THE RELATIONSHIP BETWEEN PROSODIC SENSITIVITY AT THE DISCOURSE LEVEL AND READING SKILLS: AN ELECTROPHYSIOLOGICAL INVESTIGATION

by

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This work is dedicated to my parents,

who instilled in me a passion for learning.

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ABSTRACT

A growing body of research suggests that prosody plays an important role in the acquisition of literacy-related skills. The present study sought to identify electrophysiological indices of prosodic sensitivity during spoken sentence comprehension and to examine the relationship between those brain responses and measures of reading achievement in adult typical readers. The electroencephalogram (EEG) was recorded in twenty-four participants while they listened to pairs of spoken instructions regarding the movement of objects onto shapes drawn on a mat. Each trial was composed of a context instruction (e.g., "Put the mouse on the square.") followed by a target instruction. The target instruction included either the same object ("Now, put the mouse on the circle.") or the same shape ("Now, put the frog on the square."). In addition, the prosody of the target instruction was manipulated so that the object was either correctly or incorrectly accented in relation to the context instruction, which yielded two expected prosody conditions and two unexpected prosody conditions. Participants were also administered a series of standardized reading measures. Event-related potential (ERP) results for the unexpected prosody conditions showed a P600-like component in response to superfluous accents and an N400-like component followed by a P600-like component in response to missing accents. The P600 was interpreted as reflecting a reanalysis stage that was prompted when a superfluous or missing accent was encountered, while the N400 suggested that missing accents also hindered semantic integration. The ERP to superfluous accents was negatively correlated with reading measures in the areas of phonological awareness and decoding, meaning that smaller ERP amplitudes were associated with higher scores. A negative correlation that

approached significance was found between the ERP to superfluous accents and comprehension. Thus, the higher the scores on those reading measures, the lower the reanalysis cost in response to superfluous accents. These findings suggest that a relationship between prosodic sensitivity and reading persists beyond the period of reading acquisition.

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Chapter One

Introduction

The role of phonology in reading development has been widely researched, producing results that have had a significant impact on the field of reading. One of the most prevalent explanations of reading difficulties, the phonological deficit hypothesis (Stanovich, 1986; Stanovich and Siegel, 1994), is based on the extensive evidence of a relationship between reading abilities and performance on phonological processing tasks that require phonological awareness, phonological short term memory, or rapid automatized naming. More specifically, the phonological skill of phonemic awareness (i.e., the ability to hear and articulate the individual sounds within a word) has been shown to be a strong predictor of future performance in word recognition, decoding, and spelling (Scarborough, 2005). These bodies of research have had major instructional implications, which are most prominently reflected in the National Reading Panel's (NRP; NICHD, 2000) identification of phonemic awareness as one of the five essential components of reading instruction and their overall conclusion that systematic instruction in this component improves the reading and spelling skills of learners across a range of grade levels and ages.

This convergence of research has led to the assumption that strong phonemic awareness skills assist the development of quick and accurate word recognition, which, in turn, allows more cognitive resources to be devoted to reading comprehension. However, it cannot be ignored that phonemic awareness is only one aspect of phonology, and, as a result, our understanding of phonology's contributions to reading development and performance may be incomplete. In fact, there is reason to believe that the field of reading still has much to learn about reading development in general. Recent results of the National Assessment of Educational Progress (NAEP: NCES, 2013a, 2013b) indicate that only 35% of fourth graders, 36% of eighth graders, and 38% of twelfth graders scored at the *proficient* level in reading. Thus, nearly two-thirds of the students who were tested scored at the levels of *basic* or *below basic*, meaning that they possessed limited or no mastery of the fundamental skills required for successful navigation of grade level material. A majority of students tested on the NAEP in recent years have continued to perform poorly in reading since the National Reading Panel's report was published in 2000.

It may be that the factors involved in proficient reading are even more complex than previously suspected. Storch and Whitehurst (2002) captured this complexity with a dual-path structural equation model that depicted the relationship between oral language, code-related skills, and later reading development. They assessed the language and literacy skills of 626 children from low-income families from four years of age through the fourth grade and found that the nature of the reading process changed over time. Specifically, they found that reading ability was best conceptualized as a single factor (reading accuracy) in Grades 1 and 2 and, then, as the two factors of reading accuracy and reading comprehension in Grades 3 and 4. This additional factor of reading comprehension creates new problems for many readers who may have experienced little difficulty during the beginning phases of "learning to read" but suddenly find themselves struggling with the more advanced phases of "reading to learn" (Chall, 1983). Leach, Scarborough, and Rescorla (2003) explored this very phenomenon by examining the differences between the literacy, language, and cognitive skills of children with early-and late-emerging reading disabilities and found that nearly one-third of late-emerging reading disabilities manifested in comprehension deficits without accompanying difficulties in word recognition and decoding. Together, these studies provided evidence that reading comprehension is not simply the product of strong word reading skills that have resulted from a solid understanding of the segmental aspect of phonology, namely the phoneme.

The findings of Catts, Hogan, and Adolf (2005) provided further insight into the complex nature of reading comprehension. In a longitudinal study, they investigated the relative contributions of skills in word recognition and listening comprehension in reading comprehension scores at grades 2, 4, and 8. They found that word recognition accounted for more unique variance in the early grades (27% in grade 2, 13% in grade 4, and 2% in grade 8) while listening comprehension accounted for more unique variance beyond the primary grades (9% in grade 2, 21% in grade 4, and 36% in grade 8). The growing importance of listening comprehension once again implicates phonology as a key contributor to reading development but also suggests that more than the segmental aspect of phonology may be involved.

In fact, several studies conducted during the last decade suggest that sensitivity to the suprasegmental aspects of phonology, also known as prosody, may be related to reading acquisition (Clin, Wade-Wooley, & Heggie, 2009; Holliman, Wood, & Sheehy, 2008, 2010a, 2010b, 2012; Miller & Schwanenflugel, 2006, 2008; Schwanenflugel, Hamilton, Wisenbaker, Kuhn, & Stahl, 2004; Whalley & Hansen, 2006; Wood, 2006). Prosodic features of speech are categorized as suprasegmental rather than segmental because, unlike segmental phonology, in which information is carried by discrete units of speech such as phonemes, the information transmitted through suprasegmental phonology extends over the combination of multiple segments of speech within words, phrases, sentences, and discourse. In order to comprehend spoken language, listeners must extract relevant information from the continuous speech stream. The listener must quickly interpret each word, phrase, and sentence a speaker utters while simultaneously integrating those utterances with previous discourse (Arnold, 2008). The speaker's use of prosody assists the listener with this complex process. At the word level, prosody plays a lexical role through the expression of stress patterns (Cooper, Cutler, & Wales, 2002). At the sentence level, prosody can help listeners detect clause boundaries (Pynte & Prieur, 1996), understand the emotional state of speakers (Besson, Magne, & Schön, 2002), and distinguish between questions and statements (Wales & Taylor, 1987).

Prosody also plays an important role in information structure, which concerns the way information is organized in the sentences of a discourse situation (Most & Saltz, 1979). From an information structure point of view, sentences can be divided into what is not known by the listener and what is already known by the interlocutors. Formal pragmatic theories distinguish between these two types of information using many different labels such as *given/new*, *topic/focus*, *theme/rheme*, *theme/predicate*, *topic/comment* (von Heusinger, 2002). The distinction between these labels is important for distinguishing among different linguistic phenomena. For instance, the topic refers to what is being talked about while the comment relates to what is being said about the topic. However, these terms have been used synonymously in the psycholinguistics and neurolinguistic literature, and, unless otherwise specified in the text, the labels *given/new* will be used throughout this dissertation for clarity purposes. In spoken language, the speaker often uses a pitch accent to attract the listener's attention toward the new relevant information, thus speeding-up the comprehension process (see Cutler, Dahan, & van Donselaar, 1997, for an extensive review of prosody at the word, sentence, and discourse levels).

A growing body of literature suggests that prosody sensitivity may play a major role in reading acquisition, as well. For example, second and third graders with good reading skills have been shown to exhibit more adult-like intonation when reading aloud (Miller & Schwanenflugel, 2006; Schwanenflugel, Hamilton, Wisenbaker, Kuhn, & Stahl, 2004), and the acquisition of adult-like speech intonation in first and second grades has been shown to predict later reading comprehension in third grade (Miller & Schwanenflugel, 2008). From a perception perspective, this relationship between prosodic sensitivity and reading skills has been investigated using several novel prosody perception tasks that included the manipulation of the rhythmic structure of words (Holliman, Wood, & Sheehy, 2008, 2010a, 2012; Whalley & Hansen, 2006; Wood, 2006). Overall, the results of these perception studies consistently pointed to a correlation between the children's performance on the prosodic tasks and their reading skills. In addition, prosodic task performance was found to be predictive of later reading performance (Holliman, Wood, & Sheehy, 2010b). In line with these findings, several studies have shown that individuals with dyslexia perform significantly lower than controls matched either by age or reading level on non-speech discrimination tasks varying in temporal properties (Goswami et al., 2011; Leong, Hämäläinen, Soltész, & Goswami, 2011; Thomson, Fryer, Maltby, & Goswami, 2006). These findings have led Goswami to propose that dyslexia results from a basic auditory rhythmic processing deficit, which, in turn, interferes with the acquisition of appropriate phonological representations. A possible cause of this deficit may be related to inefficient neural oscillations within the auditory cortex, which do not properly align with the rhythmic information carried by the speech signal (Goswami, 2011; Hämäläinen, Rupp, Soltész, Szücs, & Goswami, 2012).

To summarize, an increasing body of evidence highlights the relationship between prosodic sensitivity and the acquisition of good reading skills. The findings also suggest that underdeveloped sensitivity to prosody may be the basis of some forms of reading disabilities (e.g., dyslexia). It is important to note, however, that the perception tasks of the aforementioned studies focused primarily on prosodic sensitivity at the word level. Thus, the relationship between reading achievement and prosodic sensitivity beyond the word level is still poorly understood.

Purpose of the Study

Since prosody beyond the word level plays such an essential role in the comprehension of spoken language, it is likely that a relationship exists between an individual’s awareness of prosody beyond the word and sentence levels and his or her reading performance. Thus, the purpose of the present study was to establish a link between prosodic sensitivity at the discourse level and reading performance in adults. Information structure, specifically prosodic perception of the given/new distinction, served as the lens through which prosodic sensitivity was investigated.

Electroencephalography (EEG) is particularly well-suited to the study of prosodic processing. This technique allows the non-invasive recording of the brain electrical activity using an array of electrodes placed on the scalp. The main advantage of EEG is its high temporal resolution, within millisecond ranges. Event-Related Potentials (ERPs), the systematic brain responses triggered by a sensory or motor stimulus, can be extracted by averaging EEG time-locked to the presentation of a stimulus. Compared to more traditional behavioral measures (e.g., accuracy and reaction times), ERPs can be used to track the time course and distinct stages of language processing, rather than the behavioral outcomes that may be influenced by additional factors (e.g., motor, attention, memory, etc.). It is worth noting that distinct components of the ERP can be detected even when participants are not particularly attending explicitly to the stimulus being presented. Finally, ERPs can sometimes be a more sensitive measure than behavioral measures because processing differences between pairs of conditions are detected in the absence of any behavioral differences (Luck, 2005). Using the ERP method, a few studies have recently investigated the brain responses elicited by superfluous accents on given information or missing accents on new information (Dimitrova, Stowe, Redeker, & Hocks, in press; Hruska, Alter, Steinhauer, & Steube, 2001; Hruska & Alter, 2004; Ito & Garnsey, 2004; Johnson, Breen, Clifton, & Morris, 2003; Magne, Astésano, Lacheret-Dujour, Morel, Alter, & Besson, 2005; Pannekamp, van der Meer, & Toepel, 2011; Toepel & Alter, 2004; Toepel, Pannekamp, & Alter, 2007). The results of these studies are quite heterogeneous due to the variety of tasks, stimuli, and language used in their respective experimental designs. Both superfluous accents and missing accents have been associated with increased negative ERPs and/or increased positive ERPs as well as no ERP effect; however, despite the differences across these findings, it is interesting to note that the ERP effects elicited by a missing accent are often found to be different from the

ERP effects elicited by a superfluous accent, suggesting that they may be handled differently by the language network.

Research Questions, Design, and Hypotheses

Two specific questions were developed to guide this investigation. First, which ERP component is affected by prosodic sensitivity at the discourse level? Second, what is the relationship between the size of the ERP component reflecting prosodic sensitivity and reading achievement?

As a means of addressing these questions, a new prosody task, adapted from Dahan, Tanenhaus, and Chambers (2002) and Arnold (2008), was developed to investigate the brain responses to expected and unexpected prosody patterns in a discourse context. EEG were recorded as participants performed the task. In addition, a series of standardized reading measures were administered to assess participants' skills in vocabulary, phonological awareness, word reading, fluency, and comprehension. The data from the prosody task and the reading measures were then analyzed to determine the relationship between prosodic sensitivity at the discourse level and reading comprehension.

