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Effects of reading comprehension and fluency abilities on the N400 event-related potential

Annie Hirt Nelson
University of South Florida

Effects of Reading Comprehension and Fluency Abilities on the N400

Event-Related Potential

by

Annie Hirt Nelson

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Major Professor: Mary Lou Morton, Ph.D.
Jacqueline Hinckley, Ph.D.
Jim King, Ed.D.
Richard Marshall, Ph.D.

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Dedication

I dedicate this dissertation to my husband Donnie, and my parents whose

support has been invaluable. I would not have been able to complete this without

you!

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I would like to thank Dr. Mary Lou Morton, for her gentle guidance, and her beliefs in my abilities to complete this dissertation. I would also like to thank all my committee members, who guided and supported me through this process. A very special thanks goes out to Dr. Nathan Maxfield for the time he took to help me. Finally, I would like to thank Justine VanDyke, my research partner.

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Abstract

The purpose of this study is to add to the knowledge of reading development by investigating reading processes from a neurocognitive and educational perspective. This study seeks to provide some insight about reading development for the neuroscience field. The goals of this study are to attain a clearer picture of reading development by using both behavioral assessments and event-related potentials (ERPs), and to begin to bridge the gap between both fields of study. Children between the ages of 7 and 13 were placed in one of two groups depending on their reading comprehension levels for the first analyses, and reading fluency levels for the second analyses. Children were asked to read active, active violation, passive and passive violation sentences, that had been manipulated to contain primed semantic context. Brain waves were recorded during the task. Repeated measures ANOVAS were used to analyze the mean N400 like amplitudes for the groups for the sentence ending target words. The lower fluency group had the largest amplitudes for all sentence types even though the sentences were two grade levels below their actual fluency levels; decoding and reading rate were not a problem for them in the reading task. Also, the lower fluency group processed the anomalous sentences very differently than

the lower comprehension group whose average age was close to the same. Other N400 like amplitudes differences among the groups were observed. Implications for reading education consist of reintroducing the sentence processing exercises back into the classroom instruction in order to improve reading comprehension skills among fluent readers with comprehension problems.

Chapter I:

Introduction

Reading problems are a major concern of schools today. According to the

National Center for Education Statistics (National Center for Education Statistics

[NCES], 2007), 33% of the nation's fourth graders, and 26 % of the nation's 8th

graders attending public schools cannot read at a basic level. Also, of those 12th

graders who do not drop out of high school, 27% cannot read at the basic level

(NCES, 2005). A student reading at the basic level has partial mastery of the

skills necessary for proficient work at grade level; a student reading at the

proficient level is able to demonstrate competency over challenging grade level

material, and the advanced level depicts a student whose performance is

superior (The Nations Report Card, 2007). Not only is there a high percentage of

students who cannot read even at the basic level, those reading at the basic

level, 34%, 43%, and 37% respectively (NCES, 2007; 2005) have still not

acquired mastery of the reading skills needed to be proficient at their level of

school work.

Many fluent readers confront comprehension difficulties when texts

become more difficult as in the reading-to-learn stage vs. learning-to-read stage

(Chall, 1996). The reading-to-learn stage normally begins in the fourth grade,

and it is at this level when many young readers without a history of reading

problems suddenly develop them; this phenomenon is generally described as the fourth grade slump. This slump has been investigated over decades of research, and reasons to why this occurs include socio-economic reasons (Chall & Jacobs, 2003), language deficits (Cain & Oakhill, 2006; Gough & Tunmer, 1986) and poor instruction (Hirsch, 2006). While the above- mentioned reasons may contribute to this slump, it has also been noted that fourth grade texts commonly use sentences that are more complex than to what these readers are accustomed (Scott, 2004; Deane, Sheehan, & Sabatini et al., 2006). It is also important to note that reading tests that assess reading proficiency levels also use more complex sentences as well as passive structures starting around their fourth grade level passages (e.g. Gray Oral Reading Test-4). While these readers may be able to read all the words fluently, the information they are gathering while reading may be muddled and not make sense to them due the unfamiliar syntactic structures used in the texts.

Most poor readers never catch up to grade level over the years (Stanovich, 1986, Lyon, 2002). In today's post-industrial, high-tech age, it has become increasingly important to be literate due to the decrease of jobs that do not require literacy skills and the increase in jobs that do. Researchers and educators are constantly studying ways to help students become better readers.

There are many reasons for the development of reading problems. Brain research studies (e.g. Deutch et al. 2005; Shaywitz et al., 2004), speech and language studies (e.g. Cain and Oakhill, 2006; Walzman &Cairns, 2000; McDonald, 2008, Bishop & Adams, 1990), ethnographic studies (e.g. Heath,

1990/2004, Heath 1983; Taylor& Dorsay-Gaines, 1988; Skilron-Sylvester, 2002; Rubinstein-Avila, 2007), and studies investigating the roles of different reading processes on comprehension (e.g. Klauda & Guthrie, 2008; Miller & Schwanenflugel, 2008) have studied different types of readers to explain reading difficulties.

The purpose of this study is to add to the knowledge of reading development by investigating reading processes from a neurocognitive and educational perspective. The relationship between both fields can be complementary since educational researchers study reading practices and the effect of learning materials (e.g. books) on students' learning and develop theories and models based on the success or failure of strategies and learning materials, and neurocognitive studies of reading can provide information that can further test theories and models of reading by measuring brain activity during cognitive tasks. The goals are to attain a clearer picture of reading development by using both behavioral assessments and event-related potentials (ERPs), and to begin to bridge the gap between both fields of study. The theoretical perspective will encompass an interactive view of reading (Allington, 2006; Rumelhart, 1994/2004) and results will be analyzed using an interactive model.

Researchers have developed a variety of reading models to hypothesize different processes and factors that contribute to reading, and to explain how issues with some factors can make reading difficult for some individuals. Some reading models describe these processes as linear in nature with one being processed before the other (Gough, 1972; NRP, 2000; Pressley, 2006; Rand

Reading Study Group; 2002; Smith, 2004; Snow et al., 1998) while others believe that many reading processes occur simultaneously (Allington, 2006; Rumelhart, 1994/2004).

Reading Models

Researchers commonly use the following three models in reading research, however, it is important to note that reading research is not limited to these three types of models and that there are many variations to these models.

Bottom-up view. Bottom-up models organize reading as a linear process. The process begins at the letter level (lower level) before higher order processes can take place (such as meaning making). Samuels (1994/2004) explains that first the printed word must be decoded and then the decoded words must be comprehended. The more automatic the decoding process becomes, the more cognitive resources are available for comprehension. Samuels (1994/2004) emphasizes the importance of attention, whether used to decode or to comprehend written text. However, he concludes that attention can only be given to one process at a time. A reader cannot focus on decoding, and expect to comprehend. If decoding is automatic, then the attention can focus on comprehension.

Although the National Reading Panel ([NRP], 2000) emphasizes a balanced approach to reading instruction (phonics and meaning making, they also support Samuels' (1994/2004) view about reading fluency and automaticity. They state the importance of systematic phonemic awareness instruction that develops the ability to hear and manipulate sounds in words, and systematic

phonics instructions to develop sound/symbol associations. Once students become good decoders (hopefully by second grade), and have a sufficient amount of sight words in their memory, reading becomes more automatic leading to reading fluency; fluency then leads to comprehension. It is important to note that the NRP does not include comprehension in their definition of fluency; they claim that comprehension is a result of fluency (Pikulski & Chard, 2005).

Like Samuels (1994/2004), the NRP (2000) states that reading fluency frees up cognitive resources so that readers can focus their attention on meaning, however, they also believe that fluency includes the ability to group words appropriately into meaningful grammatical units (e.g. syntax). They assert that problems with reading accuracy occur due to the accumulation and inefficient processing of basic cognitive tasks such as letter sound correspondence, and these lower level processes use up resources that could otherwise be used for comprehension,

The NRP (2000) explains:

> The reader must recognize the printed word (decoding) and construct meaning from the recognized words (comprehension).…. At any given moment, the amount of cognitive resources available for these two tasks is restricted by the limits of memory. If the word recognition task is difficult, all available cognitive resources may be consumed by the decoding task, leaving little or nothing for use in interpretation. (p. 3-8)

The Rand Reading Study Group (2002) further described how reading comprehension occurs:

…accurate and fluent (automatic) word recognition is a prerequisite for

adequate reading comprehension and that language comprehension

processes and higher level processes affecting language comprehension

(applying word knowledge, reasoning, etc.) do not become fully operative

in comprehending text until the child has acquired such facility. (p.82)

The above-mentioned descriptions of reading processes are the reason

that some of the references in this study are considered bottom-up. It is important

to note that not all bottom-up views and models are as clear cut as Gough's

(1972) model, and some reading researchers may not agree with the

classification of some of the views and models this author considers to be

bottom-up. While they may seem to be interactive, the separation of the skills

that lead to fluency and then to comprehension during reading, as well as the

reasons they state readers lack fluency (decoding issues), is why they are

considered bottom-up views.

Top-down view. Top-down models also view reading as a linear process.

However, the emphasis is on the reader's background knowledge (e.g. world

knowledge) and what they bring to the reading task and to comprehension.

Smith's (2004) top-down view states that readers do not worry about specific

letters or words when they read. Instead, they automatically begin reading by

looking for meaning. Smith defines reading as "…all matters of activities when we

endeavor to make sense of circumstances; it's original meaning was

interpretation" (p.2). Reading written text is simply a special use of the term

"reading" For example one can also "read" faces to figure out someone's mood.

Top–down models do not represent reading as starting at the letter or even word level. Higher order processes, such as the application of background knowledge (e.g. from experiences to text organization) lead the reader to make sense of the words and sentences being read; higher order processes aid lower level processes when making sense of text. Fluent reading of every word in a text is not necessary for comprehension to take place (Pressley, 2006).

Interactive view. Unlike bottom-up and top-down views of reading, interactive models portray reading as a non-linear process and as bi-directional. Rumelhart (1994/2004) explains that skilled readers use sensory, syntactic, semantic, and pragmatic information to read, and these information sources (also known as knowledge sources) interact and depend on each other during the process of reading comprehension.

Rumelhart's interactive model (1994/2004) consists of a visual information store (VIS); graphemic input goes into the VIS. This information then goes into a feature extraction device where critical features from the VIS are extracted. The features then go into a pattern synthesizer. The pattern synthesizer uses all knowledge sources, sensory and nonsensory, to produce a "most probable interpretation" (pg. 1163) of the graphemic input. All the knowledge sources come together in one place, and "the reading process is the simultaneous joint application of all the knowledge sources" (p. 1164). Top-down and bottom-up processes are being applied at the same time. It is also important to note that hypotheses (or propositions) can be made at any level (feature, letter, letter cluster, lexical, and syntactic levels). If a hypothesis has to be rejected, then

another level of processing takes over (higher or lower) until the right hypothesis is made. One can surmise that if hypotheses are constantly rejected at any level, reading fluency and ultimately reading comprehension can be affected.

Allington (2006) states that fluency breaks down for a variety of reasons. For example, the degree of familiarity with the topic being presented may lead to difficulty with word pronunciations as well as the ability to understand the word meanings. Fluency difficulties may also stem from poorly organized information. On the other-hand, he explains that some children exhibit non-fluent reading behaviors even when reading about a familiar topic, and word familiarity and pronunciation are adequate. In these types of situations, lack of reading fluency is not due to decoding issues; interactive views of reading can be used to explain the possible reasons for the fluency break down. For example, a good decoder who has knowledge of the text subject, but is still reading non-fluently, may have issues with syntactic and/or semantic processes as well as have language deficits.

As mentioned earlier, it is important to note that syntactic processes allow for prediction of upcoming words as well as meaning making. Based on interactive theories of reading, syntactic and semantic processes occur together, and rely on each other when making sense of the text. Furthermore, syntactic awareness may enable readers to monitor their comprehension process more effectively, and this awareness can also help children acquire word recognition skills (Tunmer, Herriman, & Nesdale, 1988). This paper will view reading from an interactive perspective.

Statement of the Problem

Reading fluency has been described as the bridge between decoding and comprehension (National Reading Panel, 2000; Pikulski & Chard, 2005; Samuels 1994/2004). Research studies show a strong correlation between fluency and comprehension (Pinnell, Pikulski, & Wixson et al., 1995; Stanovich, 1986; Daane, Cambell, Grigg, Goodman, & Oranje, 2005; Rasinski et al., 2005). However there are unexplained variances in comprehension scores in many of these studies that fluency alone does not explain (Klauda & Guthrie, 2008, Miller & Schwanenflugel, 2008), especially since fluency measures normally consist of only reading rate and accuracy. Due to these unexplained variances, there is interest in the role of syntactic and semantic processes, and their contribution to fluency and reading comprehension (Klauda & Guthrie, 2008).

In this paper, I will view syntax similarly to the way Scott (2009) views it:

…I see syntax as a vehicle, even "workhorse," of meaning. As such, it is also a vehicle (not the only one, but a major one) for acquiring the knowledge base needed for reading comprehension. If this vehicle is flawed, it will not transport the knowledge very well. (p.185)

It is important to note that this view sees syntactic and semantic processes as coexisting and simultaneously working off each other. Semantic and syntactic processes help the construction of meaning from the text by enabling the reader to hypothesize, or make predictions, about the way the sentence is constructed, and make meaning of unfamiliar words (Oakhill & Cain, 2007; Rumelhart, 1994/2004). Readers with good syntactic awareness can utilize

sentence context clues to predict words that will come next in the text, in turn they are able to monitor their comprehension (meaning making), or lack of, of the text (Tunmer, Herriman, & Nesdale, 1988). Readers also use context clues to decipher and make meaning of unfamiliar words. Together, syntactic and semantic processes contribute to meaning making when reading (Kuhn & Stahl, 2003).

The subject of semantic and syntactic contributions in reading and learning to read is a topic of controversy and has been investigated in many fields, from reading education to neuroscience. Even though research about syntactic processing, semantic processing, and reading comprehension has been conducted over two decades, the relationship among these reading processes is still not clear (Cain, 2007; Scott, 2009).

The contribution of syntactic and/or semantic processes to the act of reading has been investigated using a variety of behavioral assessments (Bishop & Adams, 1990, Cain & Oakhill, 2006, Klauda & Guthrie, 2008; Cairns, Schlisselberg, Walzman, & McDaniel, 2006; Cain, Oakhill, & Elbro, 2003), as well as with electrophysiological testing (Hahne, Eckstein, & Friederici, 2004; Kim & Osterhout, 2005; Yamada & Neville, 2007). Investigation of the nature of these processes is important in the field of reading education due to the variety of reasons that some children fall behind their peers in reading achievement and to help them become better readers. It is important to discover the reasons why some students struggle with reading comprehension, when other factors leading

to reading problems are controlled (e.g. SES, language learning, discourse, phonological skills) so educators can remediate these students.

Furthermore, Cutting and Scarborough (2006) stated:

…gains have not always been greater for students trained in bottom-up skills than for students whose instruction placed less emphasis on decoding and phonological processing as would be predicted if bottom-up skills were the only, or predominant, factor contributing to comprehension…(p. 279)

Cunningham and Stanovich (1998) explained:

As skill develops and word recognition becomes less resource demanding and more automatic, more general language skills such as vocabulary, background knowledge, and familiarity with complex syntactic structures etc. become the limiting factors on reading ability. (p. 1)

However, many teachers use bottom-up instructions with students who already read fluently, especially since the NRP (2000) supports this kind of instruction. Also, as mentioned earlier, many researchers and educators see fluency as the bridge between decoding and comprehension, however this bridge still needs some restructuring in order to get fluent readers to comprehend. While meta-cognitive strategy instruction can help many of these readers (Pressley, 2005; Boulware-Gooden, Carreker, & Thornhill et al., 2007), some comprehension deficits have been associated with weaknesses in vocabulary, syntactic skills, and even sentence level understanding (Velluntino, Tunmer, Jaccard & Chen, 2007).

Focusing on the sentence level, Scott (2009) points out that the importance of sentence comprehension has been overlooked in reading education; very little attention has been given to the role of sentence comprehension and their effect on overall text comprehension.

Scott explains that the sentence:

…is a culprit for some readers and is commonly overlooked when thinking about improving reading comprehension and content knowledge. If a reader cannot derive meaning from individual sentences that make up a text, that is going to be a major obstacle in text level comprehension… (p. 184)

Theoretical Basis of the Study

Fluency has traditionally been defined as the speed and accuracy of reading; many behavioral reading assessments continue to use these components in their formulas that determine fluency levels such as the Gray Oral Reading Test-4 (Wiederholt & Bryant, 2001) and The Qualitative Reading Inventory-3 (Leslie & Caldwell, 2006). However, many researchers consider prosodic features of language, such as appropriate expression, pitch changes, pause placements, and phrasing to be important components of reading fluency (Dowhower, 1991; Klauda &Guthrie, 2008; Kuhn & Stahl, 2003; NRP, 2000). Studies have shown that there is a correlation between readers who read with the above-mentioned components of prosody and their reading skill level (Miller & Schwanenflugel, 2006; Klauda & Guthrie, 2008; Dowhower, 1991; Schwanenflugel, Hamilton & Kuhn et al., 2004). However, assessments that

measure prosody are controversial due to the subjective manner of scoring them. Nevertheless, what we can learn from these studies is that in addition to reading with expression, prosodic reading also includes appropriately chunking groups of words together into meaningful units using the syntactic structure of the text (Kuhn & Stahl, 2003; Miller & Schwanenflugel, 2008). The ability to do this signifies that the reader understands what they are reading. These prosodic features contribute to meaning making (semantic processes). When reading educators refer to fluency, they refer to all of the above-mentioned components; speed, accuracy and prosody.

Additionally, a number of studies suggest that semantic and syntactic processes develop over time, and differences in semantic and syntactic processing occur due to age (Wang, Dong, Ren, & Yang, 2009; Atchley, Rice, Betz et al., 2006). It is important to note that many of these studies attribute age to explain these differences and not necessarily language proficiency and/or reading comprehension levels. While age is correlated with language and reading skill levels (Chall, 1994; Curtis, 1980; Torgesen, Wagner, & Rashotte, 1994) there is variability among these components. For example, some children can read at higher levels than the rest of their peers and vice versa. While syntactic and semantic processes may very well develop over time, the nature of these processes related to reading comprehension levels need to be further investigated in order to develop reading strategies to help students progress in reading and become at least proficient at grade level reading. These processes can be further investigated using event-related potentials (ERPs) along with

behavioral tests that measure reading comprehension and fluency levels (e.g. reading inventories, GORT-4). While behavioral assessments give us specific information about reading behavior, the ERPs give information about the electrical responses that occur in the brain, within milliseconds, of reading a word.

Reading Processes and ERPs

ERPs are a noninvasive method of measuring electrical activity in the brain during cognitive processing. A cap is placed on the head during the cognitive tasks and the electrodes on the cap pick up this electrical activity. The stimulus that evokes the waves (e.g. a particular word) is time-locked in order to measure the brain activity during that specific point in time.

The study of the electrophysiology of language started when Kutas and Hillyard (1980) discovered an ERP component that is sensitive to semantic manipulations (N400). Later, other ERP components were discovered that were sensitive to syntactic manipulations (Hagoort, Brown, & Groothusen, 1993; Hagoort, 2008). Researchers who study ERPs have distinguished three types of electrical activity that are elicited during violations (or manipulations) of semantic and syntactic information during what they consider to be reading tasks. They are the N400, the P600 and E/LAN respectively. Some researchers see these elicited responses as being credible in measuring linguistic tasks (e.g. reading and auditory). Others view them more critically. The following is a brief overview of the ERPs used in linguistic (reading and auditory) research.

N400. The N400 is said to measure the electrical response elicited when identifying semantically familiar and unfamiliar words as well as semantic sentence context with congruous and incongruous words . Researchers have consistently reported a negative peak, around 400 milliseconds, from the onset of the incongruous (or unfamiliar) semantic content (Berkum, Hagoort, & Brown, 1999; Kutas & Hillyard, 1980; Osterhout & Nicol, 1999). Researchers view the N400 as occurring anywhere between 200 and 600 milliseconds from the onset of the semantically incongruous word (Kutas, Van Petten, & Kluender, 2006). It is important to note that the N400 is an actual average of this response caused by the semantic violations (e.g. the participants read many sentences containing this type of violation, and the waves caused by the violations are averaged together to get one grand mean wave). The time differences in these elicited responses are called latencies.

Some researchers argue that the N400 is not specific to language processes and needs to be further researched. For example, the N400 has also been elicited during studies involving related and unrelated pictures, but the areas of the brain where the electrical response is recorded are different; verbal stimuli evoke parietal-occipital areas of the brain (Hagoort & Brown, 2000; Kutas, M., VanPetten, C., & Kluender, R. , 2006), and picture stimuli normally occur further up front (West & Holcomb, 2002).

P600. While the N400 is a negative-going peak occurring at around 400 milliseconds after the onset of the semantically unfamiliar or incongruous stimulus, the P600 is a positive occurring peak occurring at around 600

milliseconds after the onset of syntactically incongruous context; the amplitudes are picked up from the centro-parietal areas of the brain (Friederici, 2002). Like the N400, it is also an average, and can occur between 400 and 800 milliseconds (Kutas & Federmeir, 2007; Osterhout, & Nicol, 1999). However, the P600 response is controversial in the claim that it measures syntactic processes.

Researchers have questioned the validity of P600s that are elicited during tasks that involve unexpected events (such as unexpected words), because some believe it is in the same family of waves as the P300. P300s usually occur when an individual realizes that something does not make sense (unexpected events). The P300 can occur anywhere between 300 and 800 milliseconds, and it is mainly picked up from the inferior-parietal and prefrontal regions of the brain (Linden, 2005). Its latency can be used to provide a measure of the relative timing of the evaluation process involved in cognitive tasks (Coles, Smid, Scheffers, & Otten, 1995; Linden, 2005). However, some cognitive psychologists believe that the P600 can be in the same family of waves as the P300 since it is often also observed following unexpected stimuli (Coulson, King & Kutas,1998), and the latencies between the P300 and the P600 can overlap. Other researchers believe that it does not belong in the same family (Osterhout & Hagoort, 1999), because it specifically occurs during linguistic violations.

In addition, studies investigating the effect of thematically related nouns and verbs within a sentence revealed a semantic P600 effect at the verb in sentences that were syntactically sound, but contained a semantic verb violation that matched the theme of the noun (Kim & Osterhout, 2005). This type of P600

has been referred to as a "semantic P600" (Bornkessel-Schlesewsky & Schlesewsky, 2008).

E/LAN. Another kind of ERP response to syntactically incongruous content is the early left anterior negativity (referred to as E/LAN). The E/LAN is characterized by a negative-going wave that peaks around 200 milliseconds or less after the onset of the incongruous context. It most often occurs in response to linguistic stimuli that violate word-category or phrase structure rules. It is referred to as a left anterior negativity because it is picked up by electrodes located in the left front areas of the scalp (sometimes it can occur bilaterally). Another related wave is the LAN, it is the same as the E/LAN except that it peaks a little later, between 300 and 500 milliseconds, after the onset of the syntactic violations (Kutas & Federmeir, 2007). It is important to note that some researchers view the LAN and ELAN as distinct waves (Hahne & Friederci, 1999), other researchers believe that the ELAN is just an early version of the LAN (Hagoort, 2003).

Wave amplitudes. The wave amplitude of the elicited event-related potential is the magnitude of the electrical activity involved during the processing of the particular event. Some studies show that when a participant is confronted with a challenging task, wave amplitudes are higher than when the task is easy. These wave amplitudes are relative to the individual being tested (Holcomb, Coffey, & Neville, 1992; Wang, Dong, Ren, & Yang, 2009). For example, a young participant reading a sentence with a semantic violation may rely more on context to figure out the meaning of a word or sentence, while another participant

who is more skilled at reading may rely less on context. The N400 response from the first participant would be expected to have a larger amplitude than that of the more skilled reader (Holcomb, Coffey, & Neville, 1992; Handy, 2005). One would expect that the participant who found the task easier would elicit a wave with less amplitude (negative or positive) than the individual who had difficulty with the task. The wave amplitudes are analyzed by calculating the differences between the wave elicited during the control stimuli and the wave elicited in the experimental (e.g. word violation) stimuli.

Purpose of the Study

The purpose of this study is to take a deeper look at the role of semantic processes on fluency and reading comprehension using event related potentials (ERPs). The goals are to identify differences of N400 like elicited responses in groups of different level readers between the ages of 7-13, and compare the possible difference across groups and to adult N400 ERPs. More specifically, child participants will be grouped into one of two groups based on their reading comprehension abilities measured by the Gray Oral Reading Test-4 (Wiederholt, & Bryant, 2001); higher comprehenders and lower comprehenders. In addition, another analysis will group the participants into fluency groups; higher fluency and lower fluency. The electrophysiological data will focus on the cortical activation of these groups in response to four different sentence conditions; sentence tense differences (active sentences vs. passive sentences) and semantic violations (anomalous vs. correct) in active and passive sentences that are visually presented. Specifically, this study will investigate and compare

among groups the presence and properties (amplitude, latency and topography) of the N400 component targeting the sentence ending nouns. Group wave amplitudes will be compared when participants read the sentence ending nouns in active versus passive sentences, in active versus active violation sentences, and in passive versus passive violation sentences. The ultimate purpose is to see if N400 wave amplitudes change in relation to reading comprehension and/or reading fluency scores.

Research Questions

1. With simple active sentences as controls, do reading comprehension levels and/or reading fluency levels, measured by the GORT-4 (Wiederholt, & Bryant, 2001), affect the way that individuals process the final word in active sentences with thematic role violations with respect to the N400 component amplitudes?

2. With simple active sentences as controls, do reading comprehension levels and/or reading fluency levels, measured by the GORT-4 (Wiederholt, & Bryant, 2001), affect the way that individuals process sentence final nouns in simple by-passive sentences with respect to the N400 component amplitudes?

