye Tracking: Modifier First Fixation Duration

$MFFD_2$ ~ transparency + word_length + RT + (1|subjects) + (1|items) + random error

Eye Tracking: Head First Fixation Duration

$HFFD_2$ ~ word_length + (1|subjects) + (1|items) + random error

Eye Tracking: Modifier Second Fixation Duration

$MSFD_2$ ~ transparency + word_length + age_of_acquisition + (1|subjects) + (1|items) + random error

Eye Tracking: Head Second Fixation Duration

$HSFD_2$ ~ transparency + RT + orthographic_frequency + word_length + (1|subjects) + (1|items) + random error

Table C3. Experiment 3 Model Structures

Experiment 3: Semantic Categorization

Reaction time

RT_3 ~ transparency + age_of_acquisition + (1|subjects) + (1|items) + random error

Accuracy

ACC_3 ~ transparency + age_of_acquisition + (1|subjects) + (1|items) + random error

Eye Tracking: Modifier Fixation Count

MFC_3 ~ transparency + orthographic_frequency + syllables + previous_trial_RT + (1|subjects) + (1|items) + random error

Eye Tracking: Head Fixation Count

HFC_3 ~ transparency + concreteness + (1|subjects) + (1|items) + random error

Eye Tracking: Modifier First Fixation Duration

$MFFD_3$ ~ presentation + word_length + (1|subjects) + (1|items) + random error

Eye Tracking: Head First Fixation Duration

$HFFD_3$ ~ orthographic_frequency + (1|subjects) + (1|items) + random error

Eye Tracking: Modifier Second Fixation Duration

$MSFD_3$ ~ presentation + word_length + age_of_acquisition + trial_number + (1|subjects) + (1|items) + random error

Eye Tracking: Head Second Fixation Duration

$HSFD_3$ ~transparency + (1|subjects) + (1|items) + random error

Table C4. Experiment 4 Model Structures

Experiment 4: Word Relatedness Task

Reaction time

RT_4 ~ transparency*presentation + previous_trial_RT + age_of_acquisition + (1|subjects) + (1|items) + random error

Accuracy

ACC_4 ~ transparency*presentation + RT + age_of_acquisition + (1|subjects) + (1|items) + random error

Eye Tracking: Modifier Fixation Count

MFC_4 ~ transparency*presentation + age_of_acquisition (1|subjects) + (1|items) + random error

Eye Tracking: Head Fixation Count

HFC_4 ~ transparency*presentation + word_length + RT + concreteness + (1|subjects) + (1|items) + random error

Eye Tracking: Head First Fixation Duration

$HFFD_4$ ~ transparency*presentation + syllables + (1|subjects) + (1|items) + random error

Eye Tracking: Modifier Second Fixation Duration

$MSFD_4$ ~ transparency*presentation + correct_response + (1|subjects) + (1|items) + random error

Eye Tracking: Head Second Fixation Duration

$HSFD_4$ ~ transparency*presentation + (1|subjects) + (1|items) + random error

Appendix D: Eye Tracking Additional Variables

Table D1. Experiment 1 Additional Statistical Values

Eye Tracking Component	Variable(s)	b	SE	z / t	p
Modifier: FC	Word Length	.055	.015	3.551	< .001
	Orthographic Frequency	-.069	.028	-2.496	.013
Head: FC	Orthographic Frequency	.099	.046	2.140	.032
Modifier: FFD	Word Length	-11.808	4.262	-2.771	.006
Head: FFD	Word Length	-3.433	4.371	-2.158	.032
	Previous Trial Reaction Time	-93.631	46.690	-2.005	.045
Modifier: SFD	Word Length	-15.409	4.729	-3.258	.001
Head: SFD	-	-	-	-	-

Note: Fixation Count (FC), First Fixation Duration (FFD) and Second Fixation Duration (SFD) are abbreviated

Table D2. Experiment 2 Additional Statistical Values

Eye Tracking Component	Variable(s)	b	SE	z / t	p
Modifier: FC	Orthographic Frequency	-.132	.064	-2.063	.039
	Reaction Time	.632	.079	7.977	< .001
Head: FC	Reaction Time	.546	.089	6.172	< .001
Modifier: FFD	Word Length	-16.757	3.626	-4.622	< .001
	Reaction Time	94.399	28.441	3.319	< .001
Head: FFD	Word Length	-7.960	2.659	-2.994	.003
Modifier: SFD	Word Length	-9.692	4.009	-2.418	.016
	Age of Acquisition	-7.629	2.327	-3.278	.001
Head: SFD	Reaction Time	89.461	25.853	3.460	< .001
	Orthographic Frequency	13.962	6.547	2.133	.034
	Word Length	-8.247	3.713	-2.221	.027

Note: Fixation Count (FC), First Fixation Duration (FFD) and Second Fixation Duration (SFD) are abbreviated

Table D3. Experiment 3 Additional Statistical Values

Eye Tracking Component	Variable(s)	b	SE	z / t	p
Modifier: FC	Orthographic Frequency	-.092	.026	-3.448	< .001
	Syllables	.108	.036	3.024	.003
	Previous Trial Reaction Time	.116	.047	2.481	.013
	Reaction Time	1.335	.046	29.198	< .001
Head: FC	Concreteness	-.230	.059	-3.899	< .001
Modifier: FFD	Word Length	-17.930	3.750	-4.780	< .001
Head: FFD	Orthographic Frequency	9.990	3.897	2.563	.011
Modifier: SFD	Word Length	-14.390	3.462	-4.157	< .001
	Trial Number	-.254	.111	-2.280	.023
	Age of Acquisition	-4.430	2.012	-2.202	.029
Head: SFD	-	-	-	-	-

Note: Fixation Count (FC), First Fixation Duration (FFD) and Second Fixation Duration (SFD) are abbreviated

Table D4. Experiment 4 Additional Statistical Values

Experiment Component	Variable(s)	b	SE	z / t	p
Modifier: FC	Age of Acquisition	.023	.012	1.965	.049
Head: FC	Word Length	-.066	.026	-2.564	.010
	Reaction Time	.943	.109	8.689	< .001
	Concreteness	-.128	.060	-2.135	.033
Modifier: FFD	-	-	-	-	-
Head: FFD	Syllables	-24.915	10.073	-2.474	.015
Modifier: SFD	Correct/Incorrect	-45.847	16.445	-2.788	.005
Head: SFD	-	-	-	-	-

Note: Fixation Count (FC), First Fixation Duration (FFD) and Second Fixation Duration (SFD) are abbreviated

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