Regarding the first research question, it was hypothesized that the unexpected prosody conditions (i.e., superfluous accent and missing accent) would trigger an increased early negativity and/or positivity in the ERPs, as has been previously indicated in the literature (Dimitrova, Stowe, Redeker, & Hocks, in press; Hruska, Alter, Steinhauer, & Steube, 2001; Hruska & Alter, 2004; Ito & Garnsey, 2004; Johnson, Breen, Clifton, & Morris, 2003; Magne, Astésano, Lacheret-Dujour, Morel, Alter, & Besson, 2005; Pannekamp, van der Meer, & Toepel, 2011; Toepel & Alter, 2004; Toepel, Pannekamp, & Alter, 2007). The precise time course and scalp distribution of the expected ERP effects was challenging to predict since the literature presents variable findings across studies; however, a cluster-based permutation approach specifically designed for analysis of EEG time series was used. This method allowed for the precise identification of the time course and spatial distribution of EEG differences between pairs of conditions without relying on any a priori assumptions about when and where those differences may occur. For the second research question, it was hypothesized that prosodic sensitivity, as reflected by the size of the ERP effects to superfluous and missing accents, would correlate with performance on the reading measures.

Significance of the Study

The proposed study has both theoretical and practical implications. Findings related to the neural markers of suprasegmental phonology and the relationship of those markers to reading achievement in adults will provide a view of the influence of prosody on the reading skills of individuals who have surpassed the reading acquisition phase. If a relationship still exists at the end point of reading development, it is logical that the relationship at the beginning of the process could be even stronger. Thus, this study could provide an impetus for the study of the relationship between prosodic sensitivity at the discourse level and reading achievement in children, which could potentially inform theories of reading acquisition. Furthermore, from a practical perspective, if prosodic sensitivity appears to predict reading achievement, then developing tasks and assessments that identify students who demonstrate weaknesses in this area may help students who are at risk for future reading difficulties receive intervention sooner. Lastly, the identification of students with weaknesses in prosodic sensitivity may inform the development of interventions that specifically target suprasegmental phonology, not only in children struggling with learning to read, but in adult poor readers, as well.

Chapter Two

Literature Review

Prosody can be defined in terms of phonetic properties, abstract phonological structure, and functions. At the concrete phonetic level, prosody is expressed through variations of acoustic features such as fundamental frequency (F_0), which corresponds to the rate of vibration of the vocal cords (expressed in Hertz), intensity (expressed in decibels), and duration of phonemes and syllables (expressed in seconds, milliseconds, etc.; Magne et al., 2007).

From a phonological point of view, prosody can be described in terms of basic features such as accent, length, and tone. These features interact with one another to form phrases, which, in turn, can be combined into larger phrases that are hierarchically organized. For instance, Selkirk (1986) proposed the following prosodic units from smallest to largest: syllable, foot, prosodic word, phonological phrase, intonational phrase, and utterance. In addition, many other theories of prosodic hierarchy have been offered, diverging in the definitions and number of prosodic units they propose. For example, Beckman and Pierrehumbert (1986) and Selkirk (1986) proposed similar definitions for prosodic word and intonational phrase; however, what Selkirk (1986) labeled as the phonological phrase, Beckman and Pierrehumbert (1986) defined as the intermediate phrase (for English) and the accentual phrase (for Japanese). One source of this disagreement is the result of the role syntax plays in determining these prosodic units (Jun, 1998). In some theories (e.g., Selkirk, 1986; Nespor & Vogel, 1986), the syntactic structure of the utterance drives the structure of prosodic units, whereas in other theories (e.g., Beckman & Pierrehumbert, 1986), prosodic units are derived from the utterance's intonational structure.

Accentuation also plays an important role in defining prosodic hierarchy. Fox (2000) distinguishes between accentuation level 1, which deals primarily with lexical stress, and accentuation level 2, which is more related to the intonational phrase mentioned earlier and also includes pitch accents. In English, while an intonational phrase may contain one or more pitch accents that signal prominence (i.e., information that stands out relative to the surrounding information), the last pitch accent of the intonational phrase is defined as primary, or nuclear, because it is the most prominent. It is important to note that this is an idealized prosodic structure that would only occur in isolated sentences. However, sentences often occur in the broader context of a discourse or conversation, and the speaker may adjust the location of a pitch accent depending on the information he or she wants to communicate (i.e., the part of the utterance the speaker wants to be in focus). For example, the sentence "Mary will be back around 3" may be pronounced with a pitch accent on "3" if the focus is on the time, or on "around" if the speaker wants to emphasize his or her uncertainty regarding the exact time Mary will come back. In other words, information structure closely interacts with prosody in English, and, thus, impacts the organization of the intonational phrase. While the focused word is generally assigned the nuclear accent when marked prosodically, the words that follow it are deaccented. Note that with this organization, the nuclear accent still occurs on the last word of the intonation phrase, the focused word being the right-most prominent word, while information that is not in focus may still be accented, as long as it is in pre-focus (i.e., to the left of the focus; Büring, 2007).

At the functional level, prosodic cues facilitate the listener's ability to identify boundaries between words (e.g., Mattys & Samuel, 1997). Prosody also interacts closely with morphology (e.g., Clin, Wade-Woolley, & Heggie, 2009), guides syntactic parsing of utterances (e.g., Pynte & Prieur, 1996), and allows listeners to distinguish between statements and questions (Wales & Taylor, 1987). In addition, prosody conveys emotional cues, and allows the listener to infer the speaker's feelings and intents (Besson, Magne, & Schön, 2002). Finally, as previously mentioned, prosodic cues, through variations in accentuation and intonational patterns, closely interact with information structure to guide the listener toward the most relevant information in a discourse context (see Cutler, Dahan, & van Donselaar, 1997, for an extensive review of the functions of prosody).

The present study focused on prosody at the discourse level within the context of information structure. The definition of accent adhered to was closely aligned with Fox's (2000) Level 2 accentuation, in which the accent conveys prominence within the domain of the intonational phrase. The terms accent and pitch accent are used synonymously throughout this paper. Since reading also requires the ability to derive meaning from language, albeit written language, it is logical that readers draw upon their knowledge of spoken language, and perhaps even their knowledge of prosody, to accomplish this task. Thus, the connection between prosody and reading is also discussed in this review of the literature.

Prosody and Information Structure

Spoken communication requires the transfer of information from the speaker to the listener. Information is more likely to be successfully transferred when speakers and listeners share a common understanding of the discourse context. This shared understanding creates a common ground (Stalnaker, 1974) between speaker and listener and provides a backdrop against which all other information is organized. Repeated information becomes part of the common ground while new information stands out against this established backdrop. Each time new information is introduced it must be integrated with the preceding discourse. Thus, the common ground between speaker and listener is not stagnant but continually updated and modified to reflect the momentary shared understanding at a given point in time (Féry & Krifka, 2008). This packaging of new and given information to meet the immediate and transitory communicative needs of the discourse participants is known as information structure (Chafe, 1974).

The terms *new* and *given* are relative and dependent upon the context (Breen, Fedorenko, Wagner, & Gibson, 2010). Consider the following question and answer exchange:

(1) a. Who called the police?
b. Tom called the police.

Since the act of calling the police was introduced in the question (1a), it becomes given information in the answer (1b) and *Tom* is included as new information. However, if this same reply is provided in response to a different question, the new information changes:

(2) a. Who did Tom call?
b. Tom called the police.

In this example, both Tom and the act of calling are new information in the question (2a) and given information in the answer (2b). Thus, the new information that stands out against this backdrop in the answer is *police*. If a third question is posed, this same reply can convey yet another piece of new information:

(3) a. How did Tom contact the police?
    b. Tom called the police.

Now, both Tom and the police are given information in the answer (3b) and the act of calling is provided as new information. These three examples show how the same utterance can highlight different information depending on the preceding context. In each response, the relevant information is brought to the foreground. Thus, even though the same words in the same order can be presented as an acceptable response to three different questions, each time the response is uttered it has a different *focus*: *Tom* in (1b), *police* in (2b), and *called* in (3b). While the focus may introduce completely new information, it can also mark a rejection of the interlocutor's presupposition, such as in the example (4). In this case, the focus is said to be *contrastive*.

(4) a. Paul called the police?
    b. Tom called the police.

Finally, it is worth noting that in each of these examples, the focus is categorized as *narrow* because only one lexical item is focused as new information. If the same response of *Tom called the police* were offered as an answer to a more open-ended question (i.e. *What happened last night?*), then the focus would be categorized as *wide* or *broad* because each constituent of the response provides new information (Ladd, 1980).

Production of prosodic markings. Although the actual wording of the preceding discourse establishes what is deemed given and new in the subsequent discourse, adult speakers also use prosodic cues to draw their listeners' attention to the new information they wish to highlight. Different languages mark the distinction between given and new in different ways. In English and other West Germanic languages, the focused information is typically denoted with a pitch accent while the given information is deaccented (Cutler, Dahan, & van Donselaar, 1997). For instance, Figure 1 presents the acoustic analysis of the sentence “Put the mouse on the heart” when pronounced with “mouse” in focus (Figure 1A) or “heart” in focus (Figure 1B).

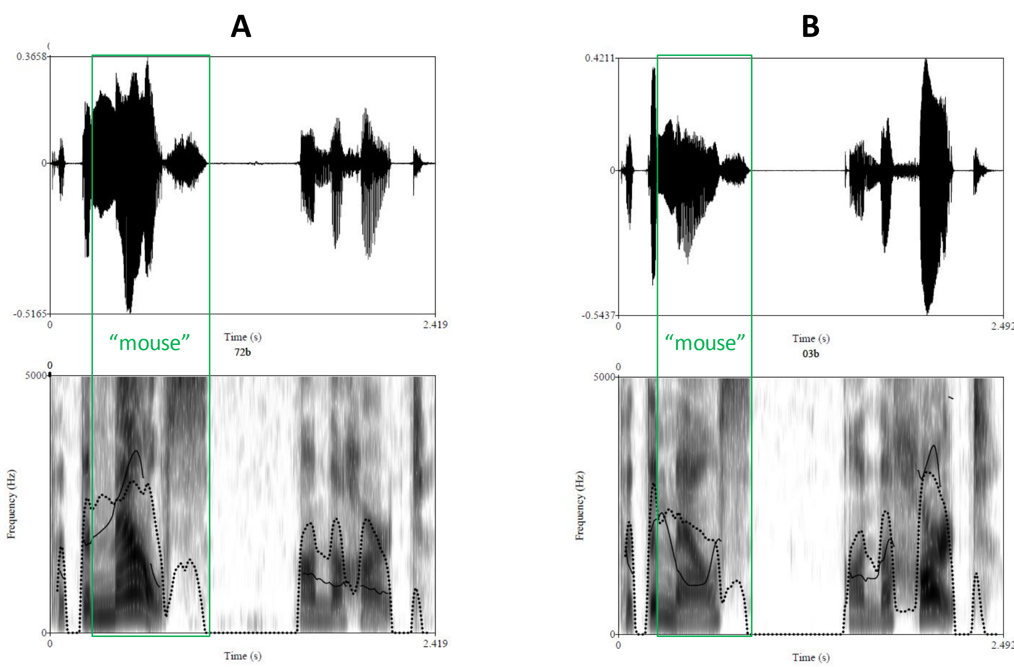

Figure 1. Acoustic properties of the word “mouse” in the sentence “Put the mouse on the heart” presented when accented (A) or unaccented (B). On both panels, the waveform is represented on the top part while the spectrogram (gray scale), pitch (solid line), and the intensity (dashed line) are represented on the bottom part. The word “mouse” presents higher pitch accent when accented than unaccented.

Considering the role that prosody at the word and sentence level appears to play in reading skills, understanding the developmental path of prosodic marking of focus may be particularly relevant. Several studies conducted in the 1970s revealed that children develop the ability to mark information structure with intonation at an early age. Wieman (1976) found that the two-word utterances produced by very young children (aged 1;9 to

2;5) reflected an appreciation for the distinction between new and given information. When producing noun + locative phrases (e.g., firetruck street), the children in her sample usually stressed the locative (e.g., firetruck *street*). However, when this type of phrase was produced in response to a 'what' question and the noun carried the new information (e.g., What is in the street?), children tended to stress the noun instead of the locative (e.g., *firetruck* street). Similarly, children typically stressed the object in verb + object phrases; however, on the only occasion in which the verb carried the new information, it was stressed instead of the object (e.g., *See* marble). Wieman (1976) found that even the youngest child in her sample assigned stress to new information, stressing the adjective in the phrase "Man. *Blue* man" even though he typically stressed the noun in adjective + noun phrases. Based on these observations, Wieman (1976) concluded that even very young children use contrastive stress to emphasize new information in relation to given and that within new information "there operates a hierarchy of semantic relations which determines stress assignment more specifically (p. 286)."