3. With simple by-passive sentences as controls, do reading comprehension levels and/or fluency levels, measured by the GORT-4 (Wiederholt, & Bryant, 2001), affect the way that individuals process sentence final nouns in by-passive sentences with thematic role violations with respect to the N400 amplitudes?.

With regard to questions one, two, and three, outlined below are the predicted ERP components based on whether reading comprehension and/or reading fluency levels have an effect on the N400 component amplitudes at the sentence final word (see tables 1, 2, & 3). These hypotheses were developed due to research that supports the view that passive sentences tend to be more difficult to process (Nation & Snowling, 2000), and this processing difficulty may lead to higher N400 amplitudes for the lower reading comprehension and/or fluency groups. Also, the few ERP studies that have used children to investigate the N400 component show that younger children show greater N400 amplitudes during reading tasks (Atchley, Rice Betz et al., 2005; Holcomb, Coffey, & Neville, 1992). While reading abilities were not used in these studies to group participants, age has been found to correlate with reading abilities (Chall, 1994; Curtis, 1980; Torgesen, Wagner, & Rashotte, 1994) and reading ability may have been a confounding factor not taken into account in these previous studies that could have affected the N400 amplitudes.

Table 1. Hypothesis for Question 1.

Group	Condition	Example	Hypothesis 1
Lower Reading Group	Active violation	The ball was kicking the <u>boy</u>.	N400. Lower reading group (fluency or/and comprehension) will have a significantly higher amplitude when compared to the higher reading group and adults.
Higher Reading Group			
Adults			

Predicted ERP components on sentences final word based on comparisons with active control sentences.

Table 2: Hypotheses for Question 2.

Group	Condition	Example	Hypothesis 1	Hypothesis 2
Lower Reading Group	Simple passive	The ball was kicked by the <u>boy</u>.	N400. Lower reading group (fluency or/and comprehension) will have a significantly higher amplitude for the passive sentences when compared to the higher reading group and adults.	Relative differences in N400 amplitudes between passive and active sentences.
Higher Reading Group				
Adults				No relative difference in N400 amplitudes between passive and active sentences.

Predicted ERP on sentence final word based on comparisons with active control sentences.

Table 3: Hypothesis for Question 3.

Group	Condition	Example	Hypothesis 1
Lower Reading Group	Passive Violation	The boy was kicked by the <u>ball</u>.	N400.
Higher Reading Group			Lower reading group (based on fluency or/and comprehension) will have a significantly higher amplitude when compared to the higher reading group and adults.
Adults			However, the relative differences between the N400 component within the groups will be less for the lower ability groups than the higher ability group.

Predicted ERP waves on sentence final word based on comparison with passive control sentences.

In interpreting the N400 results at the sentence ending noun, one also needs to take into consideration the way the verb in the sentence was processed since the meaning of the last word of the sentences may be directly related to the meaning of the context that precedes it (Rumelhart, 1994/2004). The elicited response at the end of the sentence may depend on the way the participants view the verb in the middle of the sentence; for example, some may see the "ed" ending in the passive violation sentences as morphosyntactically incorrect and others may see it as semantically incorrect (since the verb has an implausible connection to the noun). A related study (VanDyke, unfinished dissertation; see Appendix A for description) using the same participants and sentences, but examining the way the verb in the active violation was processed in regards to age group (not reading skill group), saw a trend in the younger participants (ages

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7-9) processing the verb semantically (eliciting and N400) and the older

participants (11-13) and adults (undergraduates) processing the verb as a

morphosyntactic error (eliciting a P600). ERPs at the verb level will not be

examined for the different reading level groups, however the way the verb in

each of the sentence types may have been processed will be discussed in the

results.

Significance of the Study

Studies have shown that there is a correlation between fluency and

comprehension (Fuchs, Fuchs, Hosp, & Jenkins, 2001; Jenkins, Fuchs, van den

Broek, Espin, & Deno, 2003), however as noted earlier, just because a person

can read fluently does not mean that they are processing the information

effectively for comprehension to take place. This study attempts to examine this

gray area in order to better understand the link between fluency and

comprehension, and the syntactic and semantic processes involved in reading. If

the hypothesized group differences exist, the results may warrant future studies

on a larger scale in order to continue studying how reading abilities affect

neurological responses, how individuals with different reading abilities process

different types of sentences, to possibly establish a baselines to diagnose

reading problems, and to test different instructional approaches that attempt to

improve reading skills.

By using both behavioral and electrophysiological measures, a clearer

picture of how reading comprehension and fluency levels affect the way the brain

processes semantic and syntactic information may be produced. If differences

between groups exist between these brain processes and the behavioral data, certain types of reading instruction can be promoted to help develop the sub-skills necessary to effectively and efficiently process reading material for those students who can read fluently, but lack comprehension skills.

Finally, this study attempts to bridge part of the gap between brain research in the area of reading and educational research in the area of reading. While many studies involving brain research include researchers from different disciplines in the research team (e.g. neuroscience, medical, speech and language, linguistics), hardly any researchers from the field of reading education have been involved in these studies. Researchers who study reading processes can benefit from the input of reading educators during the cognitive task development, design of the methodology, and the interpretation of results. Likewise, reading researchers can benefit from multiple perspectives, and certain neuroscience results may be beneficial to understand and improve classroom practices that may be overlooked due to the reading educators' inexperience with brain research. It is important that all disciplinary fields involved have some interdisciplinary knowledge for this research to reach its full potential.

Limitations, Assumptions, and Design Control

It is important to note that the cognitive tasks in the ERP portion of this study do not constitute authentic reading since the words in the sentences are presented one by one. Due to the method of sentence presentation a number of reading processes may be affected coming from the interactive view of reading. For example, Rumelhart (1994/2004) states "Our perception of meaning of what

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we read depends on the general context in which we encounter the text" (p. 1161). He explains that no determination of the meaning of individual words can be made without consideration of the entire sentence. He specifically gives examples of words that can have different meanings depending on the context of the sentence; the word "figure" can mean a number in one sentence and can also mean a small statue in another.

Also, Rumelhart (1994/2004) explains, "our perception of words depends on the syntactic environment in which we encounter them" (p. 1157). In the passive violation condition the readers' hypotheses of what the next word is going to be could be rejected when they encounter the violated word. Two types of rejections are possible. The reader can hypothesize the same word, but in a different grammatical form (e.g. -ing form instead of the –ed form), or the reader can hypothesize a different word that still makes sense because it is in the right grammatical form. In either case, the anomalous word that they actually encounter would make them reject their hypotheses. Nevertheless these types of processes are of interest in this study.

These assumptions on these interactions (or lack there of) are theoretical, but in order to measure the brain waves that occur when the violation to each sentence occurs without interference from the other words in the sentence, each word in the sentence needs to be time-locked. This is the reason that the participants read word for word in these types of ERP studies. In this study reading will be defined as word by word understanding of sentences for the purpose of comprehension.

Definitions of Key Terms

Due to the interdisciplinary nature of this study, it is beneficial to define some key terms in order to attain better understanding of the research.

Basic reading level: A student reading at the basic level has partial mastery of the skills necessary for proficient work at their grade level (The Nations Report Card, 2005).

Proficient reading level: a student reading at the proficient level is able to demonstrate competency over challenging grade level matter (The Nations Report Card, 2005).

Advanced reading level: and the advanced level depicts a student whose performance is superior (The Nations Report Card, 2005)

Event-Related Potentials: ERPs are a noninvasive method of measuring electrical activity in the brain during cognitive processing. An electrode cap is placed on the head during the cognitive tasks and picks up the electrical activity. The stimulus that evokes the waves (e.g. a particular word) is time-locked in order to measure the brain activity during that specific point in time (Friederici, 2005).

Reading Fluency: the ability to read with speed, accuracy and expression (NRP, 2000).

Semantic priming: using the semantic context in a phrase or sentence to recognize or predict a word (Neely, 1991). For example, using the following sentence context: The hungry boy, an individual can predict that the next possible word is "ate" based on the context.

Reading Comprehension: The ability to read and understand text (NRP, 2000).

Semantic Processes: processes involved in overall meaning making as well as making sense of specific words (Rumelhart, 1994/2004).

Syntactic Processes: processes involved in how structural information is used (e.g. the order of words in a sentence) that allows for the prediction of upcoming words as well as monitoring the understanding of the text (Rumelhart, 1994/2004)

N400: is an ERP component that is a centro-parietally distributed negativity that reflects lexical semantic processes and is observed both at the word and sentence level during semantic manipulations (Kutas & Hillyard, 1980; Friederici, 2002).

P600: an ERP component that is sensitive to syntactic manipulations. It is a centroparietally distributed positivity that correlates with processes of syntactic revision such as reanalysis (Friederici, 2002).

Amplitude: the height of the wave.

Prosody: the ability to read with appropriate expression, pitch changes, pause placements, and phrasing. It is considered to be an important component of reading fluency (Dowhower 1991; Klauda & Guthrie, 2008; NRP, 2000; Kuhn & Stahl, 2003).

Epoch: the total time the target word is time locked in order to analyze the waves elicited by it.

Time Windows: time frames within an epoch that allows for the analysis of

the elicited waves.

Phonological priming: recognizing words via their orthography even when letters are cut off or missing (e.g. Standing on your head is precari_us; Lee, 2009).

Semantic priming: the improvement in speed or accuracy to respond to a stimulus such as a word or picture, when it is preceded by a related word or context (e.g. cat and dog), relative to when it is preceded by an unrelated word or context (e.g. fish and popcorn; McNamara, 2005).

Summary

To date, the percentage of school-aged children reading at a basic level or below is large, and most poor readers never catch up over the years (Stanovich, 1986, Lyon, 2002). Even if a child has been successful in acquiring reading skills during the early elementary school years and reads fluently for their grade level, they are still at risk of developing reading problems when texts become more expository in nature and thus more difficult to read. This usually happens during the fourth grade, and reading difficulties during this time have been described as the fourth grade slump. This slump has been investigated over decades of research, and reasons to why this occurs include socio-economic reasons (Chall & Jacobs, 2003), language deficits (Cain & Oakhill, 2006; Gough & Tunmer, 1986) and poor instruction (Hirsch, 2006). While the above- mentioned reasons may contribute to this slump, it has also been noted that fourth grade texts commonly use sentences that are more complex than to what these readers are accustomed (Scott, 2004; Deane, Sheehan, & Sabatini et al., 2006).

This study will not examine fourth grade texts, but will examine brain activity when children of varying degrees of reading ability read passive sentences which are considered to be more complex than active sentence (Fox & Grodzinsky, 1998; Stromswold, 2002; Scott, 2004). Active sentences usually dominate narrative texts; narrative texts are more common in the early elementary school years, while expository texts begin to dominate during the fourth grade and beyond, and include more sentences that use the passive voice (Scott, 2004; Deane, Sheehan, & Sabatini et al., 2006). The inability to understand single sentences in a paragraph or passage can ultimately affect the overall comprehension of the paragraph or passage being read (Scott, 2009).

The comparisons between groups of different reading abilities may shed some light into the way the brain processes syntactic and semantic information between active and passive voice, and the way the brain processes information that does not make semantic sense. If these differences exist, educational strategies that involve complex sentence structures may be promoted and developed to help children with reading comprehension difficulties. The use of reading behavioral data in combination with brain research data may shed light into unresolved questions that affect the way reading is taught and remediated in schools.

In Chapter 2, literature concerning the fourth grade slump focusing on fourth grade text, syntactic and semantic processes and reading development, and ERP studies investigating reading processes are reviewed.

Chapter II:

Review of Related Literature

Only 33 % of students in the 4th grade are reading at or above the proficient level. This leaves 67 percent of 4th grade students in the U.S. reading at the basic level or below it (National Center for Educational Statistics, 2007). As explained in Chapter I, a student reading at the basic level only has partial mastery of the skills necessary for proficient work at grade level. If we are to improve students' academic success and prepare them for the future, it is important that we figure out the best way to help them with their reading skills; reading is related to all subject areas. The inability to proficiently read texts, will ultimately affect the knowledge a student will acquire in all subject areas. However, there are still many questions about how reading develops and the cognitive processes involved during reading. Furthermore there exists a gray area between fluency and comprehension that needs to be further investigated. The ability to read fluently is not sufficient for comprehension to take place.

The review of the literature includes research involving reading fluency and reading comprehension with a focus on syntactic and semantic processes during reading tasks. It begins with a general discussion of the fourth grade slump and text difficulty. Secondly, research on the role of background knowledge is reviewed. Then research on semantic and syntactic processes on

reading fluency and comprehension abilities is discussed. Finally, ERP studies that have specifically focused on children's language development and reading development in reference to semantic and syntactic processes and the N400 and P600 components are presented.

Brain studies using technology other than ERP recordings are excluded as well as research using only word level experiments (e.g. experiments where the tasks involve reading words in isolation or word lists), and research where the participants are not fluent readers or are just beginning to read. The exclusion criterion has been established because studies examining the above-mentioned are not focused on the topics related to the questions for this research study.

The Fourth Grade Slump

Many fluent readers confront comprehension difficulties when texts become more difficult as in the reading-to-learn stage versus the learning-to-read stage (Chall, 1996). This stage normally begins in the fourth grade when expository texts become more common than the narrative texts with which students are familiar (Grigg, Daane, Jin, & Campbell, 2003; Wanzek, Wexler, Vaughn, & Ciullo, 2009). It is at this level when many young readers without a history of reading problems develop them; this phenomenon is generally described as the fourth grade slump. This slump has been investigated over decades of research, and reasons to why it occurs include socio-economic reason (Chall & Jacobs, 2003), language deficits (Cain & Oakhill, 2006; Gough & Tunmer, 1986), lack of world knowledge (Best, Floyd, & McNamara, 2004) and poor instruction (Hirsch, 2006). While the above- mentioned reasons may

contribute to this slump, it has also been noted that fourth grade texts, in addition to being more expository in nature, commonly use sentences that are more complex than to what these readers are accustomed (Deane, Sheehan, & Sabatini, Futagi, & Kostin, 2006; Scott, 2004).

Deane et al. (2006) explored the differences in text structure between 3rd and 6th grade texts of various subjects. They looked at the sentence level text structure as well as the overall text structure in passages found in these grade level books. A factor analysis technique was used to explore the relations between observable text characteristics such as vocabulary and syntactic structures, and hypothesized dimensions of variation, such as the degree of "narrativity" (p. 264) detected in a text.

They (Deane et al., 2006) found that 3rd and 6th grade texts are characterized as having similar levels of vocabulary demand, however 6th grade texts have more varied vocabulary and lexical sets (e.g. words that have similar meanings or belong together such as hand, fingers, nails, nail-bed). These lexical sets tap into the depth of vocabulary knowledge (e.g. how well the meanings are known) versus the breadth of vocabulary knowledge (e.g. how many words are known). While the amount of vocabulary words known may not be an issue in text difficulty, the depth of this knowledge and the connections the reader is able to make between words can determine how difficult a particular text is to a reader and can affect the overall comprehension of the text (Ouellette, 2006).

Also 3rd grade texts were more narrative in nature while 6th grade texts were characterized as being more expository than narrative. Finally, 6th grade texts had a greater array of syntactic and discourse features than 3rd grade texts. These results show that while the 6th grade level texts are more difficult to read, the difficulty does not necessarily stem from the word level readability. Instead they become more difficult due to sentence complexity and overall text organization. However, it is important to note that while this exploratory research took into consideration the sentence complexity factor, the authors did not analyze the degree of tense usage (e.g. active versus passives) in text between the 3rd and 6th grade level. Nevertheless, it is understood that the academic language of textbooks, especially science and social studies textbooks found in 4th grade and higher grades, is different than the language used in everyday conversations and includes more complex sentence structures (e.g. complex syntactic structures) including passive sentence structures (Fang, 2006; Unswroth, 1999). In addition to the more complex sentence structures, expository texts may also be difficult to read due to the topics they cover and the reader's lack of background knowledge of the content, and unfamiliarity with expository text structure.

Background Knowledge and Schema Theory

Researchers examining the role of background knowledge have concluded that it is important for ongoing meaning (Anderson, 1984/2004). Theories such as this one fall under the schema theoretic view of reading. Schema theory implies that some individuals learn more than others because

they are able to create a mental representation of the new learning that is linked to the knowledge structure that already exists in their memory. Psychologists believe that learning new information depends on relating the new to something already known. To make sense of the world, the learner attempts to relate new information to already known information by drawing a schema or framework. Schema theory explains how prior knowledge is stored in memory and grows to include other topics, creating larger and larger schemata. Interrelationships among schemata aid understanding and information processing when reading or listening.

The discussion of how a person's schemata aids in the processing of textual information was introduced by Richard Anderson, but the concept has been studied from as early as the 1930's (Richardson & Morgan, 2003). Anderson (1984/2004) explains that the conventional view of comprehension that only consists of making meaning of words to form the meaning of clauses, that in turn form the meaning of sentences, and then the sentences form the meaning of paragraphs and ultimately the whole text, is not sufficient in explaining what comprehension truly is. A person's schemata should be added into the view of comprehension as that supports development of understanding.

Van Dijk and Kintsch (1983) suggest that we use text structure and content schemata to help us select important information when reading. A text structure schema includes the reader's knowledge of how authors structure their ideas. For example, narrative, comparison, problem/solution, description, and causation are some of the organizational patterns author's use. Content

schemata, on the other hand, are defined by the reader's world, or background knowledge (Ohlhausen & Roller, 1988).

Langer (1984) examined the role of readers' background knowledge in text comprehension with a group of 161 sixth grade students. Some students were reading above level, others on level, and others below level on measures of reading skills. Two passages, one about World War I and the other about Stonehenge, were selected from a sixth grade social studies textbook. A twenty item test measuring reading comprehension was prepared for each of the passages using both explicit and implicit questions. The students were grouped into groups of 10 and 11. Prior to reading, some groups discussed key concepts found in the passages in order to build background knowledge about the passages, some of the groups discussed the passages in a motivational way where the teacher tried to get the students excited about reading the information in the passages without imparting specific facts, some of the groups read the passage without any pre-reading activities, and some of the groups read the passage following a non-topic related discussion. The groups that discussed key concepts found in the passages prior to reading scored highest in the comprehension measures compared to all the other groups. However the low ability readers did not benefit from this prereading activity. Langer did not discuss reasons why low ability readers did not benefit from the prereading activity that addressed content knowledge, but perhaps the background knowledge of the text structure (versus content) from the construction of the sentences to the

organization of the text, made comprehension difficult even if the content schemata was intact.

Ohlhausen and Roller (1988) examined the operation on text structure and content schemata in isolation and as they interact. They tested 259 students in fifth, seventh, and ninth grades as well as adults. All the subjects received one of three possible passages about a very little known country. The topic was selected to control for background knowledge; the participants had never heard of the island country depicted in the passages, however, they could apply what they already knew about countries and islands to make sense of the passages. The first passage (C/S) had both structure and content schemata provided; the second passage (C) lacked structure schemata (it was not written in sequential paragraph form and the sentences were mixed up), but provided content schemata. The third passage (S) provided structure but no content schemata (nouns were replaced with nonsense words). ANOVAS indicated that structure strategies (e.g. used sequence of the text structure for meaning making) increased with age and structure schemata influenced processing; the use of structural strategies were higher on the S passages than on the C passages. Results also indicate that when it is possible to use content schemata, subjects did not make full use of their available structural schemata; readers tended to favor their content schemata versus their structural schemata. The results also show that adults had more fully developed their content and structure schemata, and that their structure schemata has become so well developed that, faced with a difficult text such as the C passage, they automatically activate it. Finally,

Ohlhausen and Roller conclude that both content and text structure schemata influence the processing of text. As seen from the studies conducted by Ohlhausen and Roller and Langer (1984), structural schemata as well as content schemata play a role in text processing and comprehension. Text structure schemata, however, can also impact the reader at the sentence level when readers are inexperienced with the structure of the sentences (Alexander, Schallert, & Hare, 1991; Scott, 2004).

Scott (2004) describes three factors that can make a sentence complex. She states that sentences are more or less difficult to process depending on features of open-class words (nouns and verbs) and their relationships. For example, children have a harder time processing reversible by-sentences (e.g. The cat was chased by the dog) than nonreversible by-sentences (The apple was eaten by the boy). In the nonreversible sentences, interpretation is aided by the fact that the apple is not an agent and cannot do anything; for example, apples do not eat boys. Another reason that makes a sentence more complex is the number and types of syntactic operations; this is usually reflected in sentence length. Finally, the type of syntactic operation is also a contributor to sentence complexity.

Scott (2004) lists the following types of syntactic operations that are usually harder to process: Sentences that do not conform to canonical word order such as passives or object-cleft sentences (e.g. It was the teacher that the boy admired), sentences with any type of long distance dependency in which there is a lag between the syntactic prediction and its confirmation; this happens

when the main subject and verb are interrupted by a clause or phrase. Also

sentences with local ambiguities that require reanalysis to resolve, and

sentences in which reference must be resolved (e.g. Bill talked to the dog before

turning off the light; Bill sees Spot feeding himself) add to the syntactic

operations that make sentences more difficult to process. While fluent readers

may be able to read all the words in these complex sentences, the information

they are gathering while reading may be muddled and not make sense to them

partially due to the unfamiliar or more complex syntactic structures used in the

more difficult texts.

In addition to the importance of content and structural schemata on text

processing, Dole, Duffy, Roehler, and Pearson (1991) add yet another type of

schemata that relates to the knowledge of metacognitve skills a reader uses to

process text. While some researchers consider these to be strategies, the reader

needs to possess these metacognitive strategies in their schemata to actually be

able to apply them while reading. This allows the reader to access their

metacognition schema when comprehension breaks down, and helps them find a

strategy that would help fix it. For example, when reading sentences, if

something does not make sense, the reader can access their metacognitive

strategies to help them figure out the meaning, and specifically what does not

make sense to them. The strategies Dole et al. suggest that classroom

comprehension instruction should focus on include determining the important

information in a text by identifying the text structure, summarization, drawing

inferences, generating questions and comprehension monitoring. These

strategies all relate to semantic processing.

Semantic Processing and Reading Comprehension

Nation and Snowling (1998) describe poor comprehenders as having poor

semantic skills that includes receptive and expressive vocabulary. In addition

Nation, Clarke, Marshall, and Durand (2004) found that poor comprehenders

scored lower than normal readers on tests tapping morphosyntax and the

understanding on non-literal aspects of language (e.g. inferences), as well as

vocabulary. Also Cain, Oakhill and Elbro (2003) found that children with poor

reading comprehension lacked inferencing abilities when it came to figuring out

the meaning of new words embedded in a text. The above-mentioned studies

looked at different factors that contribute to semantic processing and meaning

making (e.g. inferencing, vocabulary). It is important to note, from an interactive

perspective of reading comprehension, that syntactic knowledge and processes

also contribute to meaning making (Rumelhart, 1984/2004; Stanovich, 1980),

however, for text organizational purposes, the next section will focus only on

studies that involve the role of word knowledge and vocabulary skills, inference

skills on reading comprehension and reading ability, and the use of context for

meaning making. Later in this review the role of syntactic processes on fluency

and comprehension are discussed. Nevertheless some studies in this next

section include discussions of syntactic processes on comprehension as well. In

the next section the role of vocabulary and word knowledge are discussed first.

Tannenbaum, Torgesen, and Wagner (2006) addressed three questions in their study investigating the relationships between word knowledge and reading comprehension with third-grade children. Specifically, the questions focused on three dimensions of word knowledge; the breadth (e.g. how many words they know), depth (e.g. how rich is the knowledge of those words; it can range from simple recognition to the application of the words in everyday language tasks), and fluency (e.g. the rate at which an individual accesses the meaning of a word). It is important not to confuse what the authors of this study describe as fluency with the more common definition of fluency (e.g. rate and accuracy of reading) used in reading research. Their first question asked if the three dimensions described above are distinguishable. Their second question asked what the strength of the relationship is between the dimensions of word knowledge, and their third question asked what the relationships are between the dimensions of word knowledge and reading comprehension.

Tannenbaum et al. (2006) assessed 204 third grade students using multiple vocabulary measures that measured each of the three word-knowledge dimensions (e.g. breadth, depth, and fluency), and a reading comprehension measure. The authors used confirmatory factor analysis, structure equation modeling, and hierarchical regression analysis for the statistical analyses. The results indicated that the three dimensions of word knowledge are not completely distinguishable from one another based on the assessment used and the statistical analyses. The results also indicated that the three dimensions are

highly related. Finally, breadth of word knowledge was most highly related to reading comprehension.

In explaining why breadth, and not depth, had the highest correlation with reading comprehension, one can surmise that when a particular word appears in context, the reader can make meaning of the word even if they are unable to do so when the word is presented in isolation. The vocabulary measures used to measure depth mostly consisted of words in isolation where the reader was asked to select a picture that described a target word, orally define words, describe attributes of particular nouns, or use target words in a sentence. There was only one measure that asked the participants to read a sentence and define a target word in the sentence based on the context. It would have been interesting if the researchers correlated this particular measure with the reading comprehension scores, however this was not done in this study. Perhaps the results involving the depth of word knowledge would have been different. When it comes to semantic processing from an interactive perspective, our perception of a word comes from both the syntactic and semantic environment in which those words appear (Rumelhartt,1984/2004); the depth of a word is dependent on these two types of environment, and assessing word breadth in isolation may not have been the most efficient or appropriate way to study this particular dimension of word knowledge and its effect on reading comprehension abilities.