MacWhinney and Bates (1978) studied slightly older children (aged 3 to 6 years) and explored their use of six sentential devices to mark givenness and newness. The children, who were native speakers of English, Hungarian, or Italian, were presented with nine sets of pictorial stimuli. Each set consisted of three separate pictures in which one particular sentence element (i.e., subject, verb, direct object, indirect object) increased in newness throughout the set. Participants were shown each picture and asked to describe what was happening. Results indicated that English speakers of all ages used emphatic stress to mark newness more than Italian speakers did and that Italian speakers, in turn, used the device more than Hungarian speakers. They attributed the differences across languages to the tendency of Hungarian speakers to mark newness with word order rather than stress. Although the use of contrastive stress slightly increased with age in both English and Italian, the skill appeared to be reasonably acquired by 3 years of age. The authors interpreted their results to be supportive of the idea that children learn and acquire language-specific devices to mark newness early in their development.

In line with these findings, Hornby and Hass (1970) found evidence of children's use of contrastive stress to mark new information in 4-year-olds. Interestingly, the children were most likely to mark new information with contrastive stress when it appeared in the subject position (80%), followed by the verb position (56.25%), followed by the object position (43.75%), suggesting that children as young as four years of age are sensitive to word order when using contrastive stress to mark the given/new distinction. The authors noted that, in English, new information is typically included in the predicate, the part of the sentence that follows the subject and contains the verb. Thus, when new information occurs at the beginning of an utterance, it may be particularly useful to highlight it with contrastive stress because it attracts the listener's attention at a time when new information is not normally expected.

Together, these studies provide evidence that, by the age of 4 years, children appear to use intonation to direct their listener's attention to the new information, or focus, of an utterance. However, it should be noted that all of these studies concentrated on children's use of contrastive/emphatic stress, which is typically used to mark narrow focus, as opposed to broad focus. Thus, the results of these studies do not yield a complete picture of children's use of prosody to mark new information.

Comprehension of prosodic markings. There is strong evidence that adults use accentuation during discourse comprehension. In an early study, Most and Saltz (1979) asked their participants to pair “Wh” questions with the answers they judged to be the most appropriate. Results revealed that the participants’ decisions were greatly influenced by the position of the pitch accent in the answer. Bock and Mazzella (1983) conducted two experiments using a simple comprehension time paradigm. In the first experiment, participants listened to pairs of sentences (one context sentence and one target sentence) with an appropriate accent in the target sentence, an inappropriate accent in the target sentence, no accent in the context sentence, or no accent in either the context or target sentence. In their second experiment, the target sentences had either a passive or active construction, and the accent was either appropriately placed or inappropriately placed on the new information in the sentence. Overall, the results of both experiments revealed that comprehension times were faster when given and new information were appropriately marked with accentuation. More recently, Birch and Clifton (1995) conducted a series of experiments using question-answer pairs to examine how various patterns of pitch accents affected listeners’ judgments of prosodic appropriateness as well as their comprehension of an utterance. Again, sentences with a prosody matching the context question were judged the most appropriate and were more easily understood.

In order to better understand how prosodic sensitivity beyond the word level may contribute to the acquisition of good reading skills, the developmental path of sentence-level prosodic sensitivity must also be considered. In addition, given the strong link between language comprehension and reading comprehension, an inclusive understanding of how children use prosody must also take into account their usage of it for comprehension purposes. To this end, several studies compared prosody perception in children (ages ranging from 3 to 12 years) and adult controls. Cruttenden (1974) investigated the ability of 7- to 10-year-old British boys to use intonation clues to predict rugby scores. For each experimental trial, participants listened to an audio recording of the final score of one team and were asked to guess the score of the opposing, or "away" team. Cruttenden (1974) reasoned that a pitch accent on the name of the first team should lead participants to believe that the names of the teams, as opposed to their scores, were being highlighted, which should then lead them to predict that the scores were the same and the game was a tie. Similarly, a slightly different pitch accent on the second team should suggest that the name of the second team, rather than its score, was the last piece of new information and that, once again, the game was a tie. A third intonation pattern should signal that both the team names and their scores were different and that a win of some kind, either home or away, had occurred. These hypotheses were based on Cruttenden's (1974) proposal that the intonational knowledge required to interpret rugby results is similar to the knowledge required to understand the English intonation system.

Since all of his adult participants were able to provide the correct response to all nine stimulus recordings, despite a lack of interest in rugby, Cruttenden (1974) concluded that adults possess the necessary intonation system to successfully complete this particular task. However, his child participants responded differently. While most children, regardless of age, were able to determine that an outcome was a win rather than a tie, the number of correctly heard ties appeared to increase with age. Cruttenden (1974) interpreted these results to mean that, between the ages of 7 and 10, children are still in the process of acquiring the ability to use intonational patterns to make linguistic predictions and that, rather than using intonation to merely focus on one part of an utterance, children of this age are actually learning how to attach meaning to particular intonation patterns.

In a later study, Cruttenden (1985) tested the ability of 10-year-olds to distinguish between two sentences that were the same in every way but their intonation. He focused on 10-year-olds because many of the 10-year-olds in his 1974 study were able to make use of some of the intonation clues in his stimuli while most of the 7-year-olds were unable to make use of any. Thus, he believed that 10-year-olds would be at a transitional stage in their comprehension of intonation, not yet showing adult-like processing but proficient enough to show varying degrees of competency on a variety of tasks. Each sentence in a minimally contrasted sentence pair contained the exact same wording but differed in the word that received an accent. For example, in the sentence pair (the accented word is in italics), "I thought she had *brown* hair" and "I *thought* she had brown hair", the former implies that the speaker's prediction of brown hair was incorrect while the latter implies it was confirmed. For the experimental task, participants were presented with an audio recording of one of the sentences and asked to choose the picture that best matched the sentence. Results indicated that the adult control group significantly outperformed the children on the sentence pairs described above.

However, on another sentence pair, children and adults showed no differences in performance. For this task, participants were shown a picture of a girl talking to a boy while pointing to another boy who was standing at a distance. They were then presented with one of two versions of a sentence: (1) "That's my younger *brother* Peter" or (2) "That's my younger brother *Peter."* Their task was to point to the boy who was named

Peter. For the first sentence, participants should have pointed to the boy the girl was talking to because the accent placement indicated that “brother” was the final piece of new information, and “Peter” was the person being addressed. However, for the second sentence, participants should have identified the boy to whom the girl was pointing because the accent on “Peter” signaled that it provided new information pertaining to “brother.” Both the children and adults were highly successful on this particular task. Nevertheless, based on the results of all nine of the tasks in his study, Cruttenden (1985) concluded that the ten-year-old children he studied had not yet mastered the ability to interpret the nuances of intonation with the consistency or accuracy that was observed in his adult sample.

Since information structure can be realized through syntax, prosody, or a combination of both, other studies have investigated the relative contributions of syntactic and prosodic cues to children’s comprehension of information structure (Hornby, 1971; Hornby, 1973; MacWhinney & Price, 1980; Paul, 1985). Hornby (1971) looked specifically at first, third, and fifth grade children’s abilities to comprehend and produce topic/comment distinctions in five different surface structure constructions: active, passive, cleft, pseudocleft, and contrastive stress. Participants were shown two pictures and asked to choose the picture that best represented what the examiner was “talking about” in the spoken sentence, even though neither picture was an exact match to the sentence. For example, the sentence “The boy is riding the horse” was presented with a picture of a girl riding a horse and another picture of a boy riding a bicycle. The correct response was to point to the picture of a boy riding a bicycle because boy was the topic of the sentence. Results showed that the frequency of correct responses, as determined by pointing to the picture that included the topic of the spoken sentence, increased from first to fifth grades for all sentence conditions. Although the topic/comment distinction is not entirely synonymous with the given/new distinction, the two relationships are similar in that the topic typically is assumed to be information that is “not new” to the listener while the comment generally provides additional “new” information about the topic (Hornby, 1971; MacWhinney & Price, 1980).

In a different study, Hornby (1973) explored the roles of syntax and intonation in second, fifth, and ninth grade children’s language comprehension. This time, he concentrated on presuppositions, which can be realized in the surface structure of a sentence through syntax (cleft sentence constructions) or intonation (contrastive stress). Hornby (1973) based his experiment on Hutchinson’s (1971) proposal that listeners tend to accept presuppositions as true, in a sense taking them for granted and devoting more attention to the non-presupposed part of an utterance. To test this hypothesis, participants were presented with a prerecorded sentence followed by a picture, and were asked to judge whether the picture was an accurate representation of the sentence. For each grade level, one group of participants was presented with pictures that showed misrepresentations of the presupposed information in the stimulus sentence (i.e., a picture of a girl riding a bicycle shown after the cleft sentence, “It is the girl that is riding the horse,” or after the stress sentence, “The *girl* is riding the horse”) while another group was presented with pictures that showed misrepresentations of the non-presupposed information (i.e. a picture of a boy riding a horse shown after the cleft sentence, “It is the girl that is riding the horse,” or the stress sentence, “The *girl* is riding the horse”). All groups also were presented with pictures that were exact representations of the stimulus sentence.

Results revealed differences within and between age groups in response to the two types of sentences. In response to the cleft sentences, the ninth graders who were shown misrepresentations of presupposed information made more errors than their peers who were shown misrepresentations of non-presupposed information, whereas the second grade groups showed no differences on the cleft sentences. Results for the stress sentences indicated a reverse trend: the second graders in the group that was shown misrepresentations of presupposed information made more errors than their grade-level peers in the other group, while there was no significant difference between the two ninth grade groups. The fifth grade groups responded similarly to all sentence conditions. On the basis of these results, Hornby (1973) proposed that children become more sensitive to syntactic structure and less sensitive to intonation with age.

Using a task similar to Hornby (1971), MacWhinney and Price (1980) sought to disentangle the roles of word order and stress in first, fourth, and eighth graders' comprehension of the topic/comment distinction. They created sixteen different sentence types by varying the linguistic factors of cleft (cleft vs. non-cleft), case (agent as topic vs. patient as topic), stress (stressed first noun vs. unstressed first noun), and uniqueness (only one noun stressed vs. both nouns or neither noun stressed). Results indicated that stress appeared to influence participants' interpretation of cleft sentences differently at different grade levels. The first graders showed a tendency to select the stressed item in the spoken cleft sentences as the topic, whereas the eighth graders showed the opposite inclination and most often chose the picture containing the unstressed item. The fourth graders showed no preference for stressed or unstressed items. Thus, in line with Hornby (1973), these results pointed to a decline in children's reliance on intonation with age.

It is worth noting that MacWhinney and Price (1980) were not convinced that the forced-choice technique used in both their study and Hornby (1971) was the most suitable for investigating children's comprehension of the topic/comment distinction. Their skepticism was rooted in the reality that children's intentions for choosing one picture over another could not be determined. Both studies merely assumed that the instructions to point to the "picture I am talking about" (Hornby, 1971, p.1979) or "the picture that comes closest to what I'm talking about" (MacWhinney & Price, 1980, p.5) would compel children to search for the picture containing the topic of the sentence. However, it is highly possible that, for many sentences, children considered the comment to be the central point of the speaker's utterance and responded accordingly. In addition, MacWhinney and Price (1980) emphasized the inherent problems in using isolated sentences to test listeners' comprehension of "thematic structure" (p.11) and called for further research to use tasks that require comprehension of connected discourse.

Paul (1985) responded to MacWhinney and Price's (1980) suggestion by studying third and fifth grade children's abilities to comprehend the given/new distinction in two-sentence discourse contexts. The experimental task required participants to listen to two different context sentences followed by a stimulus sentence, which was one of three types of sentences (active, passive, or cleft) and also controlled for stress. Each trial began with the examiner presenting the participant with a spoken sentence (e.g. "In this story, first a man climbs a tree.") alongside a picture depicting that scene. Then, the examiner said a second sentence (e.g., "In this story, first a boy climbs a tree.") alongside another picture.

After these presentations, the examiner played a prerecorded stimulus sentence for the participant (e.g., “And then, it’s a *man* that climbs a tree.”) without an accompanying picture. The participant was told to point to the “story” that the prerecorded sentence was the “next part of” (e.g., the picture of the boy climbing a tree). Half of the sentences for each sentence type contained emphatic stress on the new element. Results revealed that participants responded similarly to new elements with and without emphatic stress. In fact, the only significant main effect found was that of sentence type, with participants performing better on the marked sentence structures (passives and clefts) than the unmarked active sentences. Thus, Paul (1985) concluded that markedness was the most influential factor on response.

However, stress did appear to have some effect on sentence type in that participants were more likely to misinterpret active sentences containing emphatic stress than active sentences that did not contain emphatic stress. For example, when presented with an active sentence that included emphatic stress, children tended to choose the picture that contained the stressed element regardless of whether or not it was correct. Thus, Paul (1985) inferred that the children were using a stress based strategy to comprehend active sentences, most likely because active sentences do not provide any other structural cues. Stress also appeared to assist the children in comprehending cleft sentences in that they were more likely to respond correctly to emphatically stressed clefts than clefts without emphatic stress. Thus, even on this marked sentence type which provides reliable structural cues, stress did impart an advantage to comprehension. These particular results are similar to MacWhinney and Price’s (1980) finding that their first grade participants were heavily influenced by stress, although they did not observe this influence in their fourth and eighth grade participants. In contrast, Paul's (1985) results showed that third and fifth grade children still used stress as a cue for the comprehension of specific sentence types.

The studies discussed thus far in this section involved judgment tasks that required participants to evaluate a stimulus sentence as a whole before making a specific decision such as predicting the ending of a stimulus sentence (Cruttenden, 1974), determining the accuracy of a pictorial representation of a stimulus sentence (Hornby, 1973), choosing the picture that best matched a stimulus sentence (Cruttenden, 1974; Hornby, 1971; MacWhinney & Price, 1980), or matching a stimulus sentence to the correct preceding context sentence (Paul, 1985). However, judgment tasks may not render the most accurate measures of participants' prosodic processing due to the additional cognitive demands involved in the act of making a decision. Because these cognitive demands create interference between stimulus presentation and participant response, the true comprehension abilities of the participants may be obscured. For this reason, Cutler and Swinney (1987) explored children's comprehension of accent and focus through a series of experiments using an "on-line" measure known as the word monitoring task. This task required participants to press a response button as soon as they recognized a particular target word rather than waiting until the end of a stimulus presentation to make a judgment. Thus, by eliminating the need to reflect upon and evaluate the stimulus as a whole, the authors hoped to obtain a more reliable portrait of children's comprehension of focus and accent.

For two of the experiments in this series, the stimuli were brief stories in which either focus or accent was manipulated. The target word for each story was always the name of one of the two characters in the story. In one experiment, focus was manipulated by varying the question that preceded the sentence containing the target word so that the target character's name appeared twice in a focused position and twice in a non-focused position. Participants were instructed to press a response button as soon as they heard the target character's name. Results indicated a significant focus effect in the adult control group but not in the child group, who ranged in age from 3 years 0 months to 5 years 8 months (i.e., 3;0 to 5;8). However, when the child sample was evenly divided into specific age groups (3;0-4;6, 4;7-4;11, and 5;0-5:8) and the response times of each group were analyzed, the focus effect was apparent in the oldest group, which suggested the emergence of processing advantages for focused words between the ages of 5 and 6 years old.

Cutler and Swinney (1987) followed this experiment with another experiment that compared the effects of accent to the effects of focus in the same participants, who were between the ages of 4 years 5 months and 5 years 11 months. The stimuli consisted of three "focus" stories from the previous experiment and three newly constructed "accent" stories that presented the target character's name twice in an accented position and twice in a non-accented position. The participants listened to a master tape of all six stories and were instructed to press a button as soon as they heard the target name for each particular story. Mean response times for each condition (accented, unaccented, focused, non-focused) indicated that accented targets were responded to significantly faster than unaccented targets and focused targets were responded to significantly faster than non-focused targets. Thus, the results of this experiment support those of the previous and suggest that children of around 5 years of age show processing advantages for both focus and accent.

It is difficult to draw conclusions from the studies discussed in this section, considering the varied results obtained across them. Some studies showed that children's reliance on intonation increased with age while others showed it decreased. Whereas some studies revealed that children used accenting to distinguish between given and new information, other studies found no such effect of accenting. However, the tasks in these studies were all very different, which could explain the lack of consistent findings. Many of the tasks were also confusing and required additional cognitive resources that may have interfered with a true assessment of children's prosodic sensitivity. Furthermore, most of the studies used stimuli that consisted of isolated sentences. Information structure involves the integration of new information with the information that has already been provided in the discourse. If isolated sentences are the only context provided, there is not much "other" information for the new information to be integrated with. The last two studies discussed, Paul (1985) and Cutler and Swinney (1987), marked a turning point in the literature by exploring discourse contexts. Cutler and Swinney (1987) showed even more advancement with their use of an online measure; however, the technology they used (i.e., pressing a response button) was still rather rudimentary.

Recent studies using online measures. The early studies reviewed in the previous section used primarily behavioral measures. In the past decade, several experiments have used either eye-tracking or Event-Related Potential (ERP) methodologies to investigate more directly the cognitive and neural processes underlying the use of pragmatic prosodic cues to comprehend spoken language in both adults and children.

Eye-tracking studies. In a series of two experiments, Dahan, Tanenhaus, and Chambers, (2002) investigated listeners' attention to discourse referents as they processed accented and deaccented noun phrases. Participants were presented with a computer screen displaying four objects and four geometric shapes. One particularity of the design was that two of the objects displayed on the screen shared either the same initial stressed syllable (as in the case of polysyllabic words), or the same onset and nucleus (as in the case of monosyllabic words), thus making them potential lexical competitors (e.g., "Candy" and "Candle"). The participants were given two consecutive instructions and were asked to move the objects accordingly. The first instruction established the given information (e.g., "Put the candle above the triangle."). The second instruction, also referred to as the critical instruction, either repeated the same object mentioned in the first instruction (e.g., "Now put the candle above the square.") or introduced the new, previously unmentioned competitor to the discourse (e.g., "Now put the candy above the square."). This temporary ambiguity was expected to cause the participants to look at the competitor object in some of the trials, at least while the object was unfolding in the target instruction. In addition, the object in the target instruction was either accented or unaccented. The participant's eye movements and fixations to the pictures were monitored while listening to the target instructions. Results showed that participants had more eye fixations on the previously unmentioned competitor when the object was repeated (i.e, given) and accented. Conversely, when the object was not repeated (i.e., new) and unaccented, participants had more fixations on the competitor that was previously mentioned in the context instruction. These effects were visible approximately 300 ms after the onset of the object. However, in a second experiment investigating how the information status of the noun phrase (new or given) affected the interpretation of an accent or lack of accent on that noun phrase, the results revealed that accented noun phrases were not always interpreted as new entities. Overall, these results showed that participants quickly used prosodic cues for reference resolution, and that unaccented words were interpreted as given while accented words were interpreted as new. At the same time, the findings also suggested that the associations new-accented and given-unaccented are not as rigid as might be assumed and that other pragmatics constraints from the context must be taken into account.

Using a similar design, Arnold (2008) compared 4- and 5-year-old children's use of sentence accent to comprehend new and given information within a discourse context to that of an adult control group. Participants were presented with pictures of objects and shapes on a computer screen and given directions to move one of the objects to a shape. They were then given one of the following directions: (1) move the same object to a different shape or (2) move a different object to a different shape. Two conditions were considered to be "anaphoric" in that the same object was included in both the first and second (critical) instruction ("Put the *bacon* on the star. Now put the *bacon* on the square."). The target word in the critical instruction (i.e., "bacon" in the previous example) was accented in the first condition and deaccented in the second condition. Two other conditions were considered to be nonanaphoric because the object in the critical instruction was different from the object mentioned in the first instruction ("Put the *bacon* on the star. Now put the *bagel* above the square."). Again, the target word in the second, critical instruction was either accented or deaccented. In a fifth condition, the object mentioned in the first instruction was replaced by the pronoun “it” in the second instruction (“Put the *bacon* on the star. Now put *it* on the square.”).

Results showed that, for both the adult and child samples, the proportion of first looks to the target object was greater for the unaccented anaphoric condition than for the unaccented nonanaphoric condition. Thus, when the target object in the second instruction was the same as the object that was moved in the first instruction and presented without an accent, both child and adult participants appeared to quickly resolve the reference as anaphoric. By contrast, participants displayed a similar proportion of first looks to the target object in both of the accented conditions, suggesting that accenting does not lead listeners to assume that the accent implies new information. Overall, the results for both the unaccented and accented conditions suggest that 4- and 5-year old children use accented information in a manner that is similar to that of adults. However, unlike previous studies (Dahan et al., 2002), neither the adults nor the children showed a bias towards interpreting accented expressions as nonanaphoric, or new, information. Instead, both samples appeared to be more influenced by a lack of accent, which guided them toward an anaphoric interpretation. This difference suggests that, despite the acoustic prominence of an accented expression, listeners are open to various potential referents for that expression and do not automatically assume new information is implied. Instead, listeners may be more biased toward interpreting unaccented expressions as information that is already part of a shared discourse.

More recently, Grassman and Tomasello (2010) explored how accenting affected the visual fixations of 24-month-old children on given and new referents. In three conditions (Newness and Stress, Newness only, and Stress only), children were first presented with a context picture, showing either one animal ("Newness and Stress" or "Newness Only" conditions) or an animal and an object ("Stress Only" condition) and a spoken direction to look at the contents of a picture (e.g., "Look a duck. Look the duck." for the Newness and Stress or Stress Only conditions or "Look the duck and the apple." for the Newness Only condition). This direction was followed by a target picture (always showing the same animal or same animal and object shown in the context picture) and a spoken sentence using both words (e.g., "The duck has an apple."). In the "Newness and Stress" and "Stress Only" conditions, the sentence accompanying the target picture contained an accent on the object (e.g., "The duck has an *apple*."), while in the Newness Only condition, none of the words in the sentence that accompanied the target picture were accented (e.g., "The duck has an apple."). Results revealed that only the children in the Newness and Stress Condition looked at the target picture more than would be expected by chance. Thus, neither newness nor stress alone was influential enough to direct children's attention to the target referent. The authors concluded that children as young as 2 years old direct their attention to new discourse entities that are also prosodically highlighted. They speculated that the children in the Stress Only condition assumed that the speaker had no reason to establish joint attention on the target object because both objects in the picture had already been established in the previous discourse. Furthermore, the children in the Newness Only condition pointed most frequently, which the authors proposed could indicate that the children were attempting to establish focus for the discourse because no accent was provided in the sentence that accompanied the target picture.

ERP components related to language processing. Over the past 35 years, the Event-Related Potential (ERP) method has been extensively used to identify electrophysiological markers of the cognitive processes at play during language comprehension. In the literature, components of the ERP are usually named with a letter indicating their polarity (N for negative or P for positive), followed by a number corresponding to the latency of their peak in milliseconds. A particular ERP component that has made important contributions to the study of language processing is the N400. In their classic experiment, Kutas and Hillyard (1980) found that sentence-final words that were not semantically expected (e.g., "The pizza was too hot to cry.") elicited a larger negative ERP response between 200 and 600 ms and peaking at 400 ms after the onset of the word over the centro-parietal scalp regions when compared with final words that were expected in the sentence context (e.g., "The pizza was too hot to eat."). It has since been shown that any word, spoken or written, elicits an N400 response, and that the amplitude and scalp distribution of that response is influenced by various factors. For instance, the less frequent a word is in a given language, or the lower its probability to complete a particular sentence, the larger its N400 (see Kutas & Federmeier, 2011, for a review of the N400 component). Note that, even if the word is locally expected, it may still be associated with a larger N400 if it does not fit the broader discourse context (see van Berkum, 2008, for a review of the electrophysiology of discourse).

The P600 is another component of interest. This positivity is elicited between 300 and 900 ms post word onset in response to various linguistic manipulations and is usually located over the centro-parietal regions of the scalp. Initially regarded as a distinct response to syntactic violations (Osterhout & Holcomb, 1992), subsequent studies have shown that the P600 effect extends beyond structural aspects of language. The semantic P600 has been observed in response to violations of semantic relationships (Kim & Osterhout, 2005; van Herten, Kolk, & Chwilla, 2005) and thematic roles (Hoeks, Stowe, & Doedens, 2004; Kuperberg, Kreher, Sitnikova, Caplan, & Holcomb, 2007). Prosodic violations (Astésano, Besson & Alter, 2004; Eckstein & Friederici, 2005; Magne et al., 2007; Marie, Magne & Besson, 2011) have also been found to elicit this component. Overall, the P600 has been interpreted as reflecting a repair/reanalysis step that is necessary when a given input presents contradictory sources of linguistic information (van Herten et al., 2005).

Within the same time range, another positive component has been found in response to intonational phrase boundaries (Steinhauer, Alter, & Friederici, 1999). Because this positivity was elicited at the closure of the phrase, it was named the closure positive shift (CPS) by the authors. While this ERP component was observed in prosodically correct sentences, Pannekamp, Toeppel, Alter, Hahne, and Friederici (2005) found that the CPS still was elicited by the prosodic contour of the sentences when they were meaningless (i.e., using pseudowords) or hummed (a variation in which both syntactic and semantic content was removed). Interestingly, despite the fact that intonational phrase boundaries may be marked by different acoustic cues in different languages, the CPS has been reported in German (e.g., Steinhauer et al., 1999; Pannekamp et al., 2005), Swedish (Roll & Horne, 2010), Korean (Hwang & Steinhauer, 2011), Chinese (e.g., Li & Yang, 2010), and Japanese (Wolff, Schlesewsky, Hirotani, & Bornkessel-Schlesewsky, 2008).

Finally, the P300 is a component that was initially found in response to unexpected sensory (nonlinguistic) stimuli in an oddball paradigm consisting of 80% standard, repeated stimuli and 20% novel, unexpected stimuli (Sutton, Braren, Zubin, & John, 1965). Subsequent studies (e.g., Schön, Magne, & Besson, 2004; Magne et al., 2005) have distinguished between two subcomponents: P3a and P3b (Squires, Squires, & Hillyard, 1975). P3a is more frontally distributed and reflects attentional processes during implicit tasks. P3b is more posterior on the scalp. It is related to memory-trace/context updating and is observed when there is an explicit judgment on the infrequent stimulus. Thus, active engagement in the task of detecting the unexpected targets is necessary for the P3b to occur (See Polich, 2007, for a review). Several recent studies have found P300-like components in response to prosodic incongruities as well (e.g., Schön, Magne, & Besson, 2004; Magne et al., 2005). It remains to be determined, though, whether this component is sensitive to the acoustic features of prosody, or rather reflects higher-order mechanisms (such as attention) that may be influenced by prosody during language comprehension.