Cain, Oakhill, and Elbro (2003), on the other hand, investigated the ability to learn word meanings from context between children with normally developing reading comprehension skill and children with weak reading comprehension skill

with age appropriate word reading skills. Fifteen normal readers and 15 children with weak comprehension skills were matched up according to age and word reading abilities in order to control the effects of age and decoding skills on reading comprehension; all children, regardless of group, had age appropriate reading accuracy scores and did not differ significantly in this measure. The children were asked to read two versions of four stories, for a total of eight stories. Each of the stories was written containing made-up words with a novel meaning. The meaning of the unknown word could be derived from the information found immediately following the made-up words (near condition) or after some additional filler sentences (far condition). There were four stories for each condition. The children read the stories out loud and were asked to define the novel words as they encountered them in the text (without context) and after they have read sufficient context to possibly figure out the meaning of the word (with context). Scores were taken for both the before context results and after context results. Points were awarded for the quality of the definition of the unknown word; two points when the full inference was made, and one point for partial inferences. After calculating log odds for each participant (e.g. measures of how much more likely a participant was to give a correct response after context than before the context was read), the log odds were subjected to a logistic regression to investigate whether context effects in the far condition contributed significantly in distinguishing the skilled comprehenders from the less skilled comprehenders, once context effects on the near condition were taken into account. Results indicated that the distance between a word and its defining

context is more detrimental to less-skilled comprehenders than to skilled comprehenders. There were no significant differences between groups for the near conditions or for the definitions prior to seeing the contexts.

The authors (Cain et al., 2003) surmise that the less skilled comprehenders may have issues with working memory capacity, and had difficulty keeping all the information between the novel word and the context in their heads. However, there was not a measure of working memory in this study, and this assumption needs to be further investigated. Another explanation for the differences between groups in the far condition that the authors give is that the less-skilled comprehenders' performance was affected by their inefficient or inappropriate processing strategies. Their reasoning behind this explanation was that less skilled comprehenders may focus more on decoding the words correctly, or they have immature strategies for comprehension repair, and they have less sophisticated strategies for locating information in a text. These inefficiencies may have limited their processing resources in order to consider more advanced aspects of the text, and these inefficiencies affected the performance more when processing demands of the task were high. They conclude that the findings suggest that difficulty inferring word meaning from context may be related to a deficit in text comprehension skill such as inference making. They also surmise that a deficit such as lack of inferencing skills may impede growth in vocabulary skills, and these effects may become greater as children continue to develop their reading skills (Cain, Oakhill, & Elbro, 2003).

In the Cain et al. (2003) study, the children did not have fluency issues, but they differed in comprehension skills; the low comprehenders seemed to lack inference-making skills. While the authors gave many possible reasons why the groups differed in this skill, they did not discuss another very logical reason. Perhaps the low-comprehenders selected were never taught how to appropriately use context clues (near or far) to come up with unknown word meanings. The participants were only 7-8 years of age and beginning to read for comprehension versus just learning to read; perhaps their teachers had not yet taught how to use context clues to make meaning of unknown words. Lack of proper reading instruction may have been the culprit, and not necessarily working memory or inefficient processing.

In keeping with studies that investigate the role of context on comprehension, Stanovich, West, and Feeman (1981) examined 2nd grade children through the course of a year on how the use of contextual information to predict and/or decipher upcoming words changed due to increased reading skill. The participants included 24 second grade children. Sixty-three sentences were constructed so that the last two words in each of the sentences include the word "the" and a noun that was highly predictable from the context that preceded it. The sentences were organized into pairs, and the terminal word (nouns) of each sentence was deleted; the incomplete sentences were used as sentence contexts. The deleted nouns were used as target words. A sentence context and the nouns were deemed congruent if they came from the originally constructed sentence; they were deemed incongruent if they were derived from the opposite

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members of the original sentence pairs. Using two sets of the thirty words, 12 of the participants were randomly assigned to each word set. The participants had an opportunity to practice the target words in their set during 15 sessions that took place during 15 consecutive school days, and the first experiment took place two days after the last session. During the experiments participants were asked to read out loud the context of the sentences that appeared on a screen, and after the participants pronounced the last word of the context, a target word appeared. Participants were instructed to read the target words as rapidly as possible. Of the 60 experimental trials, 20 target words were preceded by congruous context, 20 by incongruous context, and 20 by no context. Within each of the sets of 20 target words, five were easy and practiced, five were easy and unpracticed, five were difficult and practiced and five were difficult and unpracticed. This test was repeated again at the end of the school year. The mean reaction time in each condition for each participant was used in an analysis of variance. The researchers also explored the relationship between the effect of sentence context and reading ability.

Results indicated that the magnitude of context effect declined throughout the school year, and the context effects for the unpracticed easy and unpracticed difficult words revealed that later in the school year the amount of time to identify the unpracticed target words also decreased. Also, the recognition of difficult words was enhanced by the presence of prior sentence context, whereas easy words were less affected by context. Stanovich et al. (1981) conclude that as words become easier to read due to increased reading ability, the reader does

not have to rely as much on context in order to recognize and comprehend the harder words; in other words, less proficient readers rely more on sentence semantic cues, than more proficient readers.

Similar to Stanovich et al's (1981) study, Schwantes, Boesl, and Ritz (1980) also investigated children's use of context in word recognition in order to clarify the degree to which young readers relative to adults rely on contextual information to facilitate word recognition. Their study included both semantic and syntactic cues. Forty students from three grade levels (third, sixth, and college) were recruited for the study. All participants were given vocabulary and reading comprehension assessments prior to the experiment. One hundred and twenty sentences were constructed based on sentences found in second and third grade readers. All words had a readability level of third grade or below. The sentences were divided into two parts: the last word of the sentence (target words) and its preceding sentence context. Twenty-four of the target words were randomly selected and replaced with nonwords. In each of the experiments, two different lists of the 120 contexts were constructed and presented to half the students in each grade level. For the first experiment, the two lists were constructed so that the target words, preceded by their congruous contexts, were paired with incongruous contexts in list 2. For the congruous context trials, target words and their original context remained together. For the incongruous context trials, target words from two original context-target word pairs were switched so that the last word of the sentence did not make sense in light of the context.

Also, the contexts varied in lengths; some contexts were only 2 and 4 words in lengths and the others 8 words in lengths.

Each student was tested individually, and asked to read the sentence aloud, and when they got to the end of the sentence context they were asked to respond, by pushing one of two buttons, to the target word presented. They pressed one button if the target word belonged in the context, and they pressed the other button if it did not make sense. For the second experiment, after reading the four and eight words contexts, the students were asked to predict the target word. Right after stating the prediction, the correct target word or the nonwords appeared. The proportion of correct responses was entered into a three-way mixed analysis of variance with grade level and preceding context lengths as between subjects factors and context type as a within subject factor for the first experiment, and into a two way mixed analysis of variance with grade level as between subjects factors and preceding context length as a within subject factor. The results indicated that young readers' word recognition rates were affected to a much greater degree by increasing amount of context than were those of college students. Also, the results indicated that both vocabulary scores and reading comprehension scores were significantly negatively correlated with the time it took students to respond to the target words; as reading scores increased the time decreased. The researchers concluded that the findings suggest that as reading development increases, readers' reliance on context clues decreases. The semantic context of the sentences helped younger readers identify words (Schwantes et al., 1980).

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To further investigate the findings from the above-mentioned studies, Bowey (1985) examined the interactive-compensatory predictions, suggested by Stanovich (1980) that concern both word recognition and comprehension monitoring processes within an oral reading task in relation to both grade level and decoding skill. Bowey looked at children's accuracy in reading words in isolation compared to words in context. Forty-eight fourth and fifth grade children participated in the study. The participants were asked to read a 539 word narrative passage for the context material, and a list of 48 words from the passage for the isolated words condition. The oral readings were analyzed statistically and qualitatively. The findings suggested that less skilled decoders did not rely on context any more than skilled decoders in the process of word recognition. Also, the children read the word lists 50% slower than when they read the words in the passage. In addition, skilled decoders were able to use contextual information to monitor their comprehension, based on the higher rate of contextually obligatory self-corrections in the oral reading of the passage; they were better able to correct grammatically inappropriate oral reading errors compared to the less skilled readers.

The differences between Schwantes et al. (1980) and Stanovich et al. (1981) findings compared to Bowey's (1985) findings involving the use of context between skilled and less skilled readers can be attributed to the type of reading materials used. For the first two mentioned studies, sentences were purposely constructed so that the semantic context facilitated the prediction of the target words, while in the third study, Bowey used a real passage taken from a book

and did not manipulate the sentences so that they contained a higher degree of semantically-related context. While the first two studies revealed a tendency for less skilled readers to use context for word recognition, the last study did not show the same results. Instead, Bowey's study showed that skilled readers use context to monitor their comprehension, and less skilled readers did not use context any more than skilled readers to facilitate word recognition; less skilled readers did not use context to monitor their comprehension. The information that can be taken from these studies is that less skilled readers rely on semantic information for decoding words, when semantic cues are available, as the first two studies showed, while more proficient readers use context syntactic cues to monitor their comprehension as Bowey's (1985) study showed.

More recently, Nation and Snowling (1998) found evidence that support the above mentioned conclusions about contextual facilitation for word recognition as well as comprehension monitoring. In their study, Nation and Snowling predicted that both decoding and comprehension abilities will be related to contextual facilitation. They also predicted that since dyslexic children have weak word level decoding, but adequate language comprehension, they will benefit most from contextual support when compared to skilled readers and children with weak reading comprehension skills.

For Nation and Snowling's (1998) first study, 92 seven to ten year olds were selected to participate. All the children completed numerous assessments that tapped into their single word reading abilities, reading comprehension skills, phonological skills, listening comprehension, semantic skills, and contextual

facilitation of word recognition use. The results indicated that the use of context to facilitate word recognition is related to individual differences in both decoding and comprehension skills, replicating results from previous studies (Stanovich, West & Feeman, 1981; Schwantes, Boesl, & Ritz, 1980). Also, individual differences in linguistic comprehension are the best predictors of contextual facilitation partly due to the fact that listening comprehension includes both semantic and syntactic skills, whereas the other measures used in the correlational analysis tapped one or the other.

Since the findings of their first study suggested that there is a relation between the proficiency of verbal-semantic processing skills and the use of discourse level context to facilitate word recognition, Nation and Snowling (1998) completed a second experiment using three groups of readers varying in reading abilities in order to see how the group differences affect the way that the context facilitates reading. The first group consisted of 13 poor comprehenders, the second group consisted of 13 normal readers, and the third group consisted of dyslexic readers. It is important to note that Nation and Snowling define a dyslexic reader as an individual who has issues with phonological skills despite normal IQs and normal linguistic comprehension abilities. To summarize, one group had comprehension difficulties despite normal word recognition abilities, one group were normal readers, and the last group had average comprehension but low decoding skills.

The three groups were compared using the assessments and tasks from Study 1. The results indicated that the dyslexic group showed the most priming

effects where they relied on word semantic relationships and syntactic word order,in their use of context to facilitate word recognition, and the normal readers showed more context facilitation than the poor comprehenders. The researchers surmise that these results indicate that incomplete information from partial decoding attempt interacts with contextual information and, in combination, both sources of information may result in the correct pronunciation of target words. Since the dyslexic children were able to make meaning of contextual information in spite of inaccurate or incomplete decoding, the interaction between meaning making from context and a little decoding allowed them to comprehend the texts. In the normal readers the interaction between both skills existed, but in a more balanced way; they did not have to rely on context as much. On the other hand, the lack of meaning making from context that the poor comprehenders exhibited did not facilitate word recognition because the interaction between context and decoding attempt did not exist. To summarize, poor decoders used context to facilitate word recognition, but poor comprehenders did not. The results from this study show that reading processes interact differently depending on the reader's reading strengths and weaknesses. This study also supports Stanovich's interactive-compensatory model of reading (1980). In the next section I will review literature on how syntax also plays a role in meaning making and how syntactic processes vary by reading ability.

Syntactic Processing and Reading Comprehension

Bailey (2007) defines academic proficiency as the ability to use content specific vocabulary, specialized and complex grammatical structures, diverse

language functions and discourse structures in order to learn new knowledge and skills, interact about different topics learned, and impart information to others. Complex syntactic structures, found in texts in the upper elementary, middle and high school textbooks, is one of the contributing factors that defines academic language, and the lack of academic language skills are one of the reasons that researchers believe some students struggle with reading tasks (Snow & Uccelli, 2008). Syntactic knowledge and processing as they contribute to text comprehension, has been investigated in a variety of studies that involve fluency and overall comprehension of text. Similar to semantic processes, syntactic processes help the construction of meaning from the text by enabling the reader to hypothesize, or make predictions, about the way the sentence is constructed and this aids in the fluent reading of the text, which in turn aids comprehension (Oakhill & Cain, 2007; Rumelhart, 1994/2004; NRP, 2001). In addition, readers with good syntactic awareness can utilize sentence context clues to predict words that will come next in the text; in turn they are able to monitor their comprehension (meaning making) of the text (Tunmer, Herriman, & Nesdale, 1988). In this next section I will focus on syntactic awareness and syntactic processes and their contribution to reading comprehension.

The following study is reviewed first because its results influence the way the other studies investigating syntactic awareness and processes on reading ability are critiqued. Caine (2007) wanted to determine the contribution made by vocabulary, grammatical knowledge, and memory performance on different measures of syntactic awareness and reading ability. She defined grammatical

awareness as the ability to manipulate and reflect on the grammatical structure of language. She assessed two groups of children (49 seven to eight year olds, and 50 nine to ten year olds, all native speakers of English without any special needs) on measures of receptive vocabulary, grammatical knowledge, short-term memory, working memory, reading ability, syntactic awareness, grammatical correction and word order correction. The statistical analysis consisted of zero order correlations between all measures.

The results indicated that different language and memory skills were related to different measures of syntactic awareness suggesting that different measures of syntactic awareness are not equivalent. Cain (2007) also states that there is little evidence of correlations between syntactic awareness and reading ability, and the analysis suggested that correlations between the two might arise because of variances shared with language and memory skills. There was also evidence that word reading and syntactic awareness share unique variance that is not explained by vocabulary and grammatical knowledge or memory, and the data also supported that word order tasks depend more on memory than on grammatical correction tasks. Cain surmises that her findings strongly suggest that the relation between syntactic awareness and reading comprehension is indirect and arises from variance shared with vocabulary, grammatical knowledge and memory, and in studies examining syntactic contributions to reading comprehension the syntactic tasks used may affect the possible correlations between the two. This study was reviewed first because its results will affect the way the next studies are critiqued.

Flood and Menyuk (1983) investigated metalinguistic awareness and its relationship to reading ability. They defined metalinguistic abilities as " the ability to make judgments about utterances" (p. 66). For example, metalinguistic abilities include judging whether two sentences are paraphrases of each other or whether a phrase is ungrammatical or does not make sense. They hypothesized that (a) reading ability is directly related to metalinguistic ability; (b) metalinguistic ability develops over time and (c) metalinguistic development is affected by age, reading ability, type of metalinguistic awareness, task requirements, presence or absence of passage context and task type.

Sixty-four subjects participated in Flood and Menyuk 's (1983) study including 16 fourth graders, 16 seventh graders, 16 tenth graders and 16 adults. Within each grade level/age group there were good readers; readers who were reading above the 85th percentile based on a standardized reading assessment, and there were poor readers; readers scoring between the 20th and 40th percentiles on the standardized reading assessment. The good adult readers were college students and the poor adult readers were reading between the 4th and 7th grade reading levels. The participants took part in three processing tasks during three separate testing sessions.

For the writing task, the subjects were told to judge and produce corrections for nongrammatical and anomalous sentences and passages, to paraphrase sentences and passages, and to generate multiple meanings for ambiguous sentences and passages. During these writing tasks the sentences and passages were constantly in view as the participants completed each task.

For the second processing task, the participants were asked to read sentences and passages and judge whether they were nongrammatical or anomalous; they were asked to read two sentences/passages to decide whether they were paraphrases of one another; and they were asked to read sentences and passages to decide whether they noticed the multiple interpretations of ambiguous sentences/passages. The items again were in constant view during the tasks. The third task was the oral task. Subjects were asked to listen to sentences and passages and judge whether sentences were nongrammatical or anomalous and to produce correct versions of the stimuli; to judge whether sets of sentences and passages were paraphrases of each other; to judge whether sentences and passages were ambiguous, and to produce possible meanings for sentences and passages that were ambiguous (Flood & Menyuk, 1983).

A six-way analysis of variance with repeated measures was used to test the Flood and Menyuk (1983) hypothesis. Overall the data suggested that reading ability and metalinguistic abilities are related. The results indicated that reading level accounted for the largest percentage of the explained variance (20%) in metalinguistic abilities, while age/grade level accounted significantly, but to a smaller extent. The results also showed developmental growth of metalinguistic abilities for high readers and lack of this developmental growth for low readers. Also performance in the writing and listening modes appeared to improve with age for high readers, but not for low readers; in addition, producing in the oral and written form becomes equal for high readers after the 4th grade, but does not do so for low readers. In addition, the nongrammaticality task was

the best discriminator of reading ability, and suggests that readers constantly, and automatically, check the texts to determine if it fits with linguistic rules. It is also interesting to note that high fourth graders did poorly on the ambiguity task (e.g. the participants read an ambiguous sentence and had to create multiple meanings for it; John played with the dog while he was eating), and the researchers surmise that this metalinguistic skill develops only after the fourth grade for high readers.

While the Flood and Menyuk (1983) study assessed a variety of metalinguistic abilities in different modalities, it is not clear what modality affected the nongrammaticality judgment tasks the most to the extent that these tasks were the best predictors of reading ability. For example, for the nongrammaticality judgment tasks and sentence reconstructions in the reading and writing modes, the sentences were always in full view so that the participants could go back and refer to them as they reconstructed the sentences. However, in the auditory mode, this was not the case and the participants had to memorize what they heard and reconstruct it from memory. This may have put an extra load on working memory as well as attention, and may have skewed the overall average results of the ungrammaticality tasks across modes. It could be argued that the low ability readers may have had lower working memory capacity for the linguistic stimuli, possibly due to a language processing issue. Working memory, not the type of metalinguistic skill, is what might differentiate the good readers from the poor readers. Also, the amount of attention and focus on the task may also have affected the poor readers results.

Bowey (1986) also investigated the relationship between syntactic awareness and reading abilities. She hypothesized that less skilled readers are inferior relative to skilled readers in syntactic awareness and that syntactic awareness is associated with both ongoing reading comprehension monitoring and ongoing overall reading comprehension. Forty-eight fourth and fifth grade children were assessed for reading comprehension, syntactic awareness and oral reading.

For Bowey's (1986) syntactic awareness tasks the children would hear a sentence that contained an error and they were asked to repeat the sentence exactly as they had heard it. Afterwards they had to repeat the sentence again, but with the error corrected. The children had an opportunity for repetition of the sentences if they were unable to remember what they heard. For the oral reading task children were asked to read a passage and answer questions at the end. If the children came across words they did not know, they had to try to figure them out themselves or guess; no help was given. The comprehension component of the oral reading task was not used in the analyses.

Bowey's (1986) results indicated that skilled and less skilled readers, defined by word decoding skill, differed significantly on the syntactic awareness tasks; decoding ability, versus reading comprehension, was correlated more strongly to syntactic awareness. Bowey suggests that the difference between skilled and less skilled decoders may represent a substantial delay in the development of syntactic awareness. For example, the more skilled decoders may rely on the syntactic cues of the text to facilitate word reading, whereas the

less skilled decoders do not. Also to note in this study, the syntactic awareness task was also auditorally presented, and while the sentences were repeated when needed, the task also put an extra load on working memory, and could be a confounding factor in the results.

Cain and Oakhill (2006) also investigated characteristics of good and poor readers. They examined the profiles of poor comprehenders across a range of language and cognitive abilities to identify whether there are variations of deficits associated with poor reading comprehension between the ages of 8-13. Using a series of assessments that measured vocabulary knowledge, memory, knowledge of syntax, general intellectual ability and specific comprehension skills (e.g. inference and integration skill, comprehension monitoring, knowledge of story structure), they compared two groups of children good comprehenders (n=23) and poor comprehenders (n=23) at the ages of 7-8 (Time 1) and reassessed them when they were 10-11 years of age (Time 2). For the Time 1 data, a series of t-tests revealed that the groups differed in comprehension level skills, specifically verbal working memory, the ability to structure stories, knowledge about the purpose of story titles, inference and integration, and comprehension monitoring. Furthermore, the good comprehenders had significantly higher scores on measures of receptive vocabulary. However, the groups did not significantly differ on the measure of syntactic knowledge during Time 1. Cain and Oakhill surmise that the differences found during Time 1 could have led the poor comprehenders to have impaired reading growth compared to the good readers by the time they were 10 and 11 years old and were tested

again (Time 2). It is important to note that this study included a small sample of children and the results cannot be generalized. Also, although Cain and Oakhill had data about syntactic skills during Time 1, they did not reassess this skill during Time 2 to see if differences in grammatical skills and syntactic processing develop later and may lead to reading comprehension difficulties in the poor readers when they are 10 and 11 years old.

Nation and Snowling (2000) specifically investigated the syntactic awareness skills of groups of children that differed in reading comprehension, but not decoding skills. They wanted to investigate the relationship between syntactic awareness and reading development uncontaminated by individual differences in phonological skills or verbal memory. The participants consisted of 15 poor comprehenders and 15 normal readers matched for decoding skill, chronological age and nonverbal ability. Poor comprehenders were defined as reading at least one grade level below the expected level. The article did not describe the ages of the participants.

For experiment 1a, the researchers constructed 20 sentences with simple subject-verb-object structures, and all the sentences depicted unlikely scenarios in order to reduce the influence of background knowledge. Two lists of 35 sentences were created. Both lists consisted of 10 of the original 20 sentences put into passives, 10 unmodified original sentences, and 15 filler sentences that contained different syntactic constructions. Active sentences were five words long and the passive sentences were seven words long due to the addition of the

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words *was* and *by*. The sentences were presented to the participants in random scrambled order (Nation & Snowling, 2000).

For experiment 1b the researchers constructed 30 sentences with the form: agent – direct object – goal. Each sentence contained eight words and also featured an unlikely scenario. A total of 10 sentences were deemed irreversible due to the fact that only one of the nouns could actually be the agent; the other nouns were inanimate objects. Nation and Snowling (2000) gave the following example for clarification; in the sentence, *The zebra kicked the ball to the corner*, it is clear that *zebra* is the agent, *the ball* is the direct object, and *the corner* is the goal. In contrast, 10 sentences, such as *The zebra kicked the rabbit to the dog* were considered fully reversible as all three nouns were animate and each could act in any position. In addition they constructed 10 final sentences that they labeled medium sentences. These sentences contained two animate nouns and one inanimate. The following sentence is the example provided for clarification: *The zebra kicked the ball to the dog*. All of the sentences were matched for word length and syntactic structure; across the three types (reversible, irreversible, and medium), the sentences contained the same words except where noun characteristics animate/inanimate was manipulated. As in Experiment 1a, the materials were split into two lists. The order of the words in each of the sentences in both lists was scrambled randomly.

The children completed one list from each experiment during the course of two sessions that were conducted one week apart. They were told that they would hear a sentence in which the words were all jumbled up and that they had

to repeat the sentence, putting the words into the right order. Four practice

sentences were completed, before the actual testing took place. The students'

responses were scored correct only if all the words were used and were

grammatically and semantically correct. Analyses of variance were used for

statistical testing (Nation & Snowling, 2000).

For experiment 1a, the results showed that the poor comprehenders

scored lower than the normal reader. The passive sentences were difficult for

both groups, but the poor comprehenders scored significantly less well. However,

both groups scored significantly worse on the passive sentences compared to

the active sentences. For experiment 1b, the poor readers also scored

significantly worse than the regular readers. All the children were influenced by

semantic ambiguity so that the reversible sentences were more difficult than the

irreversible sentences; the medium sentences fell in-between both types in

regards to difficulty (Nation & Snowling, 2000).

Based on these results, the researchers (Nation & Snowling, 2000)

surmise that semantic factors in the form of real world knowledge influences

syntactic awareness as well as sentence comprehension. Also, the results

support the view that children's syntactic awareness skills are related to their

reading ability. They propose that poor comprehenders' impaired syntactic

awareness is due to more general language processing difficulties encompassing

both grammatical and semantic weaknesses, however, they did not assess the

children's' verbal receptive or expressive language skills in order to support this

proposition. Also, language and memory demands were not considered when

choosing this study's measure of syntactic awareness, and the memory demands in the study due to the word order correction tasks may have influenced the results (e.g. they had to listen to the sentences, remember the words in the sentences, and then they had to verbally reconstruct them so that they were grammatically correct) as Cain's (2007) study suggested.

Gottardo, Stanovich, and Siegel (1996) were also interested in the relationship between syntactic processing and reading performance, and while they assessed verbal working memory, they did not account for the memory demands that their syntactic processing tasks had. Specifically, in their correlation study, they wanted to address the relationship between phonological processing and higher order language, cognitive, and memory skills that may be related to reading ability. They tested 112 third graders who were native speakers of English with no history of speech, language, or hearing difficulties. They assessed decoding ability, word recognition ability, reading comprehension, phonological sensitivity, syntactic processing, and verbal working memory.

Although all correlations were significant, the results indicated that syntactic processing failed to account for unique variance in any of the reading ability measures once the working memory and phonological sensitivity tasks were entered into the regression equation (Gottardo et al.,1996). It is important to note however, that their syntactic processing tasks consisted of an auditory sentence judgment and correction task, and as Cain (2007) pointed out, this type of task puts a lot of demand on working memory, and the results may be affected due to these demands; their syntactic processing task may have measured more

verbal working memory than the syntactic processing that they thought they were measuring.

Plaza and Cohen's (2003) study did not use a word order correction task for their syntactic awareness task, and their results were quite different than the above-mentioned study. In their study, Plaza and Cohen wanted to explore the covariant relationship among phonological processing, syntactic awareness, and naming speed processing with French speaking five to seven year olds (n=267; mean age was 6.9). Specifically they were interested in whether the processes underlying naming speed and syntactic awareness independently contribute to both written language development and written language difficulties. The children were tested on measures of written language that included single word reading, pseudo word reading, reading comprehension, pseudo word spelling, and spelling tests. They were also assessed on measures of phonological processing, auditory sequential memory, syntactic awareness tasks, and naming speed involving pictures, digits and letters. The results indicated that syntactic awareness, phonological awareness and naming speed accounted for significant unique variance in reading and spelling skills, indicating that all three variables can be used as predictors of reading and spelling skills.

It is important to describe the type of syntactic task that the children Plaza and Cohen's (2003) study were asked to complete; the children listened to short sentences, and they focused on one word that was not grammatical and then they corrected it. The sentences were short, and they only had to correct one word, not rearrange the whole sentence; although working memory was a factor,

this type of task demanded less working memory than the other previously described studies, and perhaps this could be the reason that syntactic awareness showed significant unique variance.

Holsgrove and Garton (2006) also found that syntactic processing contributed to reading comprehension skills. The authors hypothesized that reading ability of students determines how each individual uses these processes. They wanted to explore whether age has an effect on phonological and syntactic processes, and whether working memory also contributes to how they are processed. They tested 60 students between the ages of 12-13. They assessed reading comprehension, phonological processing, syntactic processing, and working memory. The students were then divided into two separate groups based on their reading comprehension scores, high ability and lower ability.

 For their syntactic processing assessment, the researchers used a modified version of the moving window technique (Ferreria, Henderson, Anes, Weeks, & McFarlane, 1996). This technique allows participants to read a sentence one word at a time by pressing a pacing button to receive the next word in the sentence. Times between the button presses are recorded.

Sentences used in Hoslgrove and Garton's (2006) syntactic processing assessment included subject-subject sentences (e.g., The boy that sees the girl chases the policeman), subject-object sentences (e.g., The boy that the girl sees chases the policeman.), and a conjoined verb phrase in which the analogous parts of the sentence contain a verb and the conjunction "and" (e.g., The pilot bribed the clown and flew the kite in the air). The sentences for this study were

printed on cards to appear as they would on a screen, and the sentences were presented phrase, by phrase instead of word for word. Participants read the sentences phrase by phrase by flipping the pages on the booklet where they appeared. After each sentence, the participants had to answer a true or false question about what they read. Scores were based on the amount of correct responses out of 24. It is important to critique this assessment due to the fact that although it may very well measure syntactic processing, it was not compared to other assessments of syntactic processing, and its validity and reliability was not discussed or examined in this study.

Hoslgrove and Garton (2006) conducted a standard multiple regression with reading comprehension as the dependent variable and all the other measures as independent variables. Results showed the strongest correlation between reading comprehension, the phonological test, and the syntactic processing scores; both phonological processing and syntactic processing made a significant contribution to reading comprehension. Another multiple regression with comprehension as the dependent variables and syntactic and phonological processes as independent variable showed syntactic processing making a greater contribution than phonological processing. The authors conclude that this age group of students' ability on reading comprehension depends on syntactic processing, and that competency in syntactic processing distinguishes competent readers from less competent readers, and that the phonological loop plays small but significant part in the overall process.

In another study investigating syntactic processing as well as fluency, and prosody, Miller and Schwanenflugel (2006) examined the relationship among the prosodic reading of syntactically complex sentences, reading speed and accuracy, and comprehension. Eighty, third grade children were assessed along with 29 adults (the adults were used as the comparison sample). The participants read a passage that incorporated three observations of six targeted linguistic features that require a distinct prosodic reading based on the adults sampled (a) basic declarative sentence (may elicit pitch decline at the end); (b) basic quotatives (may elicit pause following a quote); (c) wh questions (may not elicit upswing in pitch); (d) yes-no questions (may elicit pitch rise); (e) complex adjectival phrase commas (may not elicit pause), and (f) phrase-final commas (may elicit pauses following phrase).

The adults were tested first in order to establish which sentence type were read similarly by adults; if particular sentences were not read consistently in the same prosodic manner then it would be unclear what the target prosody would be when the children read the sentences. The readability of the passage was also taken into consideration in order for the children to be able to decode the words easily. The oral reading recordings were collected using a recorder that records the sound waves, and the data was analyzed using software that is designed to analyze, synthesize, and manipulate digital speech data. In addition to the oral reading of the passage, the children were assessed on word reading efficiency, sight word efficiency, phonemic decoding efficiency, oral reading fluency, and reading comprehension (Miller & Schwanenflugel, 2006).

The results indicated an association between fluency (speed and accuracy) and the prosody of syntactically complex sentences, and pause structures and pitch changes. Children with quick and accurate oral reading made fewer and shorter pauses both at commas and at the end of sentences. The pauses were brief for both within sentences comma markings and before quotative tags, which resulted in reading that the researchers described as smooth and having a fluid quality. On the other hand, children with emerging reading skill read lengthy, and often inappropriately paused within and between sentences, while the good readers paused appropriately, such as at the end of syntactic units. Children with quick and accurate oral reading ended yes and no questions with a pitch rise and ended declarative sentences with a declination in pitch; children with less reading skill ended these sentences with pitch changes that were flat. Miller and Schwanenflugel (2006) hypothesized that once prosodic reading was established, prosody might make a unique contribution to comprehension skill, beyond the comprehension skills attained from quick and accurate reading. This hypothesis was supported only for specific pitch features; higher pitch changes in yes and no questions, and large declinations at the end of declarative sentences. Pausing was unrelated to comprehension skills. It is important to note that they based this hypothesis on previous research that suggests that prosodic reading may provide important syntactic and semantic feedback to the reader, which may assist in comprehension.

Also to note, while the children were assessed on many different reading skills, the researchers neglected to assess their grammatical knowledge and they

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did not take into account how this knowledge may have affected their prosodic

reading and reading comprehension scores. For example, did the children know

to pause at commas, and or pause at periods? If some of the children tested

lacked this knowledge, it would obviously show during their oral reading, but it

could also affect their reading comprehension score on the measure used; in

other words, the authors surmised that reading skill correlated with reading

prosody, but it may be that grammatical knowledge correlated with reading

prosody as well as reading skill. Also, a total picture of prosodic reading was not

taken into account in this study because many features that give prosodic cues

are not as concrete as commas and periods. Many times due to the grammatical

structure of sentences, one pauses as they parse regardless of whether a

comma exists, such as at the end of a syntactic unit (Levasseur, Macaruso,

Palubo, & Shankweiler, 2006). Finally, while the authors used a computer to

determine whether individuals read with the prosodic features in order to avoid

tester bias, they did not discuss the accuracy and reliability of the voice

recognition technology.

Klauda and Guthrie (2008) also wanted to investigate fluency including

prosody. They state that the majority of the time, fluency has only been

measured as word recognition speed, and when it comes to reading

comprehension, the correlations between this kind of fluency and comprehension

has unexplained variances; the researchers decided to break fluency into three

types; word level, sentence level (syntactic level) and passage level

(macrostructure) fluencies and see which correlated with reading comprehension

in an attempt to explain the variances between fluency and comprehension. They also wanted to see which type of fluency ability had the highest correlation with reading comprehension after a 12 week period. Fluency at the word level was defined as how quickly children can correctly identify individual words on a list; fluency at the sentence level was defined as accuracy and speed in processing sentence phrase and syntactic units of text, and fluency at the passage level was defined as expressiveness in oral reading of expository and narrative text (e.g. prosody).

Klauda and Guthrie (2008) assessed 278 fifth grade students from 13 classrooms and three schools. The sample included students with a wide range of reading abilities, from above average to below average. Assessments during Time 1 included a standardized reading comprehension measure, an inferencing measure, a background knowledge measure, a word recognition measure, a measure of fluency at the syntactic level, and a measure of passage reading fluency. At Time 2 the reading comprehension measure and the sentence fluency measure was again used. It is important to point out that although the authors established a rubric to measure oral reading fluency, the passage reading fluency assessment was highly subjective since scores depended on how individual scorers viewed/heard the oral readings. Also, the comprehension and the sentence fluency measures were used twice, only twelve weeks apart, and due to the participants' ability to remember assessment tasks, may have inflated the results of these measures at Time 2, especially for those participants who

had high comprehension scores during Time 1; they would be more likely to remember what they read due to the fact that they comprehended it.

The results indicated that reading comprehension in the Klauda and Guthrie (2008) study correlated moderately to strongly with all variables included in the analysis (word recognition speed, syntactic processing, phrasing, passage-level processing, background knowledge, inferencing, and reading comprehension). In addition syntactic processing at Time 1 strongly correlated with reading comprehension at Time 2, as did reading comprehension at Time 1 and syntactic processing at Time 2. The authors surmise that the findings are consistent with research that suggests fluency and comprehension are linked not only because they both involve processing of individual words, but also because they both involve processing of syntactic units (e.g. Kuhn & Stahl, 2003, Young & Bowers, 1995). The authors believe that assessment of fluency at multiple levels could be important in reading intervention since word, syntactic, and passage level fluency may be remediated in different ways (Klauda & Guthrie, 2008).

Young and Bowers (1995) also examined fluency but in relation to text difficulty. They wanted to find out if the lack of fluency and expressiveness observed in the oral reading of poor readers was simply due to text difficulty, and they wanted to know if phrasal knowledge made a contribution to fluency and expressiveness over and above that of reading accuracy and rate. They also wanted to examine individual differences in reading skill as it related to fluency and phrasal knowledge; phrasal knowledge is related to syntactic processes

because it aids in chunking groups of words into syntactic units (Kuhn & Stahl, 2003; Miller & Schwanenflugel, 2006).

Young and Bowers (1995) assessed 40 average and 45 poor readers in the fifth grade using different grade level reading passages (2nd, 3rd, 5th, and 8th). The assessments used included a reading comprehension assessment, a digit naming speed task, a picture vocabulary test, a phonemic deletion task, and a word identification task using some of the words from the easiest passage. Also, the oral reading of the different level passages was recorded and raters scored them based on fluency, rate, and phrasal pauses. The children were also asked to parse the sentences in each of the stories that they read, and the individual results were compared to those of 10 adult responses who were used as controls in order to verify common phrase boundaries.

Oral reading of poor readers was less fluent and expressive than that of the average readers even on texts that were well within the poor readers reading level; even on the easiest passage, the poor readers were less fluent and expressive than the average readers. A regression analysis predicting fluency in each group by parsing scores suggested that only the average readers used their ability to chunk the texts into meaningful phrases to maintain fluency in grade level texts as well as the harder texts. This shows that average readers use syntactic processes more than the poor readers in order to read and comprehend difficult text. The researchers surmised that phrasal knowledge plays a role in reading expressiveness only for readers with average reading comprehension

abilities, and poor and good readers are in part differentiated by their ability to segment texts into appropriate syntactic phrases (Young & Bowers, 1995).

It is important to note, as mentioned in Chapter 1, that the expressiveness measure used is highly subjective, however, while the ability to chunk words into meaningful syntactic phrases is also normally viewed as subjective specifically when using an auditory measure, the participants of this study (Young & Bowers, 1995) were also asked to parse the sentences on purpose and on paper, and not during the initial oral reading of the passages. In this regard, the parsing was not subjective since the children purposefully parsed the sentences as one of the cognitive tasks.

In another study investigating texts and syntactic parsing on fluency and comprehension, Levasseur, Macaruso, Palumbo and Shankweiler (2006) tested the effects of syntactically segmented text on oral reading fluency in developing readers. They predicted that visual cueing of syntactic structure would aid students in grouping syntactic units in text and thus promote fluency, and in turn facilitate comprehension. In Experiment 1 (Ex1), 32 children in second and third grade participated in the study. The researchers made sure that the children selected were fluent readers for their grade level. Passages adapted from a children's text with a lexile value of 300 were reproduced in two formats equated for mean words per line (6) and mean lines per passage (18). The first format consisted of a structure-preserving condition in which each end of a line corresponded with a clause boundary. The second format consisted of a phrase disrupting condition in which the end of a line interrupted a phrasal constituent.

The children read each passage aloud, and four comprehension questions

followed the oral reading of the adapted passages. The readings were recorded

on audiotape and were scored using the following criteria (a) words correct per

minute; (b) percentage of word errors; (c) a global fluency rating on a scale of 1-4

adapted from the National Association of Educational Progress; (d) percentages

of false starts (e.g. hesitations or stumbles on the first word of each line); (e)

percentage of other disfluencies including hesitations within the line and

stumbles and rereading on any words except for the first, and (f) the percentage

of correct responses to the comprehension questions. The results indicated that

formatting text with line breaks that preserve syntactic structure enabled more

fluent reading, however there was no effect on the comprehension measure

(Levasseur et al., 2006).

For Experiment 2 all participants were third graders tested at the end of

the year. Children's texts were once again used ranging in lexile scores between

500-720. The passages were constructed in the same way as Experiment 1, and

the same procedures were used. The only difference was that the passages

were at a higher reading level, and instead of comprehension questions, the

participants were asked to recall the study verbally. The results of this

experiment were the same as Experiment 1; formatting text with line breaks that

preserved syntactic structure enabled more fluent reading but did not assist in

comprehension (Levasseur Macaruso, Palumbo & Shankweiler, 2006)).

A limitation of both experiments has to do with the reading levels of the

passages selected. The texts used may have been so easy for the participants

(not challenging enough) that the formatted texts really did not aid anymore than if they were to read the passages as they appeared in the original text. The authors state that the participants, based on the standardized reading comprehension measure, were all reading above grade level, however the passages used were considered appropriate for the grade they were currently in (e.g. Ex 1, 2nd grade text for 2nd and 3rd graders; Ex 2, 4th grade text for 4th graders). The texts used were at the participants' independent level of reading where they do not need any help in recognizing words or comprehending the text. However, it would have been more appropriate if the texts selected were at the participants' instructional level, where with some scaffolding such as using syntactically segmented text, the participants would successfully read and comprehend the text.

Although the results indicated that parsing texts does not aid in comprehension, more studies like this one using harder texts or students reading below level could possibly reveal different results in regards to parsed texts and reading comprehension. In a typical classroom many different level readers exist. Perhaps it would be beneficial to syntactically parse the texts for them in order to help the lower ability readers comprehend reading material especially when textbooks become more difficult. These are hypotheses that need to be studied before any determination of whether modifying texts, such as syntactically parsing texts, improves comprehension.

Event Related Potentials and Semantic and Syntactic Processes

ERP's can also be used to measure syntactic and semantic processes as they occur in real time. ERPs are a noninvasive method of measuring electrical activity in the brain during cognitive processing. A cap is placed on the head during the cognitive tasks and the electrodes on the cap pick up this electrical activity. The stimulus that evokes the waves (e.g., a particular word) is time-locked in order to measure the brain's electrical activity during that specific point in time.

The study of the electrophysiology of language started when Kutas and Hillyard (1980) discovered an ERP component that is sensitive to semantic manipulations (N400). Later, other ERP components were discovered that were sensitive to syntactic manipulations (Hagoort, Brown, & Groothusen, 1993; Hagoort, 2008). Researchers who study ERPs have distinguished three types of electrical activity that are elicited during violations of semantic and syntactic information during what they consider to be reading tasks. They are the N400, the P600 and E/LAN respectively.

For this review, only studies investigating N400 and P600 wave amplitudes during sentence listening or reading tasks using children will be discussed due to the fact that they pertain to the proposed research questions and corresponding hypotheses. Research using sentence listening tasks, in addition to reading tasks, has been included in this review because there is very little research in general about the N400 and P600 components in children during sentence reading and/or listening. Research investigating the N400 during

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isolated word (e.g. no context) visual presentation or visual picture tasks will be excluded from the review since they do not pertain to the proposed research questions.

Hahne, Eckstein, and Friederici (2004) compared and examined semantic and syntactic processes during sentence comprehension in children ages 6,7,8,10 , and 13 years and compared the results to data from adults (n=16, n=18, n=23, n=20, n=25 respectively). The materials used consisted of 192 quasi-randomized, auditorally presented German sentences (the study was conducted in Germany). The three types of experimental conditions used consisted of a correct condition (e.g., no word violations within the sentences), a semantic violation condition, and a syntactic violation condition. The children were tested individually. They were fitted with an electrode-cap and sat in a chair in a room away from the experimenter. The EEG data was recorded from 11 electrodes (F7, FZ, F8, FC3, FC4, CZ, CP5, CP6, PZ, O1 & O2) for the six year olds and 19 electrodes for the rest of the children (F3, F4, FT7, FT8, P7, P8, P3, & P4 in addition to the electrodes used for the six year olds). They were asked to listen to sentences presented through a loudspeaker and judge whether the sentences were correct or incorrect by pressing one of two buttons after each sentence. Only children who judged sentence correctness in each experiment condition above chance level were entered into further analysis, and only the trials in which the participants judged correctly were used in the ERP data analysis. In order to obtain and ERP, one needs to record the difference in voltage between two electrode sites. This is done by using a reference electrode

that is not influenced by the stimulus, such as the mastoids electrodes during linguistic tasks. All recordings for this study were referenced to the left mastoid.

Statistical analyses on the ERP data were performed on the mean amplitudes within three time windows for each condition in order to capture latency changes. For the comparison of the correct condition to the semantic violation condition, they chose 300-400, 400-650, and 650-800 milliseconds. For the comparison of the correct condition to the syntactic violation condition they chose 100-300, 400-600, and 600-1500 milliseconds as time windows. All the analyses were quantified using a multivariate approach to repeated measurements and followed a hierarchical analysis schema (Hahne et al., 2004).

For the semantic condition, the results indicated a N400 pattern for all children in all age groups with an earlier onset as children got older. Specifically, children between the ages of 10 and 13 showed a similar timing as adults, and the 7 and 8 year old children showed a delayed N400 component. However, there were no significant differences in component amplitudes between the groups (Hahne et al., 2004).

For the syntactic violation condition, a biphasic ELAN-P600 pattern (e.g. two different wave forms) was not found in all groups; this pattern was found in the adults. This pattern was not observed in children between the ages of 7 and 10. However, a P600 component was present in all groups from 7-13 years. The effect was smaller and present later in the younger age groups. The researchers surmise that the smaller P600 effect is due to the fact that younger children demonstrated a more positive-going waveform even for the correct sentences,

and the findings may point to high syntactic processing expenses even for the correct sentences. It is important to note in relation to the current study proposed in this paper, that the sentences used in Hahne et al.'s (2004) study were passive constructions, and these types of constructions are known to pose processing and comprehension difficulties compared to active sentences (Scott, 2004).

As far as the ERP amplitudes for the six year olds, they showed similar ERP patterns to that of the older children on the semantic violation condition, but not in the syntactic violation condition. For the semantic violation, an N400 component was observed but it was smaller in magnitude when compared to the component's amplitude in the correct condition. These results were interpreted as reflecting difficulty in lexical-semantic integration for both correct and semantically incorrect sentences. For the syntactic violation condition, the six year olds showed a late posterior positivity resembling a P600 between 1250 and 1500 msec. An ELAN was not found for these sentence types unlike the 13 year olds and adults (Hahne, 2004).

It is important to note from an educational perspective, that the children in the Hahne (2004) study were grouped by age for the statistical analyses and to determine mean waves for each of the conditions. While the researchers controlled for neurological and learning disorders, they did not control for differences in normal learning development between individuals as well as age groups. For example, children in the 10 year old group may have varied in

listening comprehension skills, and the means of the sentences in all conditions may have been affected which would ultimately influence the group comparisons.

Atchley, Rice, and Betz et al. (2006) also investigated developmental differences in the N400 component and P600 component between adults and children in spoken language. Fourteen children, ages 8.5-13 years (average age 10.5 years), and 15 adult participants, ages 18-27 (average age 20 years) participated in the study. All participants were native English speakers. The experimental stimuli consisted of 50 sentences, each presented twice. The 50 sentences included 10 sentences ending with semantic anomalous words, 10 semantically correct corresponding sentences, 10 verb drop violation sentences, 10 agreement violation sentences, and 10 syntactically correct sentences. Control and experimental sentences were identical with the exception of the word anomaly, and they were all interrogative sentences. The participants were tested individually in a booth, and were asked to listen to the sentences. At the end of every sentence they were asked to make a grammatical judgment by pressing one of two buttons (Atchley et al., 2006).

For the EEG recordings FZ, FCz,, CZ, CPz, PZ, and OZ sites were used. Each scalp site was referred to the linked mastoids. ANOVAS indicated main effects of sentence type, age, and scalp site. In addition there was a significant interaction between age group, sentence type, and scalp site. The adults N400 was maximal over the parietal site and the cetral parietal sites, and the children's N400 was maximal over the FCz and FZ scalp sites. For the P600, the analyses revealed that adults and children processed syntactic information similarly;

latencies were around 680-692, and electrode sites CPz and PZ. This study examined the N400 and P600 elicited during an auditory sentence task and not during a sentence reading task (Atchley et al., 2006).

Holcomb, Coffey and Neville (1992) also investigated developmental differences in auditory tasks as well as sentence reading tasks with participants ranging in age from 5-26 years. To note, only the 7-25 year olds completed the reading tasks; five and six year olds were not skilled enough readers to be able to read the sentences. In their study they investigated the N400 component as it was elicited in sentences containing a sentence ending semantic anomaly. The sentences used for both tasks ranged from 3-16 words in length, and a total of 160 sentences were used for both the listening and reading tasks. The participants were asked to press a button, indicating whether the sentence was good or not. Grand mean waves between age groups (9 groups for visual stimuli and 10 for auditory stimuli) were averaged for all conditions (normal auditory, violated auditory, normal visual, violated visual) corresponding to the N400 wave amplitudes. All recordings were referenced to linked mastoids

The results in the Holcomb, et al. (1992) study for both the auditory and visual stimuli in reference to the N400 component showed amplitude, topographical, and latency differences due to age. Amplitude and latencies decreased with age, and occurred linearly from 5-16 years of age; after 16 years the amplitudes and latencies stabilized. Similar to Atchley et al.'s (2006) results, Holcomb et al. (1992) also found an interaction involving the age of the participants, scalp location of the N400, and influence of sentence context on the

N400 amplitude; children ages 5-14 showed a large N400 amplitude for all sentence types (semantically incongruous and control), and maximal over more anterior site. The N400 for the older age groups (age 17+) was maximal over more posterior locations, and occurred only for semantically incongruous sentences. In regards to sentence modality, the auditory sentence modality showed larger effects than the visual modality (Holcomb et al., 1992). This could be due to the fact that in comparison to the control conditions (unviolated sentences) reading is harder to process than listening (e.g. the brain needs to integrate more information when reading than when listening), and when the corresponding mean waves are compared, the relative differences between the auditory control condition and auditory violated conditions are greater than the relative differences between the visual control conditions and visual violated conditions because the visually controlled condition also elicited a higher N400 amplitude .

It is also important to note that while the researchers took sentence "readability" (e.g. pronunciation of the words) into consideration (Holcomb et al., 1992) the researchers did not take sentence comprehension difficulty into consideration. While all the sentences were simple declarative, they ranged in lengths from 3 to 16 words. The amount of words in a sentence contributes to the sentence difficulty, and many of these sentences may have been too difficult to comprehend for the youngest participants even if they were able to read the sentences fluently.

While the Holcomb et al. (1992) study was ambitious in that it is considered to be the first one examining the N400 component in visually presented sentences with children, there is a very important confounding variable that cannot be overlooked such as the one mentioned above. To note, while the researchers of this study are very knowledgeable about neuropsychology, they do not have a background in literacy education and reading development. While this study has merit from the neuropsychological perspective, it poses red flags from the reading development and literacy education perspective especially since the longer sentences would be considered too difficult for the youngest participants in relation to their reading abilities, and clearly more research needs to be conducted that study semantic and syntactic processes and reading development.

Using expert knowledge from both the fields of reading education as well as the neurocognitive sciences a clearer picture of reading development can be produced. This study attempts to bridge part of the gap between brain research and educational research in the area of literacy. Researchers who study reading processes can benefit from the input of reading educators during the cognitive task development, methodology, as well as the interpretation of results. Likewise, reading researchers can benefit from multiple perspectives, and certain neuroscience results may be beneficial to classroom practices. However, they may be overlooked due the reading educators' inexperience with brain research and the neuroscientist inexperience with reading education.

It is important that all disciplinary fields involved have some interdisciplinary knowledge for this research to reach its full potential.

Summary

The process of reading is very complex, and from an interactive perspective, many processes work together for reading comprehension to take place. When making meaning of text, readers use their background knowledge, as well as their syntactic and semantic processes in order to make sense of what is being read. Also, while these processes are considered higher order processes, they also affect lower level processes. For example, the reader can use background knowledge of letter-sound correspondence (phonetic processes) in order to decode words, and the perception of a decoded word is also influenced by the syntactic and semantic environments in which it is encountered (Rumelhart, 1984/2004; Stanovich, 1980).

All these processes are important for fluent reading and comprehension. A breakdown in these processes can lead to difficulty in reading text. While most 4th-7th graders do not have fluency and decoding problems, many encounter difficulty in reading comprehension when their texts become harder and more expository in nature (Deane, et al., 2006). While the lower level processes are intact, higher level processes, such as syntactic and semantic processes may not be working together efficiently; studies examining these higher level processes indicate differences between normal readers and readers with comprehension difficulties (Bowey, 1986; Cain & Oakhill, 2006; Cain et al., 2003; Flood & Menyuk, 1983; Holsgrove & Garton, 2006; Nation & Snowling, 1998).

Furthermore, ERP studies have found differences between age and components that measure these processes (Hahne, et al., 2004; Holcomb, et al., 1992). However, there is a large gap in the literature investigating neuroscientific reasons to the development of reading comprehension problems from an educational perspective. The proposed study attempts to start bridging this gap. Specifically it will examine the differences in syntactic and semantic processes of fluent readers with varying degrees of reading comprehension ability in the 2nd-7th grades using behavioral as well as electrophysiological measures.

The next chapter will describe the methodology proposed for this research. It will describe the participants, behavioral assessments, stimuli used for the electrophysiological measures, as well as the statistical analyses used to help answer the research questions.

Chapter III:

Methodology

This chapter describes the methods employed in this study. First the

participants are described. Next, the methods of collecting both the behavioral

data and the electrophysiology data from the participants are described.