ERPs and prosodic marking of focus. Over the past 15 years, only a few studies have used the ERP method to investigate the influence of prosody on the processing of information structure. Different linguistic functions of prosody have been studied, including the use of pitch accents for focus marking and the processing of prosodic boundaries (Dimitrova, Stowe, Redeker, & Hoeks, in press). The literature on the former is most relevant for this current investigation and will be discussed in further detail in this section. In order to investigate the interaction between focus and accent, these studies have looked at participants' responses to missing and superfluous accents. Missing accents occur when information that is contextually new does not receive the prominence that would be expected (i.e., unexpectedly deaccented). Superfluous accents occur when information that has already been provided within the context of the sentence or discourse is unexpectedly accented. The ERP results from these studies reveal variable findings for both missing and superfluous accents.

Several studies using two sentence question and answer dialogues (e.g., "Did Paul have tea or coffee this morning? Paul had *tea* this morning") have shown a negative response to missing accents on the focused word (e.g., "tea" in the previous example). In one such study, conducted in German, Hruska, Alter, Steinhauer, and Steube (2001) presented participants with questions that were either noun-focused (beginning with "whom") or verb-focused (beginning with "what"). The target sentence answers followed the structure of noun, verb, noun (determiner), verb phrase (infinitive). In two conditions the second noun was accented while the second verb was deaccented. In two other conditions, the accentuation was reversed so that the second noun was deaccented and the second verb was accented. Results showed that a large posterior negativity was elicited when the answer to a noun-focused "whom" question contained an inappropriate, missing accent on the second noun. This negativity was followed by a large positivity resembling the Closure Positive Shift (CPS). Ito and Garnsey (2004) conducted a similar study in Japanese. The questions were either subject-focused (beginning with "who") or object-focused (beginning with "what") and the target sentence answers contained a subject, a verb, and an object. The authors found a trend toward an anterior negativity when the answer to a "what" question included a missing accent in the object position.

Negativities in response to missing accents have also been found in studies that have investigated the effects of accentuation on focused information that was either new, meaning it provided additional information about the topic of the discourse, or contrastive, meaning it corrected information already presented in the discourse. Toepel and Alter (2004) manipulated the accentuation of the target sentence in three-sentence discourses, consisting of a setting sentence, a question, and an answer. The pairing of the questions and answers created either a “contrastive” context that elicited a narrow focus or a “new” context that elicited a broad focus. In two conditions, the focus was appropriately accented so that the narrow focus in the contrastive context carried a prominent accent and the broad focus in the new context carried an accent that was noticeable but less prominent than the contrastive accent. In two other conditions, the accentuation was reversed so that the narrow focus in the contrastive context was less prominently accented (analogous to a missing accent) and the broad focus in the new context included a prominent accent on the first word of the focused phrase. The authors conducted two experiments using the same stimuli. One experiment required participants to respond to questions about the content of the presented dialogues in 25% of the trials and a second experiment required a different sample of participants to judge the prosodic appropriateness of each trial (i.e., a prosodic judgment task). The authors found that participants in the prosodic judgment experiment showed a negativity in response to the mismatch condition in which the word in narrow focus received a less prominent accent than would be expected. In a study using a similar design, Toepel, Pannekamp, and Alter (2007) also found a central posterior negativity in response to focused nouns in contrastive contexts that were not accented appropriately.

One additional study found a negativity in response to missing accents. The English stimuli of Johnson, Breen, Clifton, and Morris (2003) consisted of three sentence dialogues including a setting (active statement), a question (always passive), and an answer (always passive). They found a frontal negativity was elicited at around 400 ms in response to the Focus/Inappropriate condition in which an expected accent was missing. This early negativity was followed by a positivity, but the positivity appeared to occur in response to focused information in general, regardless of accentuation. It was also larger when focused information occurred in a later position in the sentence.

In contrast to the studies above, three additional studies showed a positivity in response to missing accents. In the first experiment conducted by Toepel and Alter (2004), which required participants to answer questions about the content of the dialogues rather than judging the appropriateness of the prosody, the authors found that a positivity was elicited in response to the mismatch condition in which the word in narrow focus received a less prominent accent than would be expected. This finding was in contrast to the negativity followed by a positivity that was found in response to the same condition in the second experiment of the study (i.e., the prosodic judgment task).

Two other studies, one in French (Magne et al., 2005) and one in Dutch (Dimitrova et al., in press), manipulated the position of contrastive focal accents in question/answer dialogues. The target sentences of both studies included a direct object, which occurred in the middle of the sentence, and a prepositional object, which occurred as either the final word (Magne et al., 2005) or the penultimate word (Dimitrova et al., in press) of the sentence. In the prosodic mismatch conditions, the contrastive accent in the target sentence fell inappropriately on either the direct object (i.e., when the preceding question established the expectation that the accent would be on the prepositional object) or on the prepositional object (i.e., when an accent on the direct object was expected from the question). Missing accents on direct objects elicited positivities in both studies. (Since the accentuation (i.e., superfluous vs. missing) of the direct object determined the accentuation of the prepositional object that followed it (i.e., missing if the direct object was superfluously accented and superfluous if the direct object was missing an accent), only the results for the direct object are included in this discussion.) However, the positivity found by Magne et al. (2005) was more associated with the P300 whereas that observed by Dimitrova et al. (in press) was later and more reminiscent of the P600. These differences may be due to differences between the tasks used in each study. The prosodic judgment task used by Magne et al. (2005) required active engagement in the detection of inadequate prosody; thus, the elicitation of the P300 makes sense within this context. In contrast, Dimitrova et al. (in press) used an implicit task in which participants were presented with content questions pertaining to the dialogues after 25% of the trials, similar to the comprehension task used by Toepel & Alter (2004) described above. Thus, the participants were focusing more on the content of the dialogues than the prosody. In this case, a later positivity that is more associated with repair/reanalysis and integration makes more sense than an earlier positivity that is dependent on the detection of unexpected elements.

The results of these studies for superfluous accents are also inconsistent. Some studies showed positivities (the prosody task of Toepel & Alter, 2004; Magne et al., 2005). However, Toepel and Alter (2004) found a negativity followed by a positivity when the task emphasized comprehension instead of prosodic judgment. Other studies found no differences (Hruska et al., 2001; Johnson et al., 2003; Ito & Garnsey, 2004). Johnson et al., (2003) suspected that pitch accents may have had so little an effect in their study because all of their target sentences were passive. Thus, the location of focused information was predictable. However, preliminary results from a second experiment showed that including active sentences in with passives, in an effort to provide some sentences where the prosody was more "informative," did not increase participants' responsiveness to superfluous accents.

The discrepancies across studies can be explained by several factors. For instance, the studies were conducted in different languages (English, French, Japanese, Dutch, and German). The tasks (explicit judgment of prosody vs implicit comprehension of content), stimuli (isolated sentences, question/answer pairs, and dialogues), type of accent (new or contrastive), type of focus (broad or narrow), and position of target word (initial, medial, and final) also varied. In addition, different studies analyzed the EEG at different points (onset of the target sentence vs onset of the focused word vs onset of the accent). Lastly, the number of scalp electrodes used to record the EEG ranged from 24 (Ito & Garnsey, 2004) to 64 (Dimitrova et al., in press), resulting in differences in terms of spatial resolution across studies.

Only one study has investigated the developmental path of electrophysiological responses to incorrect prosodic patterns in discourse contexts. Pannekamp, van der Meer, and Toepel (2011) used electroencephalogram (EEG) technology to study the ERP markers in 12-, 8-, and 5-year-old children as they processed two types of information (new information focus or contrastive information focus as conveyed by a correction) presented with either adequate or inadequate prosodic markings. They used German dialogues consisting of a question and a target answer. The type of focus included in the target was manipulated so that it could be: (1) new information focus with adequate prosody, (2) new information focus with inadequate prosody, (3) correction focus with adequate prosody, and (4) correction focus with inadequate prosody. Results indicated that only the oldest group of children, the 12-year-olds, exhibited a late positivity component in response to both types of information focus, regardless of whether or not the focus was adequately marked with prosody. The 8-year-olds showed a similar late positivity component only in response to correction foci that were accented. The results for the 5-year-olds revealed that a late positivity component was not elicited in any listening condition. However, all age groups did exhibit an N400 in response to the two inadequate prosody conditions. Since this ERP component is typically associated with semantic expectations, its presence in all age groups suggests that even the very youngest children processed the question and answer dialogues as connected discourse rather than as isolated units. In the 12-year-olds, the N400 was followed by the late positivity component, indicating that the children were still able to perceive the new or correction focus despite the lack of prosodic highlighting. In contrast, the 5-year-olds showed only an N400 response to both conditions of inadequate prosody, suggesting that they were unable to perceive either type of foci without the assistance of prosody. The 8-year-olds revealed yet a different pattern. Like the 5-year-olds, they exhibited only an N400 in response to stimuli from the correction focus without prosodic marking condition. However, the N400 that was elicited by the new focus with inadequate prosody condition was followed by a P600. Since the P600 response is typically associated with linguistic reanalysis following the recognition of conflicting information, the authors speculated that the 8-year-olds N400 + P600 response could indicate a transitional phase on the developmental path toward the late positivity component exhibited by the 12-year-olds. In terms of the latency and topography of the N400 response, results revealed that, with increasing age, latency decreased and topography shifted towards posterior brain regions. The authors concluded that children as young as 5 years old appear to understand that the information structure of successive utterances spans across sentence borders, even though they may not comprehend the focus of the discourse. By 8 years old, the children in this study were able to use prosody to perceive correction foci, which confirms previous evidence that children's comprehension of contrastive foci precedes that of new foci. However, although the 8-year-olds did not use prosodic marking to detect new information foci, they did appear to recognize that a linguistic conflict had occurred when the new information foci were presented without prosodic highlighting. In contrast, by 12 years old, the children were able to process new or correction foci merely by using the preceding context without the support of prosodic marking.

Summary of eye-tracking and ERP studies. The results of these eye-tracking and ERP studies offer more precise insights into prosody perception and its use for the detection of new information, but, again, the findings are difficult to synthesize into an overall conclusion. The eye-tracking studies in adults are generally in line with earlier behavioral studies, in showing that adult listeners make use of prosodic cues very quickly in discourse context. The youngest children studied were sensitive to the combination of newness and stress but not to the presence of either condition alone. Older children appeared to be more influenced by unaccented, given information than accented, new information, in a way that was similar to adults. The ERP literature on the interplay between prosody and information structure is still in the early stages, and extracting a unified picture from the current state of the literature is challenging. However, two important points emerge: 1) It is possible to record brain signatures reflecting the interplay between prosody and information structure during sentence processing; 2) superfluous accents and missing accents, though both considered prosodically unexpected, are not processed in the same way at the cognitive/neural level, and, thus, may reflect distinct aspects of sentence-level prosody sensitivity. Interestingly, the results of three age groups of children in Pannekamp et al. (2011) showed that sensitivity to prosody appeared to peak in the middle age group, but was unapparent in the youngest children and eclipsed by the use of syntax in the older children. However, the older children's reliance on syntax over prosody may have been due to the discourse contexts used as stimuli, which consisted of question and answer dialogues. The children may have exhibited more use of prosody if both sentences had been declarative.

Prosody and Reading Skills

Early oral language development has been found to be a precursor to later reading skills by supporting the development of phonological representations, vocabulary development, and the various language structures that underlie comprehension (Storch & Whitehurst, 2002; Nation, Cocksey, Taylor, & Bishop, 2010). However, the role prosody plays in reading performance is less defined. This section explores the contributions prosody makes to the reading process. Specifically, the relationships between prosodic sensitivity and reading development, prosodic oral reading and reading performance, and prosody and skilled silent reading will be addressed.

Prosodic sensitivity and reading development. Prosody perception tasks have allowed for the investigation of the relationship between prosodic sensitivity and reading development. Wood (2006) created a “stress mispronunciation task” for 5- to 7-year-olds. The children were shown a picture of the inside of a house and told that a toy character, who often mixed up his words, needed help finding objects in the house. The object names were all two syllable words in which the first syllable was stressed; however, when the character presented the object name, the stress pattern was reversed. Thus, the children were required to manipulate the stress pattern back to its correct form in order to locate the corresponding object. Results showed that children’s performance on the stress mispronunciation task contributed independent variance to spelling scores after controlling for phonological awareness and vocabulary. Holliman, Wood, and Sheehy (2008) used a similar task with 5- and 6-year-olds and found that performance on the task explained additional variance in a composite measure of word reading and nonword decoding after controlling for age, vocabulary, and phonological awareness. Using a revised form of this task, Holliman, Wood, and Sheehy (2010b) conducted a longitudinal study to explore the predictive relationship of speech rhythm sensitivity to later reading abilities. During the first assessment session, the 5- to 8-year-old participants were administered the revised task along with measures of vocabulary, rhyme detection, and phoneme deletion. One year later, they were administered measures of word reading, reading comprehension, and reading fluency. Results showed that performance on the revised task predicted unique variance in word reading as well as the phrasing component of the fluency measure after controlling for age, vocabulary, and phonological awareness. Similar findings were recently reported with a sample of Spanish speaking children between the ages of 7 and 8 years (Calet, Gutiérrez-Palma, Simpson, González-Trujillo, & Defior, 2014). Taken together, these studies indicate a relationship of metrical stress sensitivity to reading development that is independent of phonological awareness.

Using a different set of tasks, Whalley and Hansen (2006) investigated prosodic sensitivity at the word level and the phrase level. The "compound nouns task" was used to assess prosodic sensitivity at the word level. Task stimuli included spoken phrases that could be interpreted differently based on the prosodic cues provided such as "chocolate-cake and honey" versus "chocolate, cake, and honey" or "highchair" versus "high chair." Children were asked to choose the picture that matched the spoken stimulus. The "DEEdee" task was used to assess prosodic sensitivity at the phrase level. Children were presented with movie or book titles followed by two phrases that contained the reiterative syllable *dee* in place of all phonemic content. One of the DEEdee phrases replicated the prosodic pattern of the original phrase while the other DEEdee phrase was included as a foil. The children were told to identify the DEEdee version that matched the original phrase. Results revealed that both tasks were related to reading performance but in different ways. The compound nouns task predicted unique variance in word identification accuracy while the DEEdee task predicted unique variance in reading comprehension. However, despite these differences, both findings point to a relationship between prosodic sensitivity and reading skills that extends beyond the development of phonological awareness.

Evidence also supports a link between prosodic sensitivity and morphological awareness, which refers to the metalinguistic ability to manipulate the meaningful units (i.e., morphemes) of words. Clin, Wade-Wooley, and Heggie (2009) explored this relationship and its connection to reading ability using prosody and morphology tasks. To assess prosody at the phrase level, they used Whalley and Hansen's (2006) DEEdee task. To assess prosodic sensitivity at the sentence level, the authors developed the "Stress Contour Discrimination" task, which required children to compare the prosodic contours of a typical sentence, which included words and prosodic structure, to a low-pass filtered sentence, which contained only prosodic information, and to judge whether the two sentences were the same or different. They also used a Morphological Awareness Task based on Carlisle's (1988, 2000) task, which required the children to produce the correct derived form of a word for a given sentence frame. For example, the children were presented with the stimulus word *collect* and the sentence frame *He has a big hockey card* ______ and asked to produce the derived form of the stimulus word that correctly completed the sentence (i.e., *collection*). The changes from the stimulus word to its derived form were categorized into four conditions: No Change (e.g., *care* to *careful*), Phonemic Change Only (e.g., *discuss* to *discussion*), Stress Change Only (e.g., *human* to *humanity*), and Both Phonemic and Stress Change (e.g., *perfect* to *perfection*). Results showed that both prosodic sensitivity and morphological awareness were significant predictors of reading ability, even after controlling for phonological awareness. In particular, the stress-shifting conditions of the Morphological Awareness task (Stress Change Only and Both Phonemic and Stress Change conditions) proved to be the most difficult for the children and also the most predictive of reading ability. Although these results provide evidence to support additional contributions of prosody to reading performance beyond phonological awareness, it should be noted that Clin et al. (2009) created the composite score referred to as "reading ability" from participants' scores on multiple measures that assessed a variety of reading skills (i.e., individual word identification, speeded word reading and decoding, as well as text reading rate, accuracy, and comprehension). Thus, their results do not provide insight into the relationships among prosodic sensitivity, morphological awareness, and specific reading skills.

Overall, the aforementioned studies indicate that prosodic sensitivity appears to be involved in reading acquisition and development. Thus, it is not surprising that evidence supporting a relationship between insensitivity to speech prosody and reading difficulties is also extant in the literature. Wood and Terrell (1998) found that young children with reading difficulties were less sensitive to rhythm and stress cues at the phrase level than typical readers of the same age. In addition, they found that, although differences in rapid speech perception between the groups dissipated once vocabulary was accounted for, differences in rhythm awareness remained. In a more recent study, Holliman, Wood, and Sheehy (2012) found that children identified as poor readers (i.e., 2 years behind same-age expectations in reading) performed significantly lower on the stress mispronunciation task (Holliman et al., 2010b) than their same-age peers.

There is also evidence that suggests the differences in prosodic sensitivity between good and poor readers may not be confined to speech. Goswami et al. (2002) developed a beat detection task to explore the rhythm sensitivity of individuals with dyslexia. The stimuli for the task were nonspeech sound sequences in which the amplitude modulation had been manipulated to create varying rise times (i.e., the time required for the amplitude to move from the minimum to the maximum value). Children were trained on the shortest and longest rise-time stimuli and then asked to identify which extreme each experimental stimulus matched more closely. Results showed that readers with dyslexia performed significantly worse on this task than their same-age peers who were typical readers. Performance on the task also accounted for 25% of the variance in reading and spelling scores. Thus, deficits in beat detection appear to be related to lower performance in reading. The authors' additional finding that precocious readers, who appeared to have taught themselves to read before formal instruction, significantly outperformed same-aged typical readers, who had learned to read as a result of instruction, suggests that beat detection abilities may be helpful in explaining the continuum of reading performance. The authors also proposed that more serious deficits in rise time perception may result in more pervasive language difficulties that span across both spoken and written language; however, the recent results of Beattie and Manis (2013) showed that the rise time perception of children identified with reading and oral language difficulties was similar to that of children identified with reading difficulties only.

Taken together, these studies suggest that sensitivity to the suprasegmental cues of spoken language contributes to reading acquisition and development beyond the contributions afforded by segmental phonology. Specifically, the findings support the proposed roles of prosodic sensitivity in the lexical retrieval of whole word representations (Lindfield, Wingfield, & Goodglass, 1999), which may facilitate accurate word recognition, as well as the development of accurate phonological representations, which are necessary for phonological awareness (Goswami et al., 2002). In addition, the abilities to perceive and manipulate the prosodic cues of stress and rhythm appear to be particularly related to performance in reading.

Prosodic oral reading and reading performance. The National Reading Panel defines fluency, one of the five essential components of reading instruction, as "the ability to read text aloud with accuracy, speed, and proper expression." The last characteristic in this definition, "with proper expression," refers to prosody. However, achieving fluent reading is not an easy feat. In the realm of written language, prosody poses added challenges because the reader, unlike the listener, must supply the correct intonation and phrasing to printed text without the benefit of incoming auditory cues.

Accomplishing this complex task requires a certain level of skill and sophistication as a reader. Thus, it is not surprising that several studies have shown a relationship between appropriate prosody in oral reading and reading performance. Klauda and Guthrie (2008) studied the relationship between reading comprehension and fluency in fifth graders and found that the prosodic characteristics of phrasing and expressiveness explained 7% of the variance in reading comprehension scores. Similar results were obtained by Rasinski, Rikli, and Johnston (2009), who found moderately strong correlations, ranging from .57 to .65, between oral reading expression and silent reading comprehension at three different grade levels (third, fifth, and seventh). These findings indicate that prosodic oral reading continues to be associated with reading skill beyond the primary grades. Furthermore, Paige, Rasinski, and Magpuri-Lavell's (2012) finding that ninth graders with higher prosody ratings scored higher in silent reading comprehension suggests that this relationship continues into high school.

Although these findings are compelling, the fluency rating scales used in these studies to assess prosody highlight the difficulties involved in measuring such a dynamic component of spoken language. Klauda and Guthrie (2008) created two separate scales:

(1) a 4-point scale for phrasing, in which 1 indicated word by word reading and 4 indicated reading in larger, meaningful phrases, and (2) a 4-point scale for expressiveness, in which 1 indicated an absence of mood or tone and 4 indicated that the mood or tone conveyed by the reader reflected the author's intent. Rasinski, Rikli, and Johnston (2009) and Paige, Rasinski, and Magpuri-Lavell (2012) used variations of the Multidimensional Fluency Scale (Zutell & Rasinski, 1991; Rasinski, 2010; Rasinski & Padak, 2005a, 2005b), a scale which includes separate 4-point ratings for the prosodic dimensions of expression and volume, phrasing, smoothness, and pace. Rating scales are beneficial because they are user-friendly and accessible to educators; however, they are also subjective because a rater's judgment could be unduly influenced by other characteristics that are not specific to prosody (Benjamin & Schwanenflugel, 2010; Binder et al., 2012). For instance, a reader who makes many errors may receive poor ratings in prosody due to a lack of accuracy more than a lack of prosodic characteristics. In addition, the evaluation of phrasing (i.e., reading in meaningful units as opposed to word by word) may be more reflective of reading rate than prosody.

In order to describe prosodic elements of oral reading more objectively and to disentangle prosody from the other characteristics of fluency (i.e., accuracy and rate), other researchers have used the technical approach of spectrographic measurement. This technique uses software (e.g., Praat; Boersma & Weenik, 2004) to extract digital speech data from audio recordings of oral reading. Thus, specific sound features of prosody related to pausing, stress, and pitch can be analyzed. Schwanenflugel, Hamilton, Wisenbaker, Kuhn, and Stahl (2004) used this technique to study the relationship between second and third graders' oral reading prosody and their decoding and reading comprehension skills. They analyzed recordings of the children's oral reading in terms of pause duration, sentence-final pitch declination, and the overall prosodic contour. Results showed that the children who performed higher on the decoding measures exhibited more adult-like intonation, and shorter intra- and inter-sentential pauses. However, they did not find strong evidence of a relationship between prosodic oral reading and reading comprehension. Miller and Schwanenflugel (2006) conducted a similar study using a passage containing more syntactically complex sentences. Results indicated that children's use of intonation in oral reading accounted for unique variance in reading comprehension but pause duration did not, which suggests that different prosodic features may affect distinct aspects of the reading process. The same authors performed a longitudinal study to further examine the relationship between intonation and reading comprehension and found that the acquisition of adult-like intonation during grades 1 and 2 predicted later reading comprehension at grade 3 (Miller and Schwanenflugel, 2008). Thus, studies that have used spectrograms to measure specific prosodic aspects of children's oral reading are consistent with the results of studies that have used fluency rating scales and provide scientific evidence that a relationship between children's prosodic oral reading and their performance in other reading skills does exist.

The findings of Binder et al. (2012) suggest that this relationship continues in adulthood. The authors compared the prosodic oral reading of adults with low literacy skills with that of adults who are skilled readers. Using spectrographic measurement, they analyzed recordings of participants reading a narrative passage that included five types of pausal cues and three types of pitch cues. Results indicated that the pauses of adults with low literacy skills occurred at more punctuation marks, including intra-sentential commas and quotations, and for longer durations than the pauses of the adult skilled readers. In terms of pitch, the two groups showed similar pitch declinations at the end of declarative statements, but the adults with low literacy skills did not show an adjustment of pitch when reading questions. The authors also administered measures of decoding and reading comprehension to the group of adults with low literacy skills. Results indicated that, in this group, lower decoding and word recognition scores were related to more pause occurrences and longer pause durations. In addition, scores on the pausing measures explained 13.3% of the variance in reading comprehension. These results are consistent with Schwanenflugel et al. (2004). However, no significant correlations were found between the pitch measures and the word reading and comprehension assessments, a finding that conflicts with Miller and Schwanenflugel (2006, 2008). Thus, although generalizations cannot be formed on the basis of one study, these findings leave open the possibility that the relationship between prosodic oral reading and reading skills may shift with age.

Overall, the studies discussed in this section show a relationship between prosodic oral reading and reading performance. The specific prosodic features of pitch and intonation appear to be particularly relevant to performance in decoding and reading comprehension. Furthermore, this relationship has been found to persist into high school and adulthood. However, the studies reveal a lack of consensus regarding the links between individual prosodic features and particular reading skills. Thus, the specific contributions of prosodic oral reading to performance in other areas of reading skill are still uncertain.

Use of prosody in skilled silent reading. Although the phenomenon of readers hearing an “inner voice” while reading silently has been discussed in the literature for some time (Huey, 1908/1968; Brown, 1958; Chafe, 1988), the specific phonological representations developed, or supplied, by the reader during this covert process have been difficult to identify. However, recent studies using eye-tracking and electroencephalogram (EEG) methodologies have begun to shed light on the role phonology plays in silent reading and the implications this role might have for comprehension of written text. These studies have provided evidence in support of the implicit prosody hypothesis (Fodor & Ferriera, 1998; Fodor, 1998), which proposes that readers project a default prosodic contour onto the text as they read silently.