Additionally, the assessment tools used to gather the reading fluency, reading

comprehension, and ERPs are discussed, followed by an explanation of the

analyses used to examine the data.

The data analyzed were obtained from a related ERP study examining

reading development (VanDyke, unfinished dissertation; see Appendix A).

Therefore, the participants and the measures come from the VanDyke study.

However, in this study the EEG data is analyzed using different target words,

different ERP time windows to fit the research questions, and participants are

grouped using the behavioral data assessment.

Participants

Forty-six children ages 7-13 and 18 adults participated (adults were

between 21-35 years of age). However, due to artifact contamination, noisy EEG

waves, and age considerations when grouping, only the ERPs from 33 of the 46

children were used for the statistical analyses. The participants were split into

three separate groups based on reading comprehension abilities

(higher/lower/adults) for the first set of analyses, and on reading fluency levels (higher/lower/adults) for the second set of analyses (see Appendix B & C for details).

For the comprehension groups, the Lower Group (n=15) ranged in comprehension scores from grade1.2-6.2 reading levels (average comprehension score was 4.43 grade level) and their age ranged from 7 to 12 years (average age 8.9). The Higher Group (n=15) ranged in comprehension scores from grade 7 to 12.7 (average comprehension score was 9.08 grade level), and their ages ranged from 7 to 12 years of age (average age 10.6). For the second set of analyses, the lower fluency group (n=15) ranged in fluency scores from third to sixth grade levels (average fluency score was 4.9 fluency grade level), and their ages ranged from 7 to 13 years (average age 9.3). The higher fluency group (n=15) consisted of children with fluency levels between 6.2 grade level through 12.7 grade level (average fluency grade was 9.8). Their ages ranged from seven to 12 years (average age 11.1). The adults consisted of a group of 18 undergraduate and graduate students [the same adult grouping were used for both (comprehension and fluency) analyses, and they were not tested for comprehension or fluency levels; based on their level of education, it was assumed that their comprehension scores and fluency scores were high. Children were recruited from various schools and community locations; they were paid $20 dollars an hour, for a maximum of three hours, for their participation. In order to be included in the related study (VanDyke, unfinished dissertation; see Appendix A for description), child participants were asked to sign assent forms

and parents signed consent forms. All adults signed consent forms.

All participants were right-handed, monolingual native speakers of English, testing within at least the normal limits of reading fluency skills for their grade level, and with normal or corrected vision. Also, participants did not have a history of neurological disorders and/or injuries, or have a history of speech or language impairment, and were not taking any medication that could have affected cognitive function (e.g. anti-depressants). Efforts were taken to include a representative sample of participants, although Latinos were not used in this study due to the above-mentioned exclusion criteria (e.g. they must be monolingual).

Materials

The Gray Oral Reading Test-4. The GORT-4 (Wiederholt and Bryant, 2001) was chosen as the behavioral assessment in this study because it is a norm referenced reliable and valid test of oral reading rate, accuracy, fluency, and comprehension. It has two parallel forms, Form A and Form B, each containing 14 separate stories; form A was used in this study. Five multiple-choice comprehension questions follow each story. While the GORT-4 is norm-referenced for individuals ages 7 years 0 months through 18 years 11 months, and the overall reading composite score is reported as a quotient (a type of statistical score with a mean of 100 and a standard deviation of 15), age equivalent scores, grade equivalent scores, and percentile ranks can also be obtained based on individual rate, accuracy, fluency, and comprehension scores.

The reliability coefficients for the GORT-4 expand over three sources of error variance: content sampling, test re-test, and interscorer differences for rate, accuracy, fluency, comprehension, and oral reading quotient. The reliability is high across all three types, and the magnitudes of the coefficients round to or exceed .90. A considerable amount of evidence shows that the GORT-4 is also a valid measure of reading performance (see GORT-4 Examiner's Manual, 2001 for details).

Sentences. A total of 192 experimental sentences were read by the participants; the sentences were read in two blocks of 96 sentences each. Of the 192 sentences, only the data from the first block (first 96 sentences) were used for the statistical analyses in this study; the second set of sentences consisted of different sentence constructions which is why they were excluded. Twentyfour sentences for each of the below mentioned sentence types were included in the analyses. Active Control (AC) sentences contain no thematic role violation; Active Violation (AC) sentences contain a semantic mismatch between the main verb and the sentence ending noun; Passive Control (PC) sentences contain no thematic role violation; Passive Violation (PV) sentences contain a semantic mismatch between the main verb and the sentence-ending noun.

Table 4: Sample Sentences.

Active	The woman was watering the <u>plant</u>.
Passive	The plant was watered by the <u>woman</u>.
Active Violation	The plant was watering the <u>woman</u>.
Passive Violation	The woman was watered by the <u>plant</u>.

The verbs used in the sentences were carefully selected from a standard word frequency index (Zeno et al., 1995). This index (SFI) is an estimate of the frequency with which a particular word appears per million words across classroom-based texts in grades 1 through 13. Verbs with a SFI between 40-60 were used. In addition, the verbs were selected based on the frequency that they appeared in 2nd, 3rd, 5th and 6th grade texts. Only verbs that appeared in all four grade level texts were used. In the construction of control sentences, verbs were matched with semantically related noun phrase arguments using the *University of South Florida Word Association, Rhyme, and Word Fragment Norms* (Nelson, McEvoy, &Schreiber, 1998). The verbs were located using Table A, and a noun phrase (NP) that was semantically related was selected from the list for each verb or a judgment was made to develop a proper related phrase, (VanDyke, unfinished dissertation). The ratio of actives to passives sentences and violations to controls was kept equal across the experiment to prevent participants from associating a particular verb form with any condition (Coulson, King, & Kutas, 1998). The sentences were piloted in a second grade classroom as well as during an ERP testing session with a third grader to ensure their readability.

Electrophysiological Measures

In this study, EEG recordings of participants reading four sentence types, active control (AC), active violation (AV), passive control (PC), and passive violation (PV) are analyzed. Amplitude data from these sentence types are used in the statistical analyses that grouped participants by reading comprehension

abilities for the first set of analyses and reading fluency levels for the second set of analyses.

Apparatus and recording. Participants were seated in a dimly lit, sound attenuated booth at a distance of approximately 36 inches from the computer monitor. A continuous electroencephalogram (EEG) was recorded, with Cz referenced at a sampling rate of 500 Hz with 32-bit accuracy from a 64-channel QuikCap. Neuroscan SCAN software was used interfaced with SynAmps2 amplifiers.

Procedures

Before signing consent forms and attaining parental permission, the participants were given a description of what they were expected to do. The participants had an opportunity to look at the electrode cap, and were informed of how the brain waves were recorded from the electrode cap. They were shown the blunt needle used, as well as the saline gel that was to be injected into the electrodes on the cap. Also, they had an opportunity to go into the sound attenuated booth where the electrophysiological testing would take place. It was emphasized that if at any point during testing they wanted to stop, they could. After the description of the study and expectations, participants signed consent forms and received parental permission.

Behavioral assessment. The youngest participants (seven and eight year olds) were assessed for oral reading fluency and oral reading comprehension grade level equivalents using the GORT-4 following the instructions in the examiner's manual. The older child participants were given the

GORT-4 either before or after the ERP testing depending on the number of children or adults who were tested during a specified block of time. Participants were assessed using the GORT-4 in the sound attenuated room where the ERP testing took place or in another quiet room close to the ERP lab, for approximately 20-30 minutes.

Electrode cap and EEG recording. After the reading skill data were gathered (for the youngest participants and some of the older participants), they were fitted with an electrode cap (some of the older participants were fitted with the electrode cap first). The sentences were presented on a computer screen using E-prime experimental delivery software. Each trial consisted of the following events: a fixation cross appeared in the middle of a white rectangle surrounded by a black screen for 700 milliseconds. After the fixation cross, each sentence was presented on a word-by-word basis. Each word was presented for 650 milliseconds followed by a blank screen interval of 50 milliseconds, for a total of 700 milliseconds between words. Sentence-ending words were followed by a period.

The timing of the presentation of the words was based on average reading rates of second and third graders. Caldwell (2008), states average reading rate for these grade levels range from 43 to114 words a minute. In addition, Bowey (1985) showed that when words are presented in context, they are read 50 percent faster than when they are presented in isolation. For this study, words were presented at a timing of approximately 83 words a minute (1 word every 700 msec.). Furthermore, prior to EEG recording, participants practiced reading

sentences at this rate, and they were assessed during the practice task to make sure they were able to keep up with the timing of the word presentation.

A 1450 millisecond blank screen interval followed each sentence, and then a prompt was presented asking participants to decide if the previous sentence was a normal sentence of English. Participants had 1400 milliseconds to respond to this question. Participants were instructed to answer "Good" if the sentence was semantically coherent and grammatically well-formed and "Not so good" if the sentence was not well formed. Participants responded by pressing one of two buttons from a small box located directly in front of the participants hands. The data acquired from this grammatical task will not be used in my study for any other purpose other than to make sure the participants were paying attention. This was assumed if the amount of correct answers was above chance level (+/- 65%). Based on the results, all participants included in this study were paying attention.

During the main testing session, participants were instructed to limit neck and trunk movements and blink as they normally would, but not excessively. ERP testing lasted for approximately 30 – 40 minutes. Each participant read a total of 192 sentences (only the first 96 sentences were used in this study); the participants had an opportunity for a long break (+/- 10 minutes) after the first block (e.g. after they read the first 96 sentences). Trials were presented as a series of 16 sentences, and participants also had an opportunity to take a quick break after each trial (+/- 3 minutes). Breaks were encouraged so the participants did not fatigue during the testing. Sentence types were pseudo-randomized to

ensure a gap of at least 4 sentences between sentences containing the same verb. All participants viewed the sentences in the same order.

Word identification task. After the electrophysiological testing, the youngest participants and participants with comprehension and/or fluency levels at grade 3 or below, were asked to look at flashcards containing the verbs and nouns found in the sentences that were read during the electrophysiological testing. They were told to place each word on one of three colored boxes. The words placed on the green box signified that they knew the word and could use it in a sentence. Words placed on the yellow box signified that they knew or have heard the word, but were unable to use it in a sentence or supply a definition for it. Finally, words placed on the red box signified that they were not familiar with the words at all. All participants identified the words correctly .

Data Analyses

Epochs and time windows. The EEG data were analyzed between 100ms before the onset of the target word through 900ms after the onset of the target word for the sentence ending nouns. Different time windows (TW) to cover potential latency shifts between groups were also analyzed. The following four TWs were used: TW1 250-350, TW2 350-450, TW3 450-550, and TW4 550-650. These time windows were selected after visual inspection of the data, and after review of the literature that examined the N400 component using similar conditions (Atchley et al., 2006; Holcomb et al., 1992; Kutas & Hillyard, 1984).

EEG corrections and rejections. Before averaging and ANOVAs were performed, trials containing artifacts due to eye blinks were corrected in order to

save as many trials as possible (Picton et al., 2000). An Independent Component

Analysis (ICA)-based (Bell & Sejnowski, 1995) ocular artifact correction

procedure modified from Dien (2005) was used. This ICA approach has been

reported in published articles as a process to accurately identify and remove

ocular artifact without significantly warping or skewing ERP variance (Maxfield,

Lyon, & Silliman, 2009). Participants who lost trials due to ocular artifacts and

whose waves were unable to be corrected using the above mentioned method

were excluded from the statistical analyses; a total of 9 child participants from the

46 tested were excluded due to ocular contamination.

After the ocular correction of the remaining participants, the data were

subjected to a bad channel (e.g. bad electrode) check. Channels whose fast-

average amplitude exceeded 200 microvolts were marked bad; as were channels

whose differential amplitude exceeded 100 microvolts because they interfered

with the amplitudes of interest. If during any single trial (trial=sentence) more

than three bad channels were detected, the trials containing three or more bad

channels were excluded from the analyses. Those trials with two or fewer

detected bad channels were corrected using spherical spline interpolation. Using

this procedure no more than one trial per sentence condition was lost due to bad

channels (e.g at least 23 sentences of 24 possible sentences were used for each

condition for each participant). All adults participants (n=18) were included. After

ocular correction, data were re-referenced to linked mastoids, and baseline

corrected.

Grand averaging. For repeated measures ANOVAS (using the Greenhouse-Geisser correction) electrodes were grouped on the basis of Anteoposterior (anterior, central, and posterior electrodes), laterality (left and right hemispheres, and midline electrodes), and four conditions per subject following Dien and Santuzzi (2005) recommendations. Between group analyses include factor Group (3 levels). The dependent repeated measure factors included sentence type (four levels), time window (four levels), and regions of interest (9 levels). Mean amplitudes were computed for time windows of interest for the epoch targeting the sentence ending nouns.

N400 amplitudes were analyzed using a mean amplitude measure instead of a peak amplitude measure based on previous studies of the N400 components. This ERP component tends to have a more heterogeneous morphology that does not provide a definite point at which to measure the peak amplitudes. Also mean wave amplitudes are recommended over peak amplitudes when unequal trials numbers are expected due to artifact contamination; mean amplitude measures are preferable when not all trials are able to be used and comparisons between conditions would have unequal trial numbers (Handy, 2005). In addition to analyzing the mean wave amplitudes between groups, latency and scalp topography were examined.

Summary

This research study focuses on semantic and syntactic processes between different reading comprehension and reading fluency level groups in order to investigate whether reading comprehension and fluency levels affect the

way sentences are processed in respect to the N400 effects. Data for this study comes from a related study that focused on linguistic development (VanDyke, unfinished dissertation). Participants consisted of children ages 7-13 recruited from schools and community locations in the Tampa area and adults (USF students). Reading comprehension abilities and reading fluency levels were used to place the children into groups. All participants were right-handed, monolingual native speakers of English. They were fluent readers for their grade level, without a history of neurological disorders or injuries, speech, language or reading impairments, and didn't take medication that could affect cognitive function.

Reading comprehension scores, fluency scores, ERP data, and word knowledge data were collected from each participant in one, 2-3 hour testing session. Reading comprehension scores were used to group children into a level of reading functioning group (higher vs. lower). In addition, data from the word identification task, that determined whether the child knew the individual verbs and nouns presented in the sentences, were used in order to exclude ERP data in the analyses from sentences that contained words an individual participant did not know. All participants knew all the words. Finally, repeated measures ANOVAS were used in the statistical analyses using group mean wave amplitudes for four time windows in order to see if group differences existed between comprehension and fluency levels in respect to the N400 wave amplitudes when reading target words in active and passive sentences, and in sentences containing semantic violations. Chapter IV will review the results of the statistical analyses.

Chapter IV:

Results

The purpose of this study was to see if reading abilities had an effect on the

N400 event related potentials (ERP). The N400 measures the electrical response

elicited when the brain identifies semantically familiar and unfamiliar words as

well as semantic sentence context with congruous and incongruous words

(Kutas, VanPetten, & Kluender, 2006). Researchers have consistently reported a

negative peak, around 400 milliseconds, from the onset of the incongruous (or

unfamiliar) semantic content (Berkum, Hagoort, & Brown, 1999; Kutas & Hillyard,

1980; Osterhout & Nicol, 1999). It was hypothesized that N400 amplitudes,

elicited by sentence final words in four sentence conditions, would differ among

groups of readers with different reading skills.

This chapter first describes how the ERPs were measured and analyzed.

Then it describes the differences between the groups in regards to group

member reading abilities and ages. Afterwards the results of the comprehension

groups' analyses are explained followed by the results of the fluency groups'

analyses.

ERP Analyses

The ERPs were analyzed by calculating individual mean amplitudes of 51

participants (originally 64 participants were tested, but 13 were excluded from

statistical analyses; see Chapter III for details). The means amplitudes were then averaged for each region of interest, depicted in a following graphic. Four time windows (TWs) were used in order to allow for potential latency shifts (e.g. a group may elicit maximal negativities at a different TW than the other groups).

Time windows were chosen after careful inspection of the data, and occur in 100 milliseconds time periods within the -100-900 msec epoch. The four TWs chosen were: 250-350, 350-450, 450-550, and 550-650. These time windows were chosen based on visual inspection of the waves; the first time window begins approximately when the waves pass below the baseline, and the last time window ends when the waves pass above the baseline. Time windows were also chosen based after review of the literature that examined the N400 component using similar conditions (Atchley et al., 2006; Holcomb et al., 1992; Kutas & Hillyard, 1984).

In averaging the electrode data, regions of interest (ROI) were used instead of individual electrodes in order to take advantage of the high density electrode caps used in this study. Figure 1 shows the electrode groupings ROI.
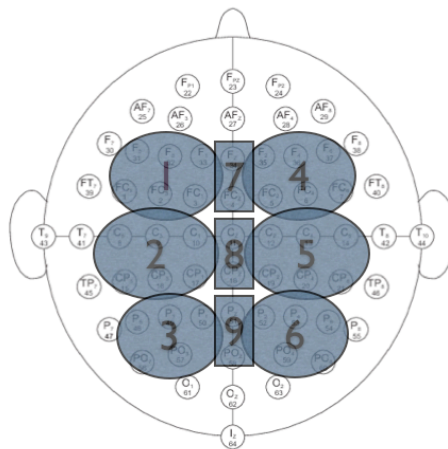
Figure 1. Regions of Interest. Regions are shaded and numbered.

Grand means for each group (low comprehension, high comprehension, low fluency, high fluency, and adults) were then calculated by averaging together the individual mean amplitudes of the participants in each group, for each of the time windows, for each of the ROI. Amplitudes were analyzed with repeated-measure ANOVAs (using Greenhouse-Geisser correction). Midline ROI (e.g.7, 8, 9) were excluded from the initial run since electrode groupings took hemisphere into consideration; when hemisphere is an electrode grouping factor, Dien and Santuzzi (2005) recommend running a separate ANOVA for the midline regions since the midline regions do not have a matching site (e.g. region 1 in the left hemisphere matches with region 4 in the left hemisphere; region 2 matches with region 5, and region 3 matches with region 6). Factors for the initial ANOVAs were sentence condition (active, active violation, passive, passive violation), electrode region (Anterior Left, Central Left, Posterior Left, Anterior Right, Central Right, and Posterior Right), TWs (250-350, 350-450, 450-550, 550-650), and Groups (Higher, Lower, Adults). For the midline ANOVAs all factors were the same as the initial ANOVA except for the electrode regions; only Anterior Midline, Central Midline, and Posterior Midline were included. For all analyses (comprehension groups regions 1-6, comprehension groups midline regions, fluency groups region 1-6, and fluency groups midline regions) ANOVA results are reported with the Greenhouse-Geisser epsilon correction. All post hoc contrasts are analyzed using a modified Bonferroni (Holm, 1979) correction.

In order to acquire the ERP wave amplitude data for the sentence ending words, all participants were asked to read 96 sentences, one word at a time, on a

computer screen. Electrophysiological recordings were taken during the sentence reading task. The electrophysiological data was epoched to the last word of each sentence starting from -100 milliseconds from the start of the last word to 900 milliseconds after the onset of the last word. After careful visual inspection of the average data for each group for the 1000 millisecond epoch, four time windows were chosen to compute mean wave averages and to input into a repeated measures ANOVA.

Results

The main questions guiding this investigation, are whether reading abilities have an effect on the N400 amplitudes during the processing of the final words in sentences; specifically active sentences with thematic role violations, passive sentences, and passive sentences with thematic role violations. The comprehension groups (lower and higher) differed in comprehension abilities by approximately 4 and a half grade levels (see Appendix B for details), and the fluency groups (lower and higher) differed in fluency by approximately 4 grade levels (see Appendix C for details). The lower and higher comprehension groups both had children with age ranges between seven and 12 years. The lower fluency group had children between the ages of seven and 13 years, and the higher fluency group had children with age ranges between seven and 12 years.

Since previous research using visually presented sentences grouped children by age and not by reading ability, a t-test was performed between the lower and higher comprehension groups and between the lower and higher fluency groups to see if there were significant differences in ages between the

groups. The t-test revealed significant results between the groups, $t(28)= -2.76$, $p<.05$ (for comprehension groups) and $t(28)=-3.36$, $p<.05$ (for the fluency groups). While these differences may affect the results of the N400 amplitudes in this investigation as shown in other research (Holcomb, Coffey & Neville, 1992), one also needs to consider the limitations of this previous research on the N400 since reading abilities were not taken into consideration in the groupings, and reading skills are learned (Wolf, 2007) and are not innate.

When individuals learn something, whether it is learning how to play a musical instrument or how to compute difficult mathematical problems, neuronal networks are changed. For example, depending on the instrument played, neuronal networks are altered by continuous practice so that the ability to play the instrument becomes more efficient due to stronger neuronal connections within the network (Münte, Altenmüller, & Lutz, 2002).

A neuronal network is composed of groups of connected or functionally associated neurons. Neurons are essentially the building blocks of the brain, and they consist of dendrites, cell body and axon. They talk to each other by sending electrical signals that are positive and negative. When an electric signal reaches the end of an axon of a neuron, that neuron releases neurotransmitters. The neurotransmitters then reach a terminal of a dendrite of the other neuron, and change the neuron's resting potential. Electrical signals can be either excitatory or inhibitory and they can either excite or suppress the activity of other neurons depending on the electrical signal received (Brodal, 2010). When an ERP has a positive polarity it is a measure of inhibition, and when it has a negative polarity it

is a measure of excitation (Axmacher, Elger, & Fell, 2009).

White brain matter is made up of axons of nerve cells that are covered in myelin, a specialized substance that insulates the neuron and that makes neural communication more efficient. Research shows a correlation between white matter and reading ability in children as well as adults when age is controlled (Niogi & McCandiss, 2005). Due to research suggesting the relationship between neuronal networks and different learned abilities, it is important to consider the affect of reading ability on ERPs and not completely discard results because of age differences between the groups; reading differences between the groups could have very well been a confounding factor in previous research investigating the N400 and age, yet the research is still of value in regards to language development and semantic processes. Since the ability to read is learned, and the more a person reads the more proficient they become at reading (Stanovich, 1986), perhaps the neuronal networks are stronger and more efficient in more proficient readers than less proficient readers as research suggests (Niogi & McCandiss, 2005), and this efficiency can lead to reduced N400 amplitudes. With this in mind, the following are the main findings of this study.

Comprehension groups. The significant differences in N400 like negativities between the active versus the active violation, active and passive sentences, and passive sentences and passive violation sentences occurred in the anterior regions (regions 1, 4, and 7) for the comprehension groups. It is interesting to note that while other studies show greater N400 negativities in the posterior regions for the adults, and in the anterior regions for children (Atchley,

Rice & Betz et al., 2005; Hahne, Eckstein, & Friederici, 2004; Holcomb, Coffey, & Neville, 1992) following semantic anomalies, this study showed the significant negativities occurring in the anterior regions for all the groups. As hypothesized, amplitude averages (see Appendix D) show that the lower comprehenders had larger negativities for all conditions compared to the higher comprehenders, and the higher comprehenders had larger negativities for all conditions compared to the adults. The lower comprehenders had the largest relative differences between the conditions compared (e.g. active versus active violation, active versus passive, and passive versus passive violation). See Appendix E for details. Tables 5 & 6 show the results of the initial ANOVAs for the comprehension groups.

Table 5: ANOVA Summary Table for Regions 1-6 for Comprehension Groups

Source	df	SS	MS	F	p
Between Subjects					
Group	2, 45	1843.14	921.57	.72	.49
Within Subjects					
Region	5, 225	22103.40	4430.68	46.09	**<.0001**
Condition	3, 135	740.62	740.62	2.70	.0572
TW	3, 135	3844.55	1281.52	11.23	**.0001**
Region*Group	10, 225	4082.88	408.29	4.26	**.0009**
Condition*Group	6, 135	1119.68	186.61	.64	.66
TW*Group	6, 135	1049.95	174.99	1.53	.2075
Region*Condition	15, 675	561.82	37.45	2.63	**.0178**
Region*Condition*Group	30, 675	339.54	11.32	.77	.6763
Region*Time	15, 675	1356.90	90.46	12.36	**<.0001**
Region*Time*Group	30, 675	233.84	7.79	1.06	.3875
Condition*Time	9, 405	261.24	29.03	1.95	.0655
Condition*Time*Group	18, 405	397.35	22.08	1.48	.1211
Region*Condition*Time	45, 2025	151.72	3.37	2.82	**.0007**
Region*Condition*Time*Group	90, 2025	186.61	2.07	1.73	**.0146**

∞=.05. Significant results are in bold.

Table 6: ANOVA Summary Table for Midline Regions for Comprehension Groups

Source	df	SS	MS	F	p
Between Subjects					
Group	2, 45	3882.11	1941.06	2.21	.1214
Within Subjects					
Region	2, 90	4982.63	2491.31	29.95	**<.0001**
Condition	3, 135	1669.58	556.53	2.86	**.0466**
TW	3, 135	4408.25	1469.42	16.66	**<.0001**
Region*Group	4, 90	712.05	178.01	2.14	.0942
Condition*Group	6, 135	542.06	90.34	.46	.8120
TW*Group	6, 135	827.70	137.95	1.56	.2021
Region*Condition	6, 270	377.07	62.85	3.04	**.0219**
Region*Condition*Group	12, 270	89.14	7.43	.36	.9317
Region*Time	6, 270	933.57	155.60	19.34	**<.0001**
Region*Time*Group	12, 270	193.84	16.15	2.01	.0840
Condition*Time	9, 405	218.04	24.23	2.27	**.0310**
Condition*Time*Group	18, 405	247.62	13.76	1.29	.2160
Region*Condition*Time	18, 810	59.23	3.29	2.03	**.0425**
Region*Condition*Time*Group	36, 810	120.16	3.34	2.06	**.0098**

∞=.05. Significant results are in bold.