Ashby and Clifton (2005) measured eye movements while participants silently read sentences containing four-syllable target words that included either one or two stressed syllables (e.g., *executive* versus *application*). They found that participants exhibited longer reading times and more eye fixations when reading words with two stressed syllables, regardless of word frequency. These results led them to conclude that silent readers do process lexical stress and to propose that word recognition involves the assembly of stress units. In another eye-tracking experiment, Ashby (2006) investigated the influence of word frequency on the lexical stress effect. She presented participants with either a two-letter preview of a target word, which was representative of the target word’s first syllable (e.g., *po_zxzxzx* for *position*), or a three-letter preview of a target word, which was inconsistent with the first syllable of the target word (e.g., *pos_zxzx* for *position)*. Results showed that reading times for high frequency words were similar regardless of the congruency between the preview and the target; however, low frequency words were read faster when the preview was consistent with the target word. Thus, silent readers appear to rely more on prosodic phonological representations when processing low frequency words than they do when processing words they encounter more often, which, again, suggests a relationship between stress unit assembly and word recognition.

Breen and Clifton (2011, 2013) explored the effect of incongruous stress patterns in sentence contexts. Their stimuli included pairs of homographs (noun-verbs or noun-adjectives) in which the stress pattern differed depending on the context in which the homograph was used. For example, the stress pattern of the noun *CONduct* is strong-weak while the stress pattern of its verb homograph, *conDUCT*, is weak-strong. Thus, a garden path effect was induced when a word was read as a part of speech that was not supported by the surrounding context. In their initial series of experiments, Breen and Clifton (2011) found increased reading times for target words whose stress patterns did not conform to the expectations set by the sentence context. However, the results of one of their experiments revealed an interesting puzzle. The eye movements indicative of reanalysis occurred during the fixation on an incongruous target word, before participants had supposedly seen the disambiguating part of the sentence that unveiled the word's intended part of speech. The authors attributed this finding to parafoveal preview of the upcoming disambiguating information. In other words, while the participants fixated on the target word, they were simultaneously processing the next region of text with their parafoveal vision, which allowed them to know that metrical reanalysis was necessary.

To test this assumption, Breen and Clifton (2013) replicated this particular experiment with one critical difference: they manipulated the stimuli so that the parafoveal view was obstructed while participants fixated on the target. This time, results showed that eye movements indicative of reanalysis were delayed until participants were provided with a full view of the disambiguating material, which suggested that they had, indeed, created an implicit prosodic representation of the target word, initially, and then revised that representation, later. Thus, the results of this follow-up study provide further evidence for the implicit prosody hypothesis (Fodor and Ferriera, 1998; Fodor, 1998), which, in addition to proposing that readers project a prosodic contour onto the text they read silently, also proposes that the implicit prosody created by the silent reader is not merely an artifact of syntactic analyses that have already occurred but a contributing factor to such analyses that actually influences initial parsing decisions. Moreover, the results of Breen and Clifton (2011, 2013) support Bader's (1998) prosodic constraint on reanalysis theory, which suggests that the difficulties associated with revising syntactic structure are compounded when an amendment of prosodic structure is also required. In all of the experiments in this series, Breen and Clifton (2011, 2013) found that the greatest reading costs were incurred in the conditions that necessitated reanalysis of both syntax and lexical stress.

Studies using the electroencephalogram (EEG) method have provided evidence regarding the neural correlates of the implicit accessing of stress prosody. Magne, Gordon, and Midha (2010) explored the effect of stress expectations on silent reading by presenting participants with lists of five bisyllabic words. The first four words of every list exhibited the same stress pattern, while the fifth word was either consistent or inconsistent with the previous pattern. Results showed that an increased N400 component was elicited in response to final words whose stress patterns did not conform to the pattern that had been previously established. Although participants' comprehension of specific word meanings was not assessed, the N400 component is typically considered to reflect access to semantic memory (Kutas & Federmeier, 2000); thus, its elicitation suggests that the stress pattern of a word is automatically processed during silent reading, which, in turn, influences the semantic processing of the word.

Suprasegmental information that extends beyond the word level may also be implicitly activated during silent reading. Steinhauer and Friederici (2001) and Steinhauer (2003) explored the implicit processing of intonational phrase boundaries in written text through a series of EEG experiments in which participants silently read sentences containing commas. Results indicated that the Closure Positive Shift (CPS) component, which was reported by Steinhauer, Alter, and Freiderici (1999) to be present when listeners perceive intonational phrase boundaries in spoken language, was also elicited during silent reading in response to a comma that marked an intonational phrase boundary. The authors proposed that similar brain structures may be involved in the perception of commas in written language and the perception of prosodic boundaries in spoken language and that the particular brain response evoked (i.e., the CPS) may be related to a prosodic parsing mechanism that influences syntactic processing when listening to spoken language and reading written text.

There is also evidence that the specific prosody of the “inner voice” supplied by a reader may reflect his or her own prosodic characteristics and habits. Filik and Barber (2011) manipulated limericks so that the rhyming potential of the final word depended upon the regional accent of the participants. For example, participants from Northern England pronounced the word “glass” with a short vowel, so that it rhymed with “mass,” while participants from Southern England pronounced it with a long vowel, so that it rhymed with “sparse.” Thus, the visually presented words “path” and “Garth” were expected to match the Southern England participants’ expectation for rhyme, but to violate the rhyme expectations of the Northern England participants. Results indicated that disruptions in eye movements occurred when a participant read the final word of a limerick that did not produce a rhyme in accordance with his or her regional accent, which suggests that the participants were imposing their own prosody, in terms of vowel length, onto the words as they silently read the text. Individual prosody habits were also indicated in the results of Steinhauer and Friederici (2001), who found that participants who adhered to strict rules of punctuation experienced more difficulties with garden path sentences containing false commas than those participants whose application of punctuation showed more variability.

In summary, eye-tracking and EEG studies have provided evidence that prosody is implicitly accessed during silent reading and may influence such reading skills as word identification, lexical retrieval, and syntactic parsing, all of which are involved in reading comprehension. In addition, some studies have shown that an individual’s application of prosody while reading silently is influenced by his or her own prosodic idiosyncrasies in both written and spoken language. Thus, an individual’s personal knowledge and use of prosody may determine how prosody is utilized during silent reading. Finally, although some of these studies have provided insight into the neural markers of implicit prosody, the brain basis of the relationship between prosodic awareness and reading performance has yet to be established.

A Place for Prosody on the Reading Path

Reading acquisition is commonly conceptualized as beginning with phonological awareness skills, which then lay the foundation for efficient phonics skills and word reading. Quick and accurate decoding at the word level facilitates the fluent reading of connected text, which, in turn, allows readers to devote more cognitive resources to text comprehension. Vocabulary skills serve as a scaffold throughout this entire process. However, for many readers, the path to reading is not so smooth. In fact, some readers appear to master the early foundational skills only to stumble on more complex skills later. Research on the role of segmental phonology in reading development has translated to instructional practice, but the number of students who struggle with reading is still too high. The studies reviewed in the previous section strongly suggest an important role of suprasegmental phonology (i.e., prosody) in reading acquisition, yet they focused primarily on the word level and sensitivity to the lexical stress in either isolated words or in words presented within a sentence context. However, an extensive body of literature highlights the role prosody also plays in the processing of larger linguistic units (e.g., phrase, sentence) as well as in organizing the relationship among those units within discourse contexts. Thus, the place suprasegmental phonology holds on the path to reading warrants further investigation, particularly the role that prosodic sensitivity at the discourse level may play in the complex skill of reading comprehension.

Ashby (2006) suggested, “When seeking to understand the role of prosodic sensitivity in reading, one might consider whether prosody is processed at the end point of reading development” (p.318). The present study followed Ashby’s advice and focused on the relationship between prosodic sensitivity and reading achievement in adults. Its specific purpose was to explore the link between prosodic perception of the given/new distinction (i.e., information structure) and reading performance in adult typical readers in an effort to establish a benchmark with which, in future studies, the relationship in children could be compared.

Chapter Three

Methods

Participants

Thirty-two college students at a southeastern regional university were recruited to participate in the study. All were native speakers of English, with normal or corrected to normal vision, without any hearing impairment, and no known history of learning disabilities. Two participants were excluded from the study because they participated in the EEG session but not the behavioral testing session. Three participants were excluded because they participated in the behavioral testing session but not the EEG session. An additional three participants were excluded because their EEG data showed excessive artifact contamination and did not yield enough trials per condition to be analyzed. Thus, the final sample included 24 participants (18 to 23 years of age, 15 females). IRB approval to conduct the study was obtained from the MTSU Institutional Review Board. Written consent was obtained from the participants prior to the start of the experiment (See Appendix A for copies of the IRB approval letter and consent form). Participants received course credit or a twenty dollar gift card as compensation.

Standardized Reading Measures

Vocabulary. Receptive vocabulary was measured using the Receptive Vocabulary subtest (Form B) of the Comprehensive Receptive and Expressive Vocabulary Test, 3rd Edition (CREVT-3; Wallace and Hammill, 2013). Participants were presented with 10 different picture plates. Each plate included 6 photographs of items related to a particular category (e.g., animals, transportation, etc.). Participants were told to select the picture that best described the meaning of a word presented by the examiner.

All picture plates were administered, but testing on each plate was discontinued if the participant gave two consecutive incorrect responses. For ages 18 to 29, Wallace and Hammill (2013) reported that Cronbach's alpha reliability coefficient for the Receptive Vocabulary subtest (Form B) was .93.

Phonological awareness. The Elision subtest of the Comprehensive Test of Phonological Processing, 2nd Edition (CTOPP-2; Wagner, Torgeson, Rashotte, & Pearson, 2013) was used to assess participants' phonological manipulation skills at the syllable and phoneme levels. The participants were verbally presented a word by the examiner and asked to repeat the word without one of its syllables or phonemes. The result of each removal always formed a new real word. Participants received correct/incorrect feedback for the first 14 items of the test, after which feedback was discontinued. Administration of the task was terminated when the participant missed 3 items in a row. For ages above 17 years, Wagner et al. (2013) reported that Cronbach's alpha reliability coefficient for the Elision subtest was .92.

To assess participants' blending and segmenting skills, the Alternate Phonological Awareness composite of the CTOPP-2, which comprises the Blending Nonwords and Segmenting Nonwords subtests, was also administered. For the Blending Nonwords subtest, participants listened to items consisting of either two syllables or a series of phonemes (up to nine individual phonemes) presented on an audio CD. They were asked to blend the syllables or phonemes together to form a pseudoword. Participants received correct/incorrect feedback for the first 12 items, after which feedback was discontinued. Adminsitration was discontinued when the participant missed 3 items in a row. For the Segmenting Nonwords subtest, participants were presented with pseudowords, consisting of up to 12 phonemes, on an audio CD. They were asked to segment each pseudoword into its individual sounds. For this subtest, correct/incorrect feedback was provided after each item. Again, administration stopped once the participant had responded incorrectly to three consecutive items. For ages above 17 years, Wagner et al. (2013) reported that Cronbach's alpha reliability coefficients for the Blending Nonwords subtest, the Segmenting Nonwords subtest, and the Alternate Phonological Awareness composite were .80, .94, and .94, respectively.

Word reading efficiency. Word reading and decoding speed were assessed using two subtests from the Test of Word Reading Efficiency, 2nd Edition (TOWRE-2; Torgesen, Wagner, & Rashotte, 2012). For the Sight Word Efficiency subtest (Form A), which was used to assess speeded word reading, participants were presented with a card containing lists of words that increased in difficulty. They were told to read down the lists as fast as they could until they were told to stop. The examiner timed the participants for 45 seconds. The raw score was calculated as the number of correct words read during the allotted time. This procedure was repeated for the Phonemic Decoding subtest (Form A), which was used to assess decoding speed. However, the presented words on this subtest were pseudowords (i.e., words that followed the syllable patterns of English but had no meaning), which allowed for the assessment of decoding skills as opposed to sight word memory. To ensure accurate scoring, participants were audio recorded during the administration of both subtests. A composite score, referred to as the Total Word Reading Efficiency Index, was calculated using the scaled scores of the two subtests. Because these measures are speeded, Torgesen et al. (2012) used alternate-form reliability instead of Cronbach's alpha. For the age range of 17-24 years, the authors reported that the alternate-form reliability coefficients for Forms A and B of the Sight Word Efficiency subtest, the Phonemic Decoding subtest, and the Total Word Reading Efficiency Index were .92, .92, and .96, respectively.

Reading fluency and comprehension. Participants' oral reading fluency and reading comprehension of connected text were assessed using Form A of the Gray Oral Reading Tests, 5^{th} Edition (GORT-5; Wiederholt & Bryant, 2012). Participants read aloud passages of increasing difficulty while being timed. After the participant finished reading, the passage was removed from the participant's view and the examiner asked five open-ended comprehension questions to which the participant verbally responded.