     The main effect of region, $F_{(5, 225)}$=46.09, p<.0001, for the ANOVA
consisting of regions 1-6, was modified by condition (e.g. sentence type) as
shown in the region*condition significant interaction, $F_{(15, 675)}$=2.63, p=.0178.
Similarly for the midline regions ANOVA, the main effect of region [$F_{(2, 90)}$=29.95, p<.0001] was also modified by condition as shown in the
region*condition interaction, $F_{(6, 270)}$=3.04, p=.0219. Post hoc tests by region
reveal statistical significant differences between active and active violation
sentences, active and passive sentences, and passive and passive violation
sentences for the anterior regions (1, 4, & 7) explaining the interaction. No other
areas showed significance for all conditions compared (e.g. regions 2, 5, 8
showed significance only with one or two of the compared conditions, but not all).
See Appendix H for details on comprehension groups' post hoc results.

     Furthermore, region*condition interactions were modified by time for regions
1-6 ANOVA, $F_{(45, 2025)}$=2.82, p=.0007, and for midline regions ANOVA, F(18,

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810)=2.03, p=.0425. Based on post hoc analyses, the above-mentioned

significant results for the anterior regions occurred during TW 2 (350-450 msec.).

Finally, the region*condition*time interactions were modified by group for

regions 1-6 and midline regions F(90, 2025)=1.73, p=.0146 and F(36, 810)=2.06,

p=.0098 respectively. However post hoc contrast between groups revealed no

significant results.

Figures 2, 3, and 4 depict visual representations of the waves for the lower

comprehenders (Figure 2), higher comprehenders (Figure 3) and adults (Figure

4). The electrodes depicted belong to each of the ROIs. The visual

representations show the ERP waves from -100 milliseconds before the onset of

the target words (last word of the sentences) to 900 milliseconds after the onset.
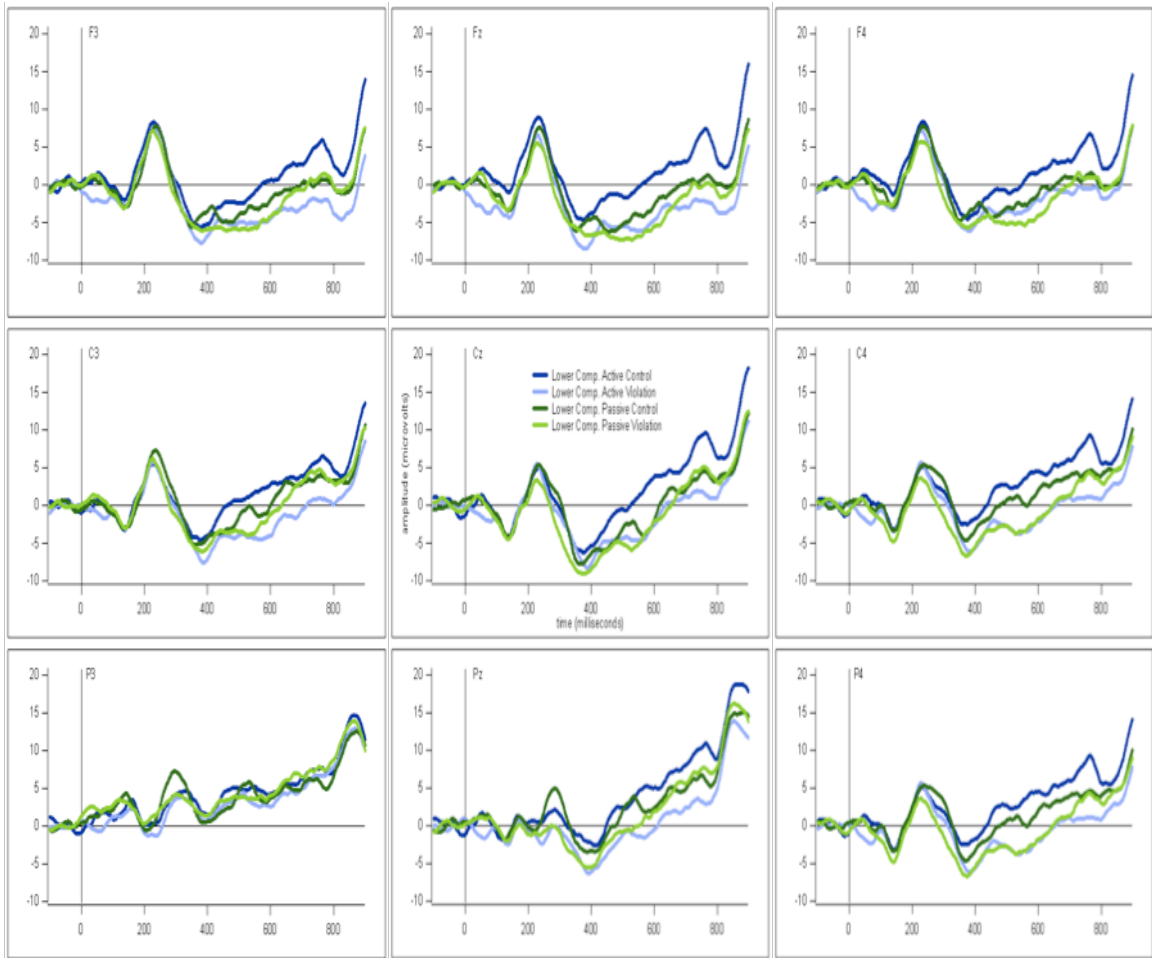
Figure 2. Lower Comprehension Group Average Wave. Waves for active, active violation, passive, and passive violation sentences. Each graph represents an electrode within each ROI. The dark blue line represents mean group amplitudes for the active control sentences, the light blue line represents mean group amplitudes for the active violation sentences, the dark green line represents mean group amplitudes for the passive control sentences, and the light green line represents the mean group amplitudes for the passive violation sentences.
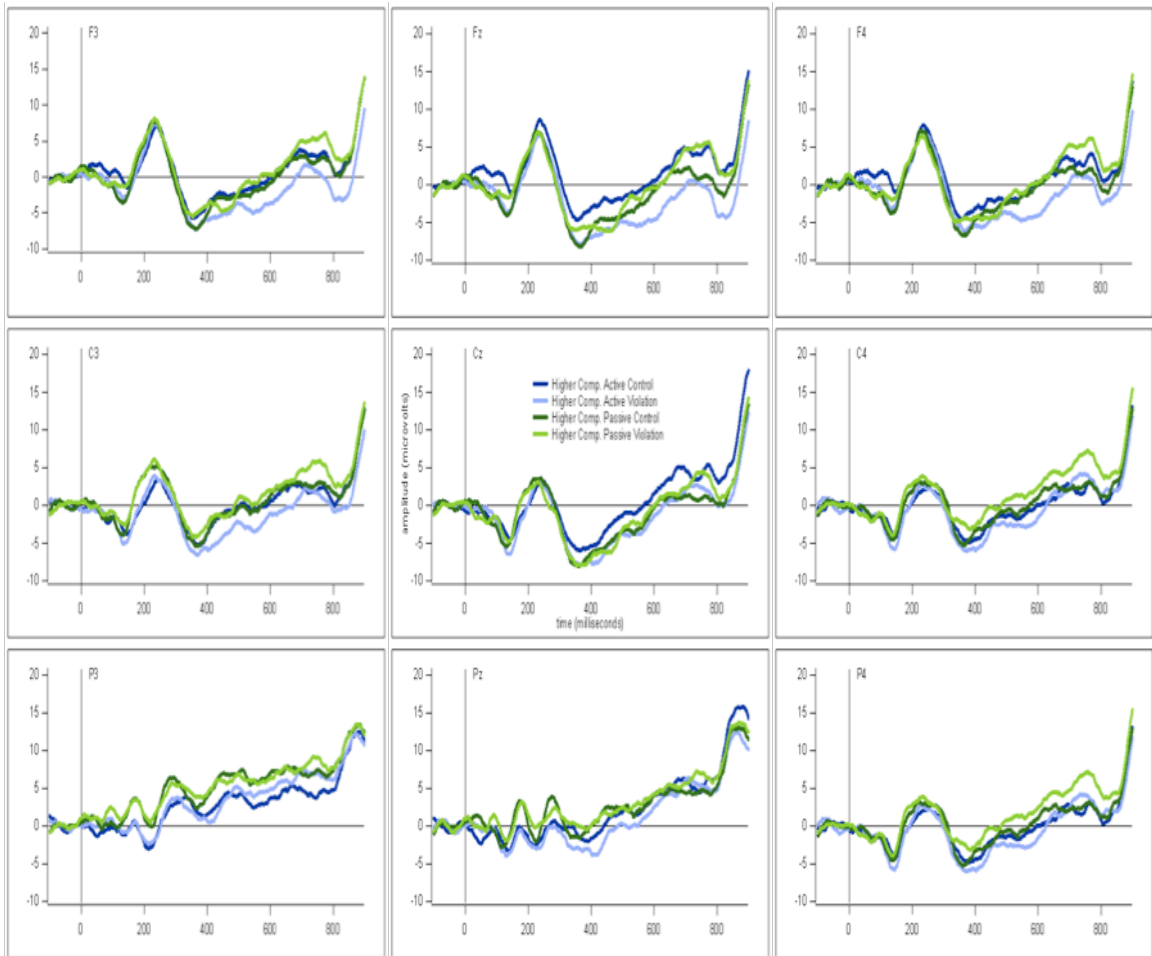
Figure 3. Higher Comprehension Group Average Waves. Waves for active, active violation, passive, and passive violation sentences. Each graph represents an electrode within each ROI. The dark blue line represents mean group amplitudes for the active control sentences, the light blue line represents mean group amplitudes for the active violation sentences, the dark green line represents mean group amplitudes for the passive control sentences, and the light green line represents the mean group amplitudes for the passive violation sentences.
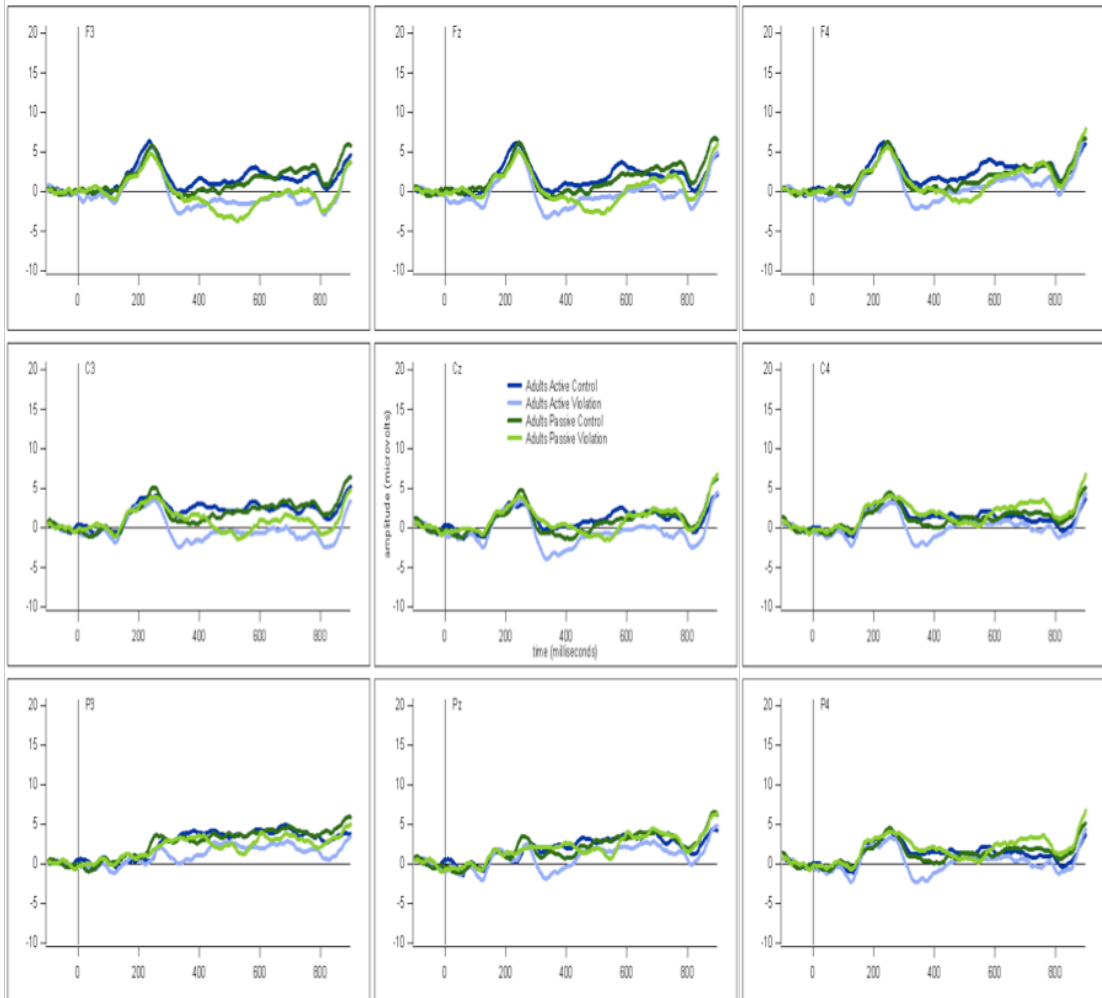
Figure 4. Adult Group Average Waves. Waves for active, active violation, passive, and passive violation sentences. Each graph represents an electrode within each ROI. The dark blue line represents mean group amplitudes for the active control sentences, the light blue line represents mean group amplitudes for the active violation sentences, the dark green line represents mean group amplitudes for the passive control sentences, and the light green line represents the mean group amplitudes for the passive violation sentences.

Fluency groups. For the fluency groups, significant differences in N400 like

negativities between the active versus the active violation, active and passive

sentences, and passive sentences and passive violation sentences also occurred

in the anterior regions (regions 1, 4, and 7). While the adult group amplitudes

were not expected to vary in comparison to the comprehension group (e.g. the

participants were the same for the ANOVAs for the adults), the lower and higher fluency groups also had similar topographies in relation to the N400 like negativities; significant differences also occurred in the anterior regions for these groups in relation to all the conditions compared (active versus active violation, active versus passive and passive versus passive violation).

As hypothesized, amplitude averages (see Appendix F) show that the lower fluency group had larger negativities for the passive and passive violation conditions compared to the higher group and adults. However, the higher fluency group had larger negativities for the active violation conditions compared to the lower fluency group. This could be due to the fact that the lower fluency group's active violation amplitudes were actually less than their active control negativities (e.g. the active sentences elicited larger negativities compared to the active violation for the lower fluency group). The lower fluency group had the smallest relative differences between the conditions compared (e.g. active versus active violation, active versus passive, and passive versus passive violation). Relative differences between the active and active violation and passive and passive violation of the lower group were actually reversed with the control conditions eliciting larger amplitudes than the violation conditions; these results were not hypothesized. See Appendix G for details. Tables 7 & 8 show the results of the initial ANOVAs for the fluency groups.

Table 7: ANOVA Summary Table for Regions 1-6 for Fluency Groups.

Source	df	SS	MS	F	p
Between Subjects					
Group	2, 45	11953.11	5976.56	2.76	.0737
Within Subjects					
Region	5, 225	28284.00	5656.80	37.46	**<.0001**
Condition	3, 135	466.71	155.57	.43	.6722
TW	3, 135	3856.11	1285.37	10.40	**.0003**
Region*Group	10, 225	7409.05	740.90	4.91	**.0010**
Condition*Group	6, 135	2982.48	497.08	1.38	.2421
TW*Group	6, 135	2454.55	409.09	3.31	**.0227**
Region*Condition	15, 675	328.46	21.90	1.34	.2440
Region*Condition*Group	30, 675	389.53	12.98	.79	.6500
Region*Time	15, 675	1419.47	94.63	12.71	**<.0001**
Region*Time*Group	30, 675	346.54	11.55	1.55	.1628
Condition*Time	9, 405	144.26	16.03	.79	.5335
Condition*Time*Group	18, 405	600.73	33.37	1.66	.1094
Region*Condition*Time	45, 2025	135.56	3.01	2.29	**.0081**
Region*Condition*Time*Group	90, 2025	186.13	2.07	1.57	**.0430**

∞=.05. Significant results are in bold.

Table 8: ANOVA Summary Table for Midline Regions for Fluency Groups.

Source	df	SS	MS	F	p
Between Subjects					
Group	2, 45	10867.15	5433.57	3.54	**.0373**
Within Subjects					
Region	2, 90	6978.66	3489.33	25.25	**<.0001**
Condition	3, 135	390.42	130.14	.52	.6185
TW	3, 135	4247.72	1415.91	15.98	**<.0001**
Region*Group	4, 90	1265.20	316.30	2.29	.0934
Condition*Group	6, 135	2075.57	345.93	1.38	.2417
TW*Group	6, 135	1455.39	242.56	2.74	**.0462**
Region*Condition	6, 270	289.01	25.08	2.20	.0704
Region*Condition*Group	12, 270	300.95	25.08	1.15	.3346
Region*Time	6, 270	894.78	149.13	16.45	**<.0001**
Region*Time*Group	12, 270	197.92	16.49	1.82	.1240
Condition*Time	9, 405	159.63	17.74	1.24	.2945
Condition*Time*Group	18, 405	411.52	22.86	1.60	.1202
Region*Condition*Time	18, 810	44.10	2.44	1.40	.1949
Region*Condition*Time*Group	36, 810	101.29	2.81	1.61	.0645

∞=.05. Significant results are in bold.

The main effect of region, $F_{(5, 225)}=37.46$, $p<.0001$, for the ANOVA consisting of regions 1-6, was modified by group as shown in the region*group significant interaction, $F_{(10, 225)}=4.91$, $p=.0010$. This signifies that the amplitudes in the regions were significantly different due to group differences.

Post hoc ANOVAs by region reveal main effect of group for regions 1, 2, and 4 (also for region 7 although midline ANOVA did not reveal a main effect of group).

Region was also modified by time as shown in the significant interaction $F(15, 675)=12.71$, $p<.0001$. Post hoc tests show significant differences in amplitudes during TW 2 for the anterior regions (1, 4, & 7) and the central midline region (region 8). Furthermore, the region*time interaction was modified by condition (sentence type). For the anterior regions (1, 4, & 7) and central midline region (region 8), post hoc tests reveal significant differences during TW2 between the active and active violation sentence, active and passive sentences, and passive and passive violation sentences.

Finally, the three-way region*time*condition interaction was modified by group. Post hoc tests reveal group differences, specifically between the lower fluency group and the higher fluency group and the lower fluency group and adult group, for region 1 (anterior left), and the central regions (2, 5, & 8) during TW 2 between the active control and active violation conditions. Figures 4, 5, & 6 (note the adult waves are depicted under the comprehension groups since the same group of adults were used for both analyses) depict visual representations of the waves for the lower fluency group (Figure 5) and higher fluency group (Figure 6). The electrodes shown belong to each of the regions of interest. See Appendix I for details on comprehension groups' post hoc results.
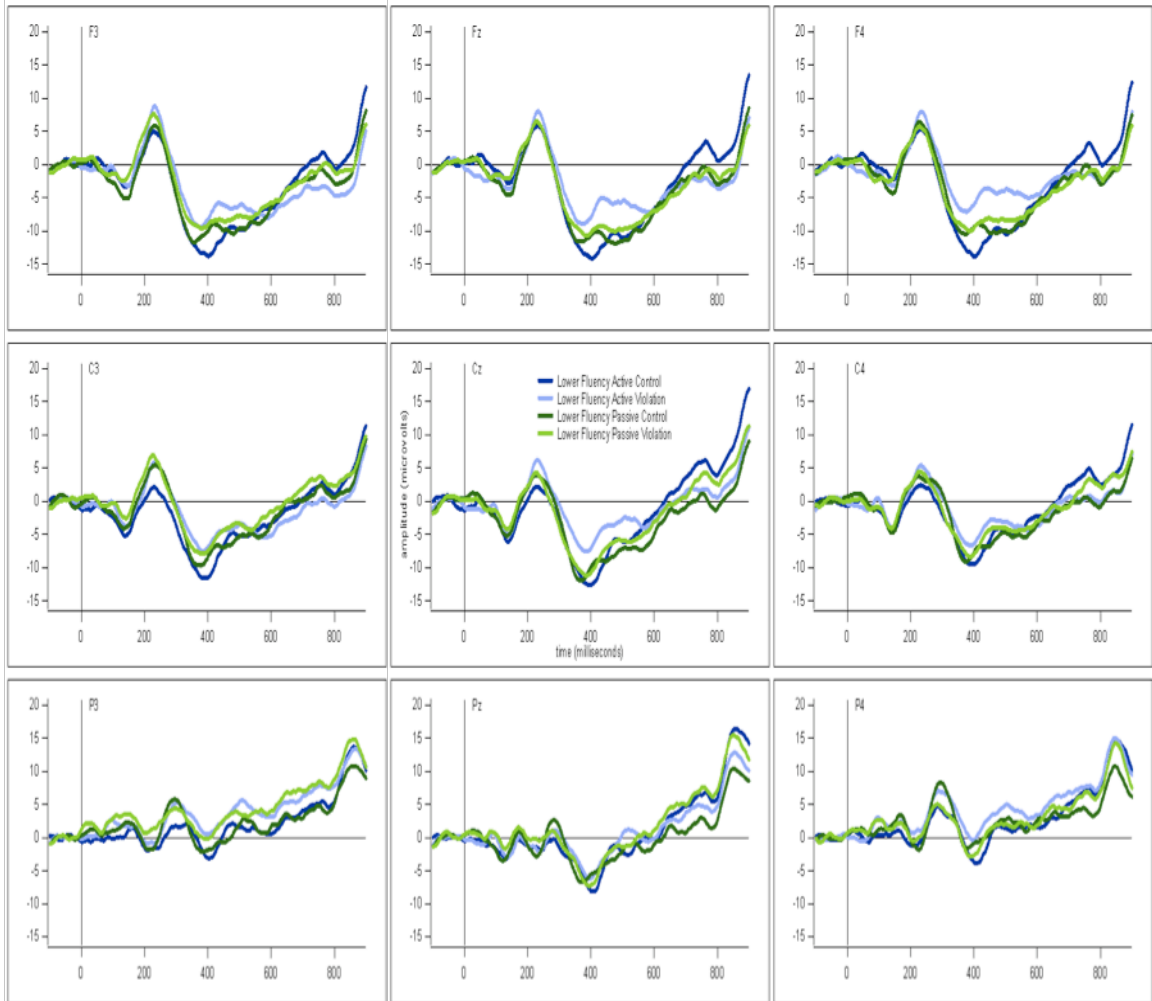
Figure 5. Lower Fluency Group Average Waves. Waves for active, active violation, passive and passive violation within each ROI. The dark blue line represents mean group amplitudes for the active control sentences, the light blue line represents mean group amplitudes for the active violation sentences, the dark green line represents mean group amplitudes for the passive control sentences, and the light green line represents the mean group amplitudes for the passive violation sentences.
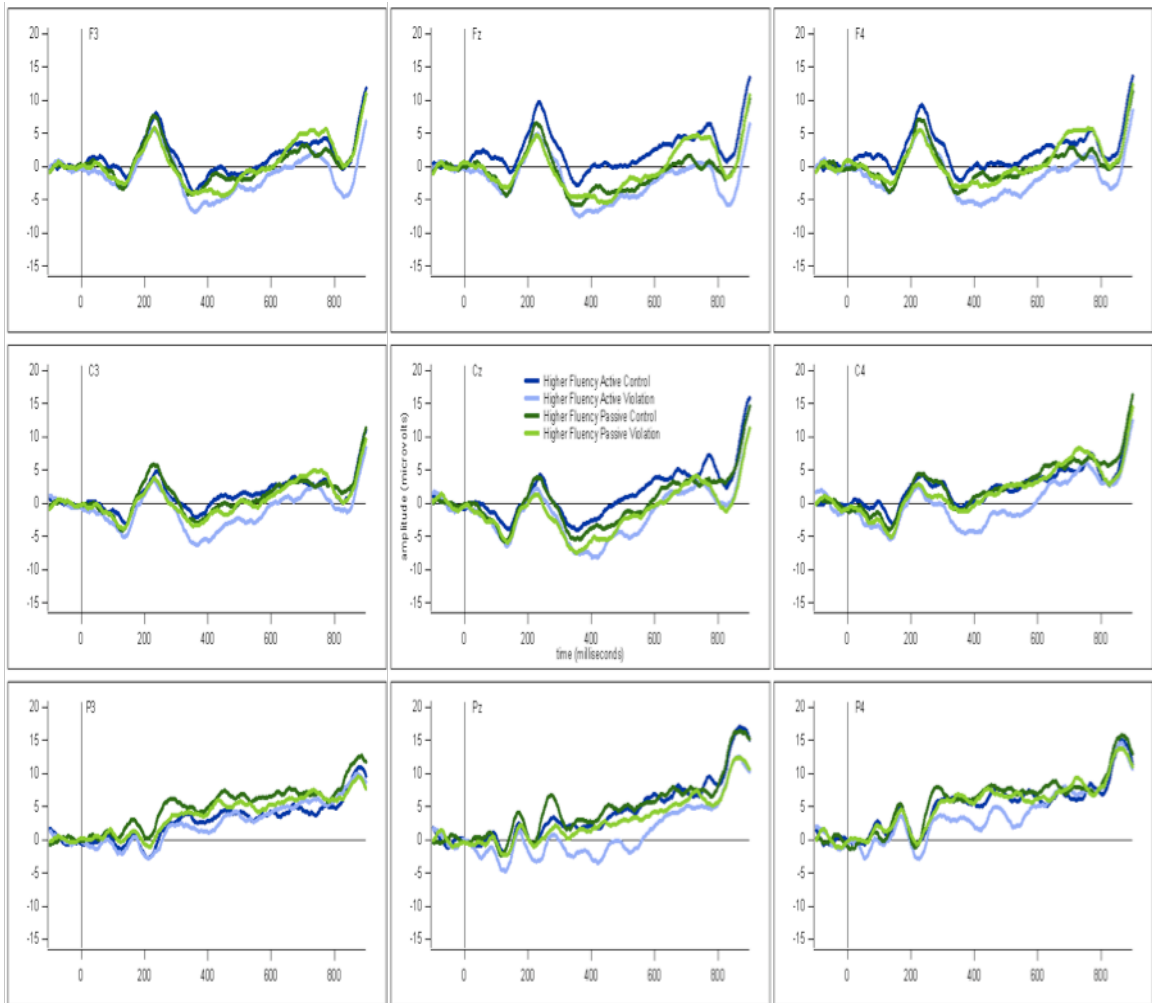
Figure 6. Higher Fluency Group Average Waves. Waves for active, active violation, passive and passive violation within each ROI. The dark blue line represents mean group amplitudes for the active control sentences, the light blue line represents mean group amplitudes for the active violation sentences, the dark green line represents mean group amplitudes for the passive control sentences, and the light green line represents the mean group amplitudes for the passive violation sentences.

Summary of Results

The comprehension group ANOVA showed a four-way interaction between region, condition, time and group. While the post hoc tests did not reveal any significant contrasts between the groups, contrast between all conditions revealed significant results in the anterior regions (regions 1, 4, & 7) during TW 2

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(350-450 msec)**.** Descriptive analyses of the wave amplitudes show larger N400 amplitudes for the lower comprehenders suggesting that they had higher neuronal demands than the higher comprehension groups. Also, unlike previous studies investigating the N400 in adults and children, the N400 largest negativities for all three groups occurred in the anterior regions; previous research shows the N400 amplitudes occur in central posterior regions for the adults and in the frontal regions for children (Atchley, Rice & Betz et al., 2005; Hahne, Eckstein, & Friederici, 2004; Holcomb, Coffey, & Nevile, 1992). This will be discussed in further detail in the following chapter.

The differences between the fluency groups were more dynamic in the N400 amplitude variations between the sentences than the comprehension groups. There was a four-way interaction of region, condition, time and group in the ANOVA consisting of regions 1-6. Post hoc tests showed significant main effects of group for anterior regions (1, 4, & 7) and region 2. There was also group*condition interactions for the central regions (2, 5 & 8) and region 4. For these regions, post hoc tests showed significant contrasts between lower and higher fluency groups, and the lower fluency group and adults. The lower fluency group had larger N400 amplitudes than the higher fluency group, however, the control sentences elicited larger N400 amplitudes than the violated sentences for the lower fluency group. Like the comprehension groups, the N400 amplitudes were also significant in the anterior regions for all the groups.

Although differences between all the groups (fluency and comprehension) could not be statistically analyzed due to the violation of the independence

assumption (there was participant overlap between the comprehension and fluency groups), visual inspection of the waves show larger N400 amplitudes for the lower fluency group. These results are interesting for three reasons. The sentences were below the lower fluency group's actual fluency levels as measured by the GORT-4, but they elicited higher amplitudes compared to the lower comprehension group even though their word accuracy and speed were intact for the level of the sentences. Secondly, the control conditions for the lower fluency group elicited larger amplitudes than the violated sentences; this pattern is not evident with the lower comprehension group. This pattern was also seen in Holcomb, Coffey, and Neville's (1992) study with their six-year old group. Finally, the lower fluency group was older than the lower comprehension group by three months, yet their amplitudes were larger based on visual inspection of the waves.

To conclude, based on the results, reading abilities (fluency and/or comprehension) can very well affect the N400 amplitudes at the sentence ending word during on-line reading of active and passive sentences and active and passive sentences with thematic role violations. However, these results need to be further explored by eliminating some of the limitations of this study (e.g. age differences between the groups and independent comprehension and fluency groups). The next chapter will discuss the results from theoretical perspectives as well as reading development perspectives.

Chapter V:

Discussion

This study was conducted to examine the elicited N400 amplitudes following sentence final words between groups of different skilled readers in order to examine semantic and syntactic processes from a reading education and neuroscience perspective. It was hypothesized that lower ability groups (comprehension and/or fluency) would have larger N400 amplitudes for all sentence conditions compared to the other groups (e.g. higher ability and adults). Also, the relative difference between the passive control and the passive violation conditions would be less for the lower ability groups compared to the higher ability groups and adults. Finally, adults would not elicit a relatively larger N400 for the passive control sentences compared to the active control sentences; lower and higher ability groups would.

The participants consisted of 33 children (out of 46 tested) ages 7-13 and 18 undergraduate adults ages 21-35. The children were assessed for reading abilities (fluency and comprehension) using the GORT-4, and their scores were used to place them into reading ability groups; lower comprehenders and higher comprehenders for the first analysis, and lower fluency and higher fluency for the second analysis. This chapter discusses the results of this study and how it connects to previous research, implications, and limitations and direction for

future research. It will begin with a summary of the study.

Summary of the Study

Reading fluency has been described as the bridge between decoding and comprehension (National Reading Panel, 2000; Pikulski & Chard, 2005; Samuels 1994/2004). Research studies show a strong correlation between fluency and comprehension (Pinnell, Pikulski, and Wixson et al., 1995; Stanovich, 1986; Daane, Cambell, Grigg, Goodman, & Oranje, 2005; Rasinski et al., 2005), but there are unexplained variances in comprehension scores in many of these studies that fluency alone does not explain (Klauda & Guthrie, 2008, Miller & Schwanenflugel, 2008). Due to these unexplained variances, there is interest in the role of syntactic and semantic processes, and their contribution to fluency and to reading comprehension (Klauda and Guthrie, 2008; Smith & Goodman, 1971).

This study examined how children with varying reading abilities processed the final sentence ending nouns in four types of sentences; active, passive, active violation, and passive violation. The research questions asked whether varying reading comprehension and/or fluency skills would affect the way the sentence ending nouns were processed in relation to the N400 amplitudes. Specifically, the differences in N400-like amplitudes between the active and active violation sentences (e.g. "The girl was brushing her hair." versus "The hair was brushing the girl."), the active and passive sentences (e.g. "The girl was brushing her hair." versus "The hair was brushed by the girl."), and the passive

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and passive violation sentences (e.g. "The hair was brushed by the girl." versus "The girl was brushed by the hair.") were examined.

The literature reviewed consisted of studies using behavioral methods that focused on semantic and syntactic processes and reading abilities (Bowey, 1985; Cain, Oakhill & Elbro, 2003; Kuhn & Stahl, 2003; Miller & Schwanenflugel, 2006, Nation & Snowling, 1998; Stanovich, West, & Feeman, 1981; Young & Bowers, 1993). The review also included ERP studies, of which there are only three, investigating the N400 and P600, in children in visually and auditorally presented sentences (Atchley, Rice & Betz et al., 2005; Hahne, Eckstein, & Friederici, 2004; Holcomb, Coffey, & Neville, 1992). The major differences between the ERP research reviewed and the current study are in the way the children were grouped and the way the sentences were constructed.

In the current study the sentences used were constructed keeping children's reading abilities in mind. The verbs used in the sentences were carefully selected from a standard word frequency index (Zeno et al., 1995). This index (SFI) is an estimate of the frequency with which a particular word appears per million words across classroom-based texts in grades 1 through 13. Verbs with a SFI between 40-60 were used. In addition, the verbs were selected based on the frequency that they appeared in 2nd, 3rd, 5th, and 6th grade texts. Only verbs that appeared in all four grade level texts were used. In the construction of control sentences, verbs were matched with semantically related noun phrase arguments using the *University of South Florida Word Association, Rhyme, and Word Fragment Norms* (Nelson, McEvoy, & Schreiber, 1998). In addition to

tailoring the sentences so that the youngest readers would not have difficulty recognizing the words in the sentences, the children were grouped based on reading comprehension skills (lower versus higher) for the first set of analyses and reading fluency levels (lower versus higher) for the second set of analyses using the GORT-4 to determine reading abilities.

The children came from a variety of public and private schools in Hillsborough County originally recruited for another related study (VanDyke, unfinished dissertation) on language development (see Appendix A for description of related study). The participants used in the analyses for this study were in grades 1 through 7, and had age ranges between 7 to 12 for the comprehension groups, and 7 to 13 for the fluency groups. The lower comprehension group (n=15) and the lower fluency group (n=15) had close to the same average age: the lower comprehension group had an average age of 8.9 years and the lower fluency group had an average age of 9.29 years. However, the lower fluency group had slightly higher comprehension scores than the lower comprehension group, and the lower comprehension group had higher fluency scores than the lower fluency group. Likewise, the higher comprehension groups (n=15) and the higher fluency group (n=15) also had similar average ages: the higher comprehension group average age was 10.6 years and the higher fluency group average age was 11.14 years. However, the higher fluency group had lower comprehension scores than the higher comprehension group, and the higher comprehension group had lower fluency scores than the high fluency

group (see Appendix B & C for participant characteristics by group, age, comprehension, and fluency levels).

Discussion of Findings

In order to discuss the main findings, background on the neurobiological processes of reading may help explain some of the results. Neuroimaging studies show that normal readers use an organized cortical system that integrates processing of orthographic, phonological, and lexico-semantic features of written language. This system includes three areas of the brain (Sandak, Mencl, Frost & Pugh, 2004) occipitaltemporal, temporoparietal (Wernicke's area) and the inferior frontal gyrus (Broca's area). See Figure 7 for visual.
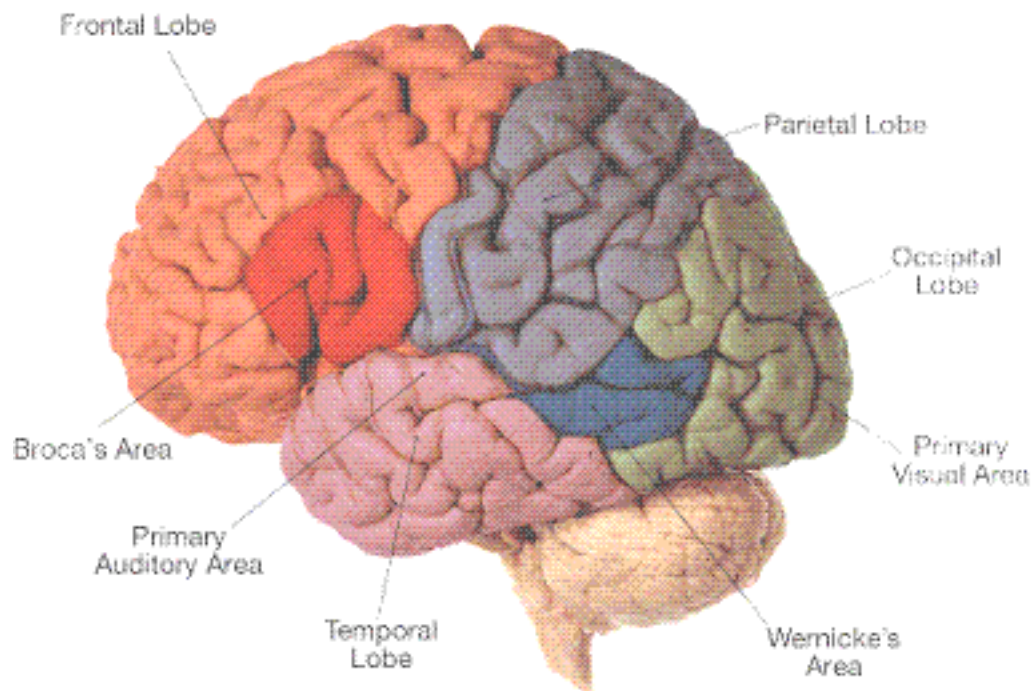
Figure 7. Lobes on the Left Hemisphere.

In reading, the occipitaltemporal area is considered the visual word form area. The temporoparietal area is involved in mapping visual percepts of print onto the phonological and semantic structures of language. In skilled readers this area responds with greater activity to psuedowords than to familiar words, and it is hypothesized that the temporoparietal system plays a role in the phonological analyses that are important to learning new material. Finally, and most important to this study's results, the anterior system in the inferior frontal gyrus in the frontal lobe, appears to be associated with phonological recoding, phonological memory, and syntactic processing; the more anterior areas of the inferior frontal gyrus also seem to play a role in semantic retrieval (Sandak, Mencl, Frost & Pugh, 2004). Furthermore, Just, Carpenter, & Keller et al. (1996) found that in sentence reading tasks, the middle frontal gyrus showed bilateral activation (e.g. activation in both hemispheres), and this activation increased as the complexity of the sentence increased.

In this study, the negativities for all groups were largest at all the anterior regions (see Appendices D-G for amplitude averages by region, group, and condition), and the central midline region. As noted earlier, other studies show greater N400 amplitudes in the central posterior regions for the adults, and in the anterior regions for children (Atchley, Rice & Betz et al., 2005; Hahne, Eckstein, & Friederici, 2004; Holcomb, Coffey, & Neville, 1992) for sentence ending semantic anomalies. While atypical anterior maximal N400-like negativities were found for adults in this study, it is important to note that the scalp topography of the N400 is typically widespread even though regional differences have been

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observed (Curran, Tucker, Kutas & Posner, 1993).

Nevertheless, the violation conditions may have caused processing difficulty at the verb level (e.g. The hair was brushing the girl.) because some of the children and adults may have processed the verb as a semantic error (hair usually does not do the brushing). Likewise, some of the children and adults may have processed the verb as a morphosyntactic error possibly due to their syntactic knowledge of the passive tense (they may have assumed that the sentence meant to say brushed versus brushing). The N400 like maximal negativities occurring more at the anterior locations versus the central posterior locations may have resulted because of the processing demands these sentences elicited.

Language processing demands have been shown to use more neuronal resources in the frontal areas of the brain (Just, Carpenter, & Keller et al., 1996). The violation sentences not only contained a possible morphosyntactic error (based on how the individuals processed the verb), but also contained a possible semantic error (depending on how the participant processed the verb) at the verb level as well as the sentence-ending noun. These violations may have caused increased demand of semantic and syntactic processes compared to other studies whose sentences only consisted of one type of violation (syntactic or semantic). Due to the possible increased demand of neuronal resources involved in syntactic and semantic processes, the pattern of maximal negativities in the frontal regions for all groups in this study can be explained through studies showing the role of the inferior frontal gyrus in semantic and syntactic processing

(Sandak, Mencl, Frost & Pugh, 2004 for a review), studies showing increased activation in this area due to sentence complexity (Just, Carpenter, & Keller et al., 1996), and/or neuronal networks in this area that are recruited for the solutions of diverse, simple to complex, cognitive problems (see Duncan & Owen, 2000 for a review).

Comprehension groups. In regards to amplitude differences between the comprehension groups, there was an interaction of region, condition, time, and group for the comprehension groups. However, post hoc tests revealed no significant differences. A descriptive look at the raw amplitude scores as well as the visual representation of the waves show the lower comprehension group amplitudes were more negative for all sentence types than the higher comprehension group's amplitudes, and the relative differences between the active control and active violation, active and passive sentences, and passive and passive violation sentences were greater for the lower comprehension group compared to the higher comprehension group. This could be an effect of reading comprehension abilities. The lower comprehenders may have used more neuronal resources to make sense of the sentences due to greater processing demands compared to the other two groups.

However, age differences between the groups cannot be ruled out in regards to the larger negativities in the lower comprehension groups since the average age of the lower comprehenders was about 1.2 years younger than the average age of the higher comprehenders. Previous studies examining the age differences (although not controlling for language abilities) on the N400

amplitudes show that the younger children elicit larger negativities than the older children (Atchley, Rice & Betz et al., 2005; Hahne, Eckstein, & Friederici, 2004; Holcomb, Coffey, & Neville, 1992). However, as explained in the previous chapter, there is a correlation between white matter and reading abilities (Niogi & McCandiss), and differences in white matter alters neuronal networks, which can impact N400 amplitudes. This was something that was not taken into consideration in the previous studies.

Fluency groups. The differences between the lower and higher fluency groups were more dynamic. While the topography of the N400–like amplitudes were similar to the comprehension groups', the low fluency group's active violation amplitudes were the inverse of the higher fluency group's negativities. In other words, the control sentence elicited larger N400-like amplitudes at the sentence final word than the violation sentences, and these results are different than the relationship shown between control and violated sentences in other studies (Atchley, Rice & Betz et al., 2005; Hahne, Eckstein, & Friederici, 2004; Holcomb, Coffey, & Neville, 1992), as well as the relationship between the violated sentences and the control sentences with the lower and higher comprehension groups, higher fluency group, and adults in this study.

The way the lower fluency group processed the verbs in the violation sentences may have contributed to the lesser negativities for the violation conditions at the end of the sentences. For example, if the lower fluency group had syntactic processing problems at the verb level within the sentence, their semantic processing at the end of the sentence may have been halted, and not

efficiently used. In other words, the lower fluency group may have been so confused by the verb within the sentence (possibly due to their inability to make sense or make automatic predictions of the syntactic structure of the sentences), that they were not able to make meaning of the rest of the sentence. This in turn may have lead to the underutilizing of the neuronal networks that are used in semantic processes, leading to a lesser negativity compared to the control conditions. Note, the sentences were read on-line (e.g. EEGs were recorded in real-time as the participants read the sentences), and the participants did not have time to reflect on sentence construction while reading; the syntactic and semantic processes discussed above as well as in the rest of this chapter is from the perspective that these processes occur automatically for efficient processing of written language.

Furthermore, the lower fluency group's N400 like amplitudes for all sentence types were larger than the lower comprehenders (based on averages and visual inspection; see Appendix D & F for amplitude averages by group, condition and regions), possibly indicating the need to use more neural resources in the processing of all the sentences. The above mentioned factors could affect the lower fluency group's understanding of a text in which different types of sentences are imbedded since they need to work harder to understand each of the sentences within the paragraph and or passage even when they do not have problems with reading speed and word accuracy. The lower fluency group average fluency grade level was 4.9; the sentences were written at approximately the second grade level; when in doubt (e.g. when participant

GORT-4 scores were third grade level or below for fluency and/or comprehension, or they were seven and eight years old), participants were asked to read the words presented in the sentences printed on flash cards after the ERP testing to ensure that they were able to easily and quickly recognize the words.

The question now arises as to why the lower fluency group may have had processing issues indicated by the inverse negativities between the control and violation conditions if their word identification and reading rate for the level of the sentences were intact. This leads to a discussion of a possible gray area in the bridge between fluency and comprehension as discussed in the first chapter.

Much of the emphasis on reading instruction, and reading research, in regards to improving reading comprehension in the past couple of decades has focused on fluency at the word level (speed and accuracy), and comprehension at the word level (e.g. vocabulary), the paragraph, passage, or text levels (NRP, 2001). However, as Scott (2009) points out, the importance of sentence comprehension has been overlooked in the overall comprehension of a text (e.g. paragraph, passage). As shown in this study, even if word recognition and reading speed is intact for the level of the text, some children (e.g. the lower fluency group in this study) may still have problems with syntactic processes as they attempt to make sense of a sentence which in turn leads to inefficient semantic processing.

Although it may seem that an assumption has been made in this study about the verbs in the sentences, in the related study (Vandyke, unfinished

dissertation) the younger children trended (the word "trended" is used because this trend was seen in the waves, but not yet statistically analyzed) towards processing the verbs in the active violation as a semantic error (eliciting an N400 at the verb level) and the older children and adults trended towards processing the verbs in the active violation sentences as a morphosyntactic error (eliciting a P600). While the related study did not group the children by reading ability levels, there is a correlation between age and reading abilities (both fluency abilities and comprehension abilities), and when compared to the older children, the younger children had lower reading comprehension and fluency abilities; lower fluency levels may have affected the way the children processed the verbs even if word recognition and speed were intact.

All previous studies examining sentence ending N400 negativities in children (Atchley, Rice & Betz et al., 2005; Hahne, Eckstein, & Friederici, 2004; Holcomb, Coffey, & Neville, 1992) show a larger negativity for sentence ending semantic violations compared to the control conditions (note only the six year old group in Holcomb et al.'s study had larger negativities for the control condition), however, these studies did not have violations in the middle of the sentences (some may not see the verb in the active sentences used in this study as a violation since they can be plausible within the context of the preceding words) at the verb level too.

Theoretical and Practical Implications

The differences in the wave amplitudes between the lower fluency group and the rest of the groups, in regards to the inverse negativity, can be explained

by the perspective of the Indexical Hypothesis (IH) proposed by Glenberg and Robertson (1999), and further additions to this model by Kaschak and Glenberg (2000). The IH has been investigated (see Glennberg & Robertson, 1999; Glenberg, Gutierrez, Levine et al., 2004; Kaschak & Glenberg, 2000; Glenberg & Kaschak, 2002) and results support it. The IH proposes that words become meaningful by simulating the content of sentences, and is accomplished by three processes. First, words and phrases are indexed, then affordances are derived from the objects, and third, the affordances are combined, or meshed, as directed by the syntax to produce a coherent simulation.

More specifically, indexing establishes the content of the language (who or what is being talked about). Derivation of affordances refers to all the possible hypotheses that an individual can refer to when interpreting word meaning as they read a sentence. Kaschak and Glenberg (2000) use the word 'crutch' as an example. A person can interact with this word in different ways; a crutch can be used for walking, it can be used to strike something, or can be used to push something through a crevice. All these possibilities for interaction are the affordances for the word 'crutch'. Meshing is a process that combines affordances into coherent patterns of actions that can actually be completed to accomplish a goal. For example, the understanding of the following sentence (sentence adapted from Kaschak & Glenbeerg, 2000) is constraint by the physical affordance of string; "The apple was pushed through the crevice using a string." Physically, a string cannot push an object such as an apple. Affordances are also integrated as directed by the syntax of a sentence.

According to the IH model (Glenberg & Robertson, 1999; Glenberg & Kaschak, 2002), the syntax of a sentence provides constraints on meshing because the form of the sentence is hypothesized to provide cues to the general event that is being described (Glenberg & Kaschak, 2002). The "event" brings out certain affordances, and the syntax of the sentence (e.g. the identification of the subject, direct object, etc.), "…provides instructions for the meshing process such that all the objects and people are placed in the right relations to each other" (Kaschak & Glenberg, 2000, p. 511).

Kashak and Glenberg (2000) explain:

These three processes interact dynamically, not serially. Upon reading that "Lyn pushed the apple through the crevice using a crutch," referents for Lyn, crutch, apple, and so on, are indexed and used to establish a mental model. As affordances are derived from Lyn and the apple, the meshing process begins. As the sentence continues, the affordances are meshed into what amounts to a mental simulation of the event being depicted in the sentence. The syntax of the sentence will be used at all of these stages to both aid in the indexing process (e.g. forming noun phrases) and to provide general constraints on how the mental simulation is to operate. Changes in any of these steps, such as a change in the syntactic analysis of the sentence, will result in the simulation being systematically altered to accommodate these changes. (p. 511)

Referring back to the lower fluency group, it could be hypothesized that they did not change the syntactic analysis of the thematic violated sentences

at the verb level compared to the other groups. If the other groups automatically thought that the verb was incorrect (e.g. morphosyntactically incorrect) and automatically self corrected it to allow for the affordances of the agent, then this could have aided them in their efforts to make meaning of the implausible sentences. However, if the lower fluency group did not change the syntactic analysis, even if the sentences did not make sense to them, then by the time they got to the end of the violated sentences, they were no longer making meaning leading to lesser negativities compared to the control conditions. If this hypothesis is correct, then perhaps the lower fluency group did not have the automatic syntactic analysis skills that the other groups had, and due to this lack of syntactic skills, or lack of ability to screen affordances, they could not automatically change their original syntactic analysis of the verbs to one that allowed plausible affordances to the agent of the verbs.

It is also theorized that when readers comprehend what they are reading, they build meaning representations at different levels that include the surface code, text base, mental model, text genre, and communication channel (Graesser, Millis, & Zwaan, 1997; Kintsh, 2004); the text makes sense when there are connections within and between these levels; this is an interactive perspective of reading comprehension. The surface code level is considered to be the wording and grammar of the sentences; the text base level are the meanings of clauses that are explicit in the text; the mental model level are the ideas of what the text is about; the text genre is the type of text such as expository and narrative (among many others); and the communication channel

involves the purpose of the text and for whom the text was written (Graesser, McNamara & Louwerse, 2003). According to Graesser, McNamara and Louwerse (2003) children need to master each of these levels to the point of over learning them so that the codes, structures, and processing skills become automatic, and the only way they can do this is through practice. Currently, in reading instruction in schools, all of these levels are practiced with the exception of the first level, the surface code (Scott, 2009; Conners, 2000).

Conclusion

This paper investigated if reading comprehension abilities and/or reading fluency abilities had an effect on the N400 amplitudes for active violation, passive, and passive violation sentences. Based on the statistical analyses, visual inspection of the waves, and looking at the average wave amplitudes by region, condition, and group, the answer is yes, reading abilities can affect N400 wave amplitudes; this is especially seen in the difference between the lower comprehension group and the lower fluency group mean wave amplitudes by condition. However, this conclusion cannot be generalized due to the limiting factors in this study. More research is needed to see if the results are reliable, and to see if reading skills do impact the N400 wave during tasks that require sentence reading. However, this study can serve as a springboard for other studies where the limitations are no longer limiting factors, and see if differences still exist. Ideas for future studies will be discussed later in the chapter.

If the results of this study hold true, perhaps part of the bridge between fluency (accuracy and speed) and comprehension, is the ability to automatically

identify sentence structures and how the structure relates to the meaning of the sentence. As theorized in this study, if a reader is not automatic in recognizing and hypothesizing the possible structure of the sentence (e.g. hypothesizing that the verb in the active violation sentences could be a morphosyntactic error due to the affordances of the agent) this can lead to sentence processing difficulties that can affect the comprehension of the paragraphs in which the sentences are imbedded. If this is the case, then educators need to reconsider making the sentence important again in writing and reading instruction. Automatic sentence structure flexibility, where a child can read sentences with different structures and automatically recognize the structures in order to help them make meaning, should also be considered when thinking about fluency. Perhaps it should be considered a separate ability, maybe the actual road that leads fluent readers to the land of comprehension.

Finally, and stepping away from possible reading education implications, this study showed how easily N400 wave amplitudes can differ depending on how children are grouped; this is especially seen between the lower fluency group and the lower comprehension group. This could be due to inconsistencies in the N400 amplitudes in children due to brain maturation differences, or it could be due to actual reading skills (fluency and/or comprehension). Nevertheless, care should be taken in interpreting N400 wave amplitudes in children in visually presented sentences until more research is completed and researchers are able to clarify the possible causes of N400 wave differences in children.

Future Research and Study Limitations

This study may have opened a can of worms for future studies. The first of which should be to see if the results of this study are reliable, but controlling certain factors that this study was not able to control. For example, future ERP studies looking at sentence ending N400s can investigate different level reader groups (eg. low comprehenders/high fluency, low comprehenders/low fluency, high comprehenders/high fluency, and high comprehenders/low fluency) with children who are approximately the same age. Studies such as the one proposed, systematically studying children at different age levels with different types of reading abilities, can shed light into the trajectory of reading development for the different types of readers (e.g. low comprehenders/high fluency, low comprehenders/low fluency, high comprehenders/high fluency, and high comprehenders/low fluency) controlling for brain maturation that can affect ERP waves (Picton, et. al, 2000).

If studies such as the one proposed above do show differences depending on different components of reading ability (e.g. fluency and comprehension), investigating how certain reading instruction and exercises may affect the sentence ending N400-like negativities for different types of readers could also be insightful. For this type of investigation pre and post behavioral reading assessments also need to be used in conjunction with ERP data to see if a change in reading ability (e.g. fluency and/or comprehension) causes a changed in the waveforms. Of course, only using pre and post behavioral assessments could also be beneficial (pending that the assessments used are valid, reliable,

and not biased towards a subgroup of children) in investigating whether strategies and exercises work.

Other limitations to the current study involve how the participants were grouped. Only one reading assessment was used to group the children into comprehension and fluency groups, and the adults were not behaviorally assessed since it was assumed that their comprehension and fluency abilities were high since they were undergraduate and graduate students at a university. Future studies, in addition to using a current reading assessment, should attempt to get reading assessment data from classroom teachers and/or parents in order to have more than one assessment determine what level and type of reader a particular child fits into.

Finally, for the above proposed future research using ERP methods, researchers from the fields of neurocognitive sciences, reading education, and linguistics should join forces in order for the research to reach its full potential. Linguists can help in the construction of sentences, and neuroscientists specializing in ERP research can help in the ERP data. Neuroscientists will have a better understanding of how the ERP data should be analyzed (e.g. using more complicated analyses such as principle component analysis for ERP data). Reading educators can help in determining which reading assessment to use, as well as the administration and collection of the reading assessment data used for participant groupings; reading educator can also assist the linguist with the sentence constructions. Also reading educators can contribute by providing the

instructional treatment(s) that are being assessed behaviorally and neurologically. Finally, all the disciplines can converge in interpreting the results.

The results of this study were analyzed strictly from a neuroscience perspective with a focus on reading development and reading abilities. The hypotheses in the first chapter stated that differences between groups and between sentence conditions were predicted to occur. The first set of hypotheses involving the relationship between the active and active violation sentences revealed surprising results for the lower fluency group. The hypotheses stating that the lower ability groups would have higher N400 like negativities were correct, however, it was not expected that the lower fluency group would have larger negativities for the control condition compared to the violation conditions.

The hypothesis involving the active versus the passive sentences predicted that the passive sentences would lead to larger N400 like amplitudes compared to the active sentences since previous behavioral studies show that children (both skilled and less skilled readers) have a harder time with passive constructions versus active constructions. All the groups showed larger N400 like amplitudes for the sentence ending nouns in the passive sentences compared to the active sentences, although these differences were not as large as the differences between the control sentences and their violation counterpart.

Finally, the last hypothesis predicted what would happen between the passive control sentences and the passive violation sentences. The results of these comparisons were also surprising. It was predicted that the passive violation sentences would elicit a larger N400 like amplitude for the sentence

ending nouns for all groups, with differences between the groups in relation to the relative differences between the control condition and the violation condition. The hypotheses were correct for all the groups except for the lower fluency group. For the lower fluency group the control sentences elicited larger negativities than the violation sentences, similar to the negativities between the active and active violation sentences. This may indicate a processing problem for the lower fluency group that started towards the beginning of the sentence as discussed earlier in this chapter.

Although this study does not specifically address the 4th grade reading slump, it may shed some light into what happens when children transition between the learning to read stage and reading to learn stage (Chall, 1996). Differences in sentence processing, as shown in the electrophysiological results of this study, show that reading abilities can affect the N400 waveform. The instructional implications, if the study findings hold true (it is important to continue investigating differences between reading abilities through the use of behavioral and electrophysiological testing), are great. By bringing reading researchers, linguists, and neuroscientists together we may be able to provide ideas in the future for instructional strategies that support greater success in reading for specific types of readers.

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Appendices

Appendix A: Related Study Description

Vandyke (unfinished dissertation), a linguist, was interested in how linguistic developments affected the way the verbs in the sentences were processed using electrophysiological measures. The overall goal of her study was to determine whether children engage in qualitatively or quantitatively different language comprehension processes as they are reading, and to determine whether children's language processes change over time as they become more experienced with the language. Specifically, her research questions were the following:

1. Do older and/or younger children differ from adults with respect to the P600 component when reading sentences containing thematic role violations?

2. Are older and/or younger children as sensitive to thematic role violations as adults?

Her initial analyses shows a trend where the younger children (ages 7-9) process the verb in the active violation sentences as a semantic anomaly eliciting an N400, and the older children (ages 11-13) and adults process the verb as a morphosyntactic error, eliciting a P600.

Appendix B: Comprehension Groups Participant Characteristics

Child Subject	Gender	Age	Grade	Comp. Grade Equiv.	Fluency Grade Equiv.
Lower Comp. Group					
CS07	Female	7.5	2nd	6	5.4
CS08	Female	9.25	3rd	6	6.2
CS10	Female	11.92	5th	4.2	6
CS12	Female	7.417	2nd	5.2	5
CS14	Female	12.25	7th	5.2	8.2
CS15	Female	7.25	1st	2.4	4
CS22	Female	7.83	2nd	3.7	3
CS25	Male	9.333	4th	6	6.2
CS26	Male	7.42	2nd	1.2	3
CS27	Male	9.58	4th	6.2	5
CS29	Female	8.167	2nd	2.7	5.4
CS34	Male	9.83	4th	4	5.7
CS38	Female	7.167	1st	3.7	3.7
CS44	Female	11.75	6th	6	8
CS36	Female	7.167	1st	4	4.4
Average		8.92		4.43	5.28
Higher Comp. Group					
CS04	Female	8.83	3rd	7.2	4.7
CS06	Male	11.167	5th	12.7	12.7
CS09	Female	10.083	4th	7.4	3.7
CS11	Female	8.333	3rd	8.6	4.7
CS16	Male	12.5	7th	9.7	12.7
CS18	Female	9.333	3rd	8	5.4
CS21	Female	10.167	4th	9.7	6.4
CS23	Female	11.417	6th	12.7	12.7
CS43	Male	12.67	7th	7.4	9.7
CS30	Female	11.25	5th	10.4	9.2
CS31	Male	10.67	5th	7.4	6
CS35	Female	11.083	5th	8.7	9.4
CS39	Female	11.83	6th	8.2	12.7
CS40	Male	11.92	6th	11.2	12.7
CS46	Male	7.83	2nd	7	12.3
Average		10.61		9.09	9.00

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Appendix C: Fluency Groups Participant Characteristics

Child Subject	Gender	Age	Grade	Comp. Grade Equiv.	Fluency Grade Equiv.
Lower Fluency Group					
CS07	Male	7.42	2nd	1.2	3
CS09	Female	7.83	2nd	3.7	3
CS10	Female	10.083	4th	7.4	3.7
CS11	Female	7.25	1st	2.4	4
CS15	Female	8.83	3rd	7.2	4.7
CS18	Female	8.333	3rd	8.6	4.7
CS22	Male	9.58	4th	6.2	5
CS26	Female	8.167	2nd	2.7	5.4
CS27	Male	9.333	3rd	8	5.4
CS29	Female	7.5	2nd	6	5.4
CS31	Male	9.83	4th	4	5.7
CS34	Female	11.92	5th	4.2	6
CS38	Male	10.67	5th	7.4	6
CS4	Female	13.333	7th	8.2	6
CS42	Female	7.167	1st	3.7	3.7
Average		9.29		5.51	4.856
Higher Fluency Group					
CS14	Female	12.25	7th	5.2	8.2
CS16	Male	12.5	7th	9.7	12.7
CS21	Female	10.167	4th	9.7	6.4
CS23	Female	11.417	6th	12.7	12.7
CS25	Male	9.333	4th	6	6.2
CS45	Male	12.83	7th	8.2	8
CS30	Female	11.25	5th	10.4	9.2
CS35	Female	11.083	5th	8.7	9.4
CS39	Female	11.83	6th	8.2	12.7
CS40	Male	11.92	6th	11.2	12.7
CS43	Male	12.67	7th	7.4	9.7
CS44	Female	11.75	6th	6	8
CS46	Male	7.83	2nd	7	12.3
CS6	Male	11.167	5th	12.7	12.7
CS8	Female	9.25	3rd	6	6.2
Average		11.1498		8.606666667	9.80666

Appendix D: Comprehension Groups Average Amplitudes

Lower Comprehension Group

Region	Active	Active Vio	Passive	Passive Vio
1	-1.411971616	-4.181429784	-3.223607897	-4.440275052
2	0.624329357	-2.547970362	-0.39415463	-1.178066306
3	4.243008667	2.24757814	4.948290508	3.339881355
4	-0.166720523	-3.402428796	-2.072204426	-4.10426664
5	2.545213867	-1.080792596	0.991122353	-1.366547553
6	5.968868187	4.499627016	5.452010625	3.300672792
7	-0.821704504	-4.326618468	-2.978189672	-5.430050287
8	-0.435189035	-3.461466391	-2.05650238	-4.32462545
9	1.133544366	-0.992716515	1.503236671	-0.767997111
Averages	1.297708752	-1.471801973	0.241111239	-1.663474917

Higher Comprehension Group

Region	Active	Active Vio	Passive	Passive Vio
1	-1.207886591	-3.749087317	-2.174421279	-1.589711124
2	0.292777977	-1.64172814	0.606795326	0.954663305
3	3.461893512	3.906717302	4.660060489	5.49585639
4	-1.256897194	-3.419883959	-2.603785263	-1.83001955
5	-0.046065338	-1.009205731	0.215921569	1.012326469
6	3.390823053	3.568349129	4.226797243	4.862093611
7	-1.26755513	-4.385368015	-3.958045254	-3.238169353
8	-1.358512219	-3.126053837	-2.505716297	-2.488813489
9	1.303697564	0.652378104	2.115422867	2.396280783
Averages	0.368030626	-1.022653607	0.064781045	0.619389671

Adults

Region	Active	Active Vio	Passive	Passive Vio
1	1.514199414	-0.747550224	1.188270031	-0.597013102
2	2.432594443	0.198803212	2.030999822	1.328892357
3	2.949850274	1.798517045	3.275990512	2.748060906
4	1.812025311	0.082610331	1.045138287	0.70964441
5	2.540898339	0.906874969	2.440066823	2.43741175
6	3.391739785	2.25045545	3.672771136	3.690193671
7	1.463104736	-1.049038193	0.75744499	-0.305227729
8	1.723574116	-0.399706453	0.974723999	0.754277571
9	2.511948129	0.940569898	2.444163366	2.423567864
Averages	2.259992727	0.442392893	1.981063219	1.465534189

Appendix E: Relative Amplitude Differences Between Conditions for Comprehension Groups

	ActvsActVio	ActvsPass	PassvsPassVio
Lower Comprehenders			
Region 1	2.769458167	1.81163628	1.216667155
Region 2	3.172299719	1.018483987	0.783911675
Region 3	1.995430527	-0.705281841	1.608409153
Region 4	3.235708273	1.905483904	2.032062213
Region 5	3.626006464	1.554091515	2.357669906
Region 6	1.469241172	0.516857562	2.151337833
Region 7	3.504913964	2.156485168	2.451860615
Region 8	3.026277356	1.621313345	2.26812307
Region 9	2.126260881	-0.369692305	2.271233783
Average	2.769510725	1.056597513	1.904586156
Higher Comprehenders			
Region 1	2.541200726	0.966534688	-0.584710155
Region 2	1.934506117	-0.314017349	-0.347867979
Region 3	-0.44482379	-1.198166976	-0.835795901
Region 4	2.162986765	1.346888069	-0.773765713
Region 5	0.963140393	-0.261986907	-0.7964049
Region 6	-0.177526076	-0.83597419	-0.635296367
Region 7	3.117812882	2.690490121	-0.719875901
Region 8	1.767541618	1.147204077	-0.016902808
Region 9	0.651319459	-0.811725304	-0.280857915
Average	1.390684233	0.303249581	-0.554608627
Adults			
Region 1	2.261749638	0.325929384	1.785283133
Region 2	2.233791231	0.401594621	0.702107465
Region 3	1.151333228	-0.326140238	0.527929606
Region 4	1.72941498	0.766887024	0.335493877
Region 5	1.634023369	0.100831516	0.002655073
Region 6	1.141284335	-0.281031351	-0.017422535
Region 7	2.512142929	0.705659746	1.062672719
Region 8	2.123280568	0.748850116	0.220446428
Region 9	1.57137823	0.067784762	0.020595503
Average	1.817599834	0.278929509	0.51552903

Appendix F: Fluency Groups Average Amplitudes

Lower Fluency

Region	Active	Active Vio	Passive	Passive Vio
1	-7.501672431	-5.006703685	-7.06717558	-5.986830293
2	-4.159936467	-2.298084139	-3.321258984	-1.870861972
3	1.382202397	3.570753204	2.755356683	3.481169601
4	-7.211865824	-4.21542401	-7.22993767	-6.292943035
5	-2.724574904	-0.970890313	-2.632477306	-2.346485797
6	3.267624463	5.305186595	3.647052755	3.668520744
7	-7.928961633	-4.500360563	-7.869939228	-7.494413718
8	-4.935803704	-2.599005381	-5.401237216	-4.772532707
9	-1.864752487	-0.33744368	-1.245695713	-0.874893137
Average	-3.519748955	-1.227996886	-3.151701362	-2.498807813

Higher fluency

Region				
1	0.052061209	-3.415595801	-1.643993737	-1.750776631
2	2.026490467	-1.497822278	1.407587013	0.60671915
3	3.949370099	2.796999727	5.083158879	4.078526126
4	0.578315277	-3.181188821	-1.200293973	-1.318781287
5	3.229974182	-0.306754916	3.138613684	2.308360073
6	5.338313712	3.494394406	5.962798659	5.005089762
7	0.363023635	-4.142045394	-3.061827062	-2.979327395
8	0.572342874	-3.2946752	-0.482241958	-2.316740003
9	2.80144783	0.404694853	4.177317182	2.244187162
Average	1.806631153	-1.335158592	1.004690114	0.250012844

Adults

Region				
1	1.514199414	-0.747550224	1.188270031	-0.597013102
2	2.432594443	0.198803212	2.030999822	1.328892357
3	2.949850274	1.798517045	3.275990512	2.748060906
4	1.812025311	0.082610331	1.045138287	0.70964441
5	2.540898339	0.906874969	2.440066823	2.43741175
6	3.391739785	2.25045545	3.672771136	3.690193671
7	1.463104736	-1.049038193	0.75744499	-0.305227729
8	1.723574116	-0.399706453	0.974723999	0.754277571
9	2.511948129	0.940569898	2.444163366	2.423567864
Average	2.259992727	0.442392893	1.981063219	1.465534189

Appendix G: Relative Amplitude Differences Between Conditions for Fluency Groups

	ActvsActVio	ActvsPass	PassvsPassVio
Lower Fluency Group			
Region 1	-2.494968746	-0.434496851	-1.080345287
Region 2	-1.861852328	-0.838677484	-1.450397012
Region 3	-2.188550807	-1.373154287	-0.725812918
Region 4	-2.996441814	0.018071845	-0.936994635
Region 5	-1.753684592	-0.092097598	-0.285991509
Region 6	-2.037562132	-0.379428292	-0.021467989
Region 7	-3.42860107	-0.059022405	-0.37552551
Region 8	-2.336798323	0.465433512	-0.628704509
Region 9	-1.527308807	-0.619056773	-0.370802577
Average	-2.291752069	-0.368047593	-0.652893549
Higher Fluency Group			
Region 1	3.46765701	1.696054946	0.106782894
Region 2	3.524312745	0.618903453	0.800867863
Region 3	1.152370372	-1.133788779	1.004632753
Region 4	3.759504098	1.77860925	0.118487314
Region 5	3.536729098	-3.4453686	0.830253611
Region 6	1.843919306	-0.624484947	0.957708898
Region 7	4.505069029	3.424850697	-0.082499667
Region 8	3.867018074	1.054584833	1.834498045
Region 9	2.396752977	-1.375869352	1.93313002
Average	3.141789745	0.801941039	0.75467727
Adults			
Region 1	2.261749638	0.325929384	1.785283133
Region 2	2.233791231	0.401594621	0.702107465
Region 3	1.151333228	-0.326140238	0.527929606
Region 4	1.72941498	0.766887024	0.335493877
Region 5	1.634023369	0.100831516	0.002655073
Region 6	1.141284335	-0.281031351	-0.017422535
Region 7	2.512142929	0.705659746	1.062672719
Region 8	2.123280568	0.748850116	0.220446428
Region 9	1.57137823	0.067784762	0.020595503
Average	1.817599834	0.278929509	0.51552903

Appendix H: Comprehension Group Post Hoc Results by Region

Region 1: Left anterior region. Post hoc tests revealed an interaction in region 1 between sentence condition and TW, but no group interaction [F (9,405)=3.51, p=.0021]. Condition and TW contrasts revealed no significant results. There was, however, a significant main effect of condition [F(3,135)=14.71, p<.001]. Contrasts between conditions revealed significant results between the active control condition and active violation condition [F(1,45)=33.79, p<.001], the active control condition and the passive control condition [F(1,45)=10.79, p=.0020], and the passive control condition and passive violation condition [F(1,45)=34.96, p<.001]. This shows that sentence condition had an effect on the N400 like amplitudes of the participants in the left anterior region.

Region 2: Left central region. Post hoc tests revealed an interaction between sentence condition and time [F(9,405)=2.68, p=.01], and a marginally significant interaction between condition, time, and group [F(18,405)=1.65, p=.06]. Furthermore, there was an interaction between condition and group [F(6,135)=2.64, p=.05], but no significant contrasts. Finally, there was a significant effect of condition [F(3,135)=12.94, p<.0001]. Contrast between conditions revealed significant differences between active control and active violation sentences [F(1,45)=25.06, p<.0001], and between passive control and passive violation sentences [F(1,45)=16.58, p=.0002]. Unlike region 1, there were no statistical significance in the differences in amplitudes between the active and passive sentences.

Region 3: Left posterior region. There were no significant interactions or main effects in the post hoc analysis therefore no contrasts were made.

Region 4: Right anterior. Post hoc tests in this area revealed a three-way interaction between condition, time, and group [F(18, 405)=2.4, p=.0057]. There was also a main effect of condition [F(3,135)=17.9, p<.0001]. Contrast revealed significant differences between active and active violation sentences [F(1,45)=40.81, p<.0001], active control versus passive control sentences [F(1,45)=11.28, p=.0016], and passive versus passive violation sentence [F(1,45)=37.73, p<.001].

Region 5: Right central. There were no significant interactions in this region. However there was a main effect of condition [F(3, 135)=15.37, p<.0001]. Contrast revealed significant differences between active and active violation sentences [F(1,45)=32.57, <.0001], and passive and passive violation sentences [F(1,45)=29.43, p<.0001].

Region 6: Right posterior. There were no significant interactions or main effects in this region.

Region 7: Anterior midline. There was a marginal interaction between condition, time, and group [F(18, 405)=2.32, p=.0538], however contrasts were non-significant. There was also a significant interaction between condition and time [F(9,405)=2.32, p=.0325]. Contrasts revealed no significant results. Finally there was a main effect of condition [F(3,135)=17.65, p<.0001]. Contrasts revealed significant differences between active and active violation sentences

[F(1,45)=36.64, p<.0001], active control and passive control sentences [F(1,45)=11.8, p=.0013], and passive versus passive violation [F(1,45)=47.78, p<.0001].

Region 8: Central midline. There was an interaction between condition and time [F(9,405)=2.74, p=.0102]. Contrasts for this interaction revealed no significant differences. There was also a main effect of condition [F(3,135)=20.54, p<.0001]. Contrasts revealed significant differences between active and active violation sentences [F(1,45)=30.31, p<.0001].

Region 9: Right posterior. There were no significant interactions in this region, however there was a main effect of condition [F(3,135)=12.7, p=.0001]. Contrasts between the conditions revealed no significant differences between the active and active violation sentences, active and passive sentences, and passive and passive violation sentences.

Appendix I: Fluency Group Post Hoc Results by Region

Region 1: Left anterior. The post hoc results showed significant differences between groups [$F(2,45)$=5.24, p=.009]. Contrast between the groups revealed a significant differences between the lower fluency and adult groups p=.0026. All other group contrasts were not significant.

Further analysis of the data also revealed a number of interactions. There was a significant three-way interaction between condition, time and group [$F(18,405)$=2.14, p=.0238], but no significant contrasts that pertain to the research questions. There was a marginally significant two way interaction between condition and group [$F(3,135)$=2.64, p=.0545]. Contrast revealed significant group differences between the active control and active violation conditions [$F(2,45)$=6.38, p=.0037], specifically between the low fluency group and adults, p=.0010. All other contrasts for the marginally significant interaction between group and condition were not significant. Finally, there was a main effect of condition [$F(3,135)$=16.00, p<.0001], and contrasts revealed significant differences between the active and active violation sentences [$F(1,45)$=38.59, p<.0001], the active and passive sentence [$F(1,45)$=12.20, p=.0011], and the passive versus the passive violation sentences [$F(1,45)$=39.48, p=<.0001].

Region 2: Left central. There was a main effect of group [$F(2,45)$=3.80, p=.0300], but no significant group contrasts. Also, there was a three way interaction between condition, time, and group [$F(18, 405)$=1.94, p=.0384], but no significant contrasts. There was also an interaction between condition and group [$F(6,135)$=4.09, p=.0090]. Contrast revealed significant group differences

between the active control and active violation conditions [F(2,45)=10.63, p=.0002], specifically between the low fluency group and high fluency group, p=.0011, and between the lower fluency group and adults, p=<.0001. There was a main effect of condition [F(3,135)=12.20, p=.0001]. Contrasts reveal significant differences between the active and active violation condition [F(1,45)=28.93, p<.0001], and the passive and passive violation sentences [F(1,45)=14.71, p=.0004].

Region 3: Left posterior. There were no significant interactions or main effects in this region.

Region 4: Right anterior. There was a main effect of group [F(2,45)=4.43, p=.0175], but no significant group contrasts. There was an interaction between group and condition [F(6,135)=2.66, p=.0487], however there were no significant contrasts. There was also a main effect of condition [F(3,135)=17.86, p<.0001]. Contrast revealed significant amplitude differences between the active and active violation sentences [F(1,45)=42.53, p<.0001], the active and the passive sentences [F(1,45)=12.55, p=.0009], and the passive and passive violation sentences [F(1,45)=35.76, p<.0001].

Region 5. Right central. There was an interaction of condition and group. Contrasts show group differences between the active and active violation condition [F(2,45)=12.33, p<.0001], with significant differences between the lower fluency group and higher fluency group, p=.0002, and the lower fluency group and adults, p=<.0001. There was also a main effect of condition [F(3,135)=13.45, p<.0001], with significant contrasts between the active and active violation

sentences [F(1,45)=37.22, p<.0001]; other contrast between the sentences were not significant.

Region 6: Right posterior

There were no significant interactions or main effects in this region.

Region 7: Anterior midline. There was a main effect of group [F(2,45)=4.03, p=.0245]. There were no significant interactions. There was also a main effect of condition [F(3,135)=18.34, p<.0001]. Contrast show significant amplitude differences between the active and active violation sentences [F(1,45)=39.26, p<.0001], between the active and passive sentences [F(1,45)=12.60, p=.0009], and between the passive and passive violation sentences [F(1,45)=51.20, p<.0001].

Region 8: Central midline. There was a significant interaction between condition and group [F(6,135)=3.45, p=.0171]. Contrast revealed significant group differences between the active control and active violation conditions [F(2,45)=8.06, p=.0010], specifically between the low fluency group and the high fluency group, p=.0036, and the low fluency group and adults, p=.0004. There was also a main effect of condition [F(3,135)=20.67 p<.0001]. Contrast revealed significant amplitude differences between the active and active violation sentences [F(1,45)=35.77, p<.0001], and the passive and passive violation sentences [F(1,45)=36.13, p<.0001].

Region 9: Posterior midline. There was only a main effect of condition

[F(3,135)=8.97, p=.0012]. Contrasts revealed significant differences in

amplitudes between the passive and passive violation sentences [F(1,45)=16.21,

p=.0002].

About the Author

Annie Nelson was born in Puerto Rico, and earned her Bachelor's degree in advertising and public relations from the University of Central Florida. Later, she earned a Master's degree, and then a Ph.D. in reading education from the University of South Florida. After working in the field of public relations for a couple of years, she went back to school in order to become certified to teach 6th to 12th grade Language Arts. She taught middle school Language Arts for three years in Hialeah, Florida. After receiving her Master's, she worked as a Reading Coach in Tampa, Florida. While working on her doctoral degree she worked as a graduate assistant for four years. She is currently an Assistant Professor at Pacific University in Eugene, Oregon.