On the GORT-5, a Rate score for each passage was calculated by converting the participant's total reading time for the passage to a score on the rubric provided in the testing booklet. An Accuracy score for each passage was derived using the same procedure. The rubric contains scores ranging from 1 to 5 for each of the two scores. The fluency score for each passage comprises the Rate and Accuracy scores derived from the rubric. A basal is established when the participant obtains Fluency scores of 9 or 10 for two consecutive passages. A ceiling is established when the participant obtains Fluency scores below 2 on two consecutive passages. The Comprehension score for each passage is the total number of questions answered correctly (1 to 5). The Rate subtest score for the entire test is the total of the participant's Rate scores on each passage administered. This same procedure is used to calculate subtest scores for Accuracy, Fluency, and Comprehension. The Oral Reading Index composite score is calculated from the sum of the Fluency and Comprehension scaled scores. All of these scores were calculated for the participants in this study. For the age range of 18 to 23 years, Wiederholt and Bryant

(2012) reported that Cronbach's alpha reliability coefficients for Form A of the four subtests and the Oral Reading Index ranged from .93 to .98.

Participants' oral reading and responses to the comprehension questions were audio recorded to ensure accurate scoring. Because of the open-ended nature of the comprehension questions, some responses were more challenging to score than others. Responses for these particular items were transcribed and emailed to the Technical Advisor for the ProEd publishing company for scoring confirmation.

Prosody Task

Participants were asked to follow spoken instructions regarding the movement of objects onto shapes. The 36 nouns used to represent the 32 objects and 4 shapes were selected based on their high lexical frequency (Balota et al., 2007). Half of the nouns represented common animals while the other half corresponded to manufactured objects. (See Appendix B for a complete list of objects and shapes)

Following a similar approach as Dahan, Tanenhaus, and Chambers (2002) and Arnold (2008), each trial was composed of a context instruction (e.g., "Put the mouse on the square.") followed by a target instruction (e.g., "Now, put the mouse on the circle."). The target instruction included either the same object or the same shape that was mentioned in the context instruction (e.g., "Put the mouse on the square. Now, put the mouse on the circle." versus "Put the mouse on the square. Now, put the frog on the square.").

The auditory stimuli were recorded by a female native speaker of English at a sampling rate of 44.1 kHz (16 bit, mono) in a soundproof booth. Each target instruction was recorded in two different contexts. In one context, the object was accented and the shape unaccented (e.g., “Put the frog on the square. Now, put the *mouse* on the square.”). In the alternative version, the object was unaccented and the shape accented (e.g., “Put the mouse on the circle. Now, put the mouse on the *square*.”).

Four conditions were created by manipulating the prosody of the context instruction and the target instruction so that the object in the target instruction was: 1) expectedly accented, 2) expectedly unaccented, 3) unexpectedly accented, or 4) unexpectedly unaccented (See Table 1 for examples in each experimental condition). Overall, participants were presented with a total of 128 sets of instructions (32 per condition).

Table 1

Examples of Stimuli in each Experimental Condition.

	Target object Accented	Target object Unaccented
Expected Prosody	Put the mouse on the square Now, put the *frog* on the square	Put the mouse on the square Now, put the mouse on the *circle*
Unexpected Prosody	Put the mouse on the square Now, put the *mouse* on the circle	Put the mouse on the square Now, put the frog on the *square*

Note: Accented words are indicated in italics.

Acoustic Analysis

Praat 5.4 (Boersma & Weenink, 2007) was used to analyze the differences in acoustical properties between the two recorded versions of each target instruction. First, the acoustic onsets and offsets of each word in the sentence were manually detected. It is important to note that, while the prosodic manipulation introduced in the present study focused on the accentuation of the object of the target instruction, the prosodic properties of the surrounding words were also altered by the presence (or lack) of an accent (e.g., Di Cristo & Jankowski, 1999). Thus the average duration and maximum pitch (f0) values were extracted for the object as well as the preceding two content words (*Now* and *put*). In addition, the duration of the pause following the word *Now* also was analyzed since Arnold (2008) found differences in this time period between accented and unaccented conditions.

Based on the previous literature (Arnold, 2008), planned comparisons (paired sample t-tests) were conducted on the extracted acoustic values using Matlab to specifically test for any potential differences between the accented and unaccented versions of the sentence material. Results of the acoustic analysis are summarized in Figure 2. For the word *Now*, there was no significant difference between accented and unaccented versions in terms of duration (t_{127} =0.81, p = 0.42) or maximum pitch (t_{127} =0.04, p = 0.96). The pause following *Now* was significantly longer in the accented than the unaccented conditions (t_{127} =2.52, p = 0.013). The word *put* had a significantly lower maximum pitch (t_{127} =-3.78, $p < 0.001$) and a marginally longer duration (t_{127} =1.89, p = 0.061) in the accented condition than the unaccented condition. Finally, the object was significantly longer (t_{127} =14.29, $p < 0.001$) and had a higher maximum pitch (t_{127} =22.6, $p < 0.001$) in the accented than the unaccented conditions. Overall, the acoustic properties of the stimuli were in line with those of Arnold (2008). Since significant differences were found in both the duration of the pause preceding *put* and the pitch maximum of *put* between accented and unaccented conditions, each participant's EEG was analyzed relative to the onset of *put*.

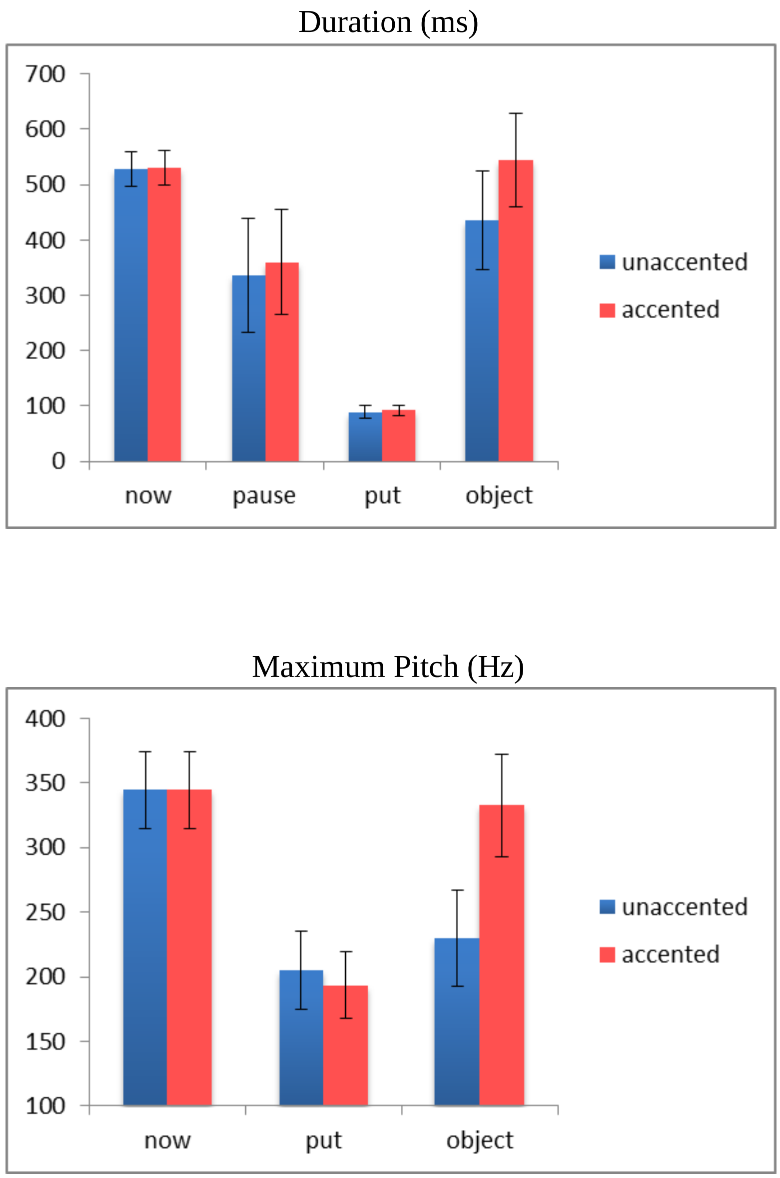

Figure 2. Acoustic analysis of the target instruction in the unaccented (blue) and accented (red) conditions. Top panel shows the mean duration (ms) of the word *Now*, the following pause, the word *put*, and the object. Bottom panel shows the maximum pitch (Hz) of the word *Now*, the word *put*, and the object.

Protocol

Each participant was administered the EEG prosody task in one session and a series of reading measures in a separate session. The two sessions occurred on different days and in different locations, usually within three weeks of each other. Half the participants completed the EEG task before the reading measures while the other half completed the reading measures before the EEG task. Approximate times for each session were 2 hours for the EEG prosody task and 1.5 hours for the reading measures. Thus, the total time commitment per participant was approximately 3.5 hours.

Each EEG session took place in a sound-dampened room. Participants were seated at a small desk facing a computer screen. The objects and the mat displaying the shapes were placed on the desk in front of them. (See Appendix C for a display of the shape mat.) The objects were small plastic toys and the mat was a 3’ by 2’ laminated poster board with a white background and shapes printed in green. The sets of instructions were presented via headphones using a Toshiba Portege Tablet PC and the software E-prime (PST, Inc., Pittsburgh, PA). Each session began with a practice block that included 8 correct trials. A researcher remained in the room with the participant throughout the experiment. The 192 sets of instructions were presented in eight blocks. At the beginning of each block, the researcher placed the four objects for that particular block on stickers that were spaced evenly below the mat. The objects were always placed in alphabetical order. To prevent confusion, the researcher pointed to and named each object with the same label that was used in the instructions (e.g., “These objects are car, nail, rock, spoon.”). During the presentation of the context and target instructions, participants were asked to look at a fixation cross displayed on the computer screen in order to minimize movements of their eyes, head, or other body parts. They were asked to remain still until the end of each instruction. Each trial began with the presentation of a context sentence. After the participant moved the specified object to the specified shape, the researcher pressed a button on a response box to trigger the presentation of the target instruction. After each target instruction, the researcher moved the objects off of the mat and back to their original stickers on the desk in preparation for the next trial. The researcher then pressed the button on the response box to begin the context sentence for the next trial. This procedure was repeated for all trials. At the end of each block, the researcher replaced the objects from the completed block with the new objects for the next block. In between each block, participants were offered the opportunity to rest. The order of the blocks was counter-balanced across participants.

The behavioral reading measures were administered individually in a quiet room by the principal investigator, who is a trained reading specialist experienced in the administration and scoring of each measure. The tasks were counter-balanced across participants to prevent any potential order effect or attentional confounds.

EEG Data Acquisition

EEG were recorded continuously from 128 Ag/AgCl electrodes embedded in sponges in a Hydrocel Geodesic Sensor Net (EGI, Eugene, OR, USA) placed on the scalp with Cz at the vertex, connected to a NetAmps 300 high-impedance amplifier, using a MacBook Pro computer. (See Appendix D for the electrode layout on the scalp.) The frequency of acquisition was 500Hz, and impedances were kept below 50 kOhm. Data were referenced online to Cz and later re-referenced offline to the average of the left and right mastoid sensors. The vertical and horizontal electrooculograms (EOG) were also recorded in order to detect the blinks and eye movements. EEG preprocessing was carried out with NetStation Viewer and Waveform tools (EGI, Eugene, OR, USA). The EEG were filtered offline with a bandpass of 0.1 to 100 Hz. Epochs lasting 100 ms before and up to 1000 ms after the onset of the word "put" were extracted from the continuous EEG data. Trials contaminated by artifacts (e.g. eye movements, blinks, amplifier saturation, electrode drifting or muscle activity) or incorrect answers were excluded from further analysis. The ERPs were computed by averaging the remaining epochs for each participant, condition, and electrode site, relative to a 100 ms pre-stimulus baseline.

EEG Data Analysis

Statistical analyses were performed on the ERPs using Matlab (The Mathworks, Natick, MA) and the open-source Fieldtrip toolbox (Oostenveld, Fries, Maris, & Schoffelen, 2011). Planned comparisons were performed using a cluster-based permutation procedure (Maris & Oostenveld, 2007) to investigate the effects of a superfluous accent (Expectedly Accented *vs* Unexpectedly Accented) and missing accent (Expectedly Unaccented *vs* Unexpectedly Unaccented). This innovative method proposes a data-driven approach to temporal and spatial localization of the effects without the a priori specifications of latency ranges or regions of interest. In addition, it offers a comprehensive solution to the multiple comparisons problem that arises during the analysis of EEG data (Maris & Oostenveld, 2007). Since EEG data collection involves multiple sensors and multiple time points, data analysis requires the evaluation of a very large number of sensor-time pairs (e.g., 64,000 in the present study), which compromises the ability to control the family-wise error rate with the standard statistical procedures that are typically used for single pairs (e.g., Bonferroni-corrected alpha-level would be $\alpha_{PC} = 1 - \sqrt[64000]{.95}$). The cluster-based permutation procedure offers a solution to this problem by calculating a nonparametric statistical test involving the following steps: First, for each time-sensor sample, the EEG signal is compared between conditions using dependent *t*-tests. Second, all samples with a *t*-value larger than the critical value for an alpha-level of 0.05 are selected. Then, the selected sensor-time samples are clustered based on temporal and spatial adjacency (in the present study, neighbors were identified for each electrode using a triangulation algorithm; See Figure 3). Finally, the cluster-level statistics are computed by performing a nonparametric permutation test on the sum of the t-values within the cluster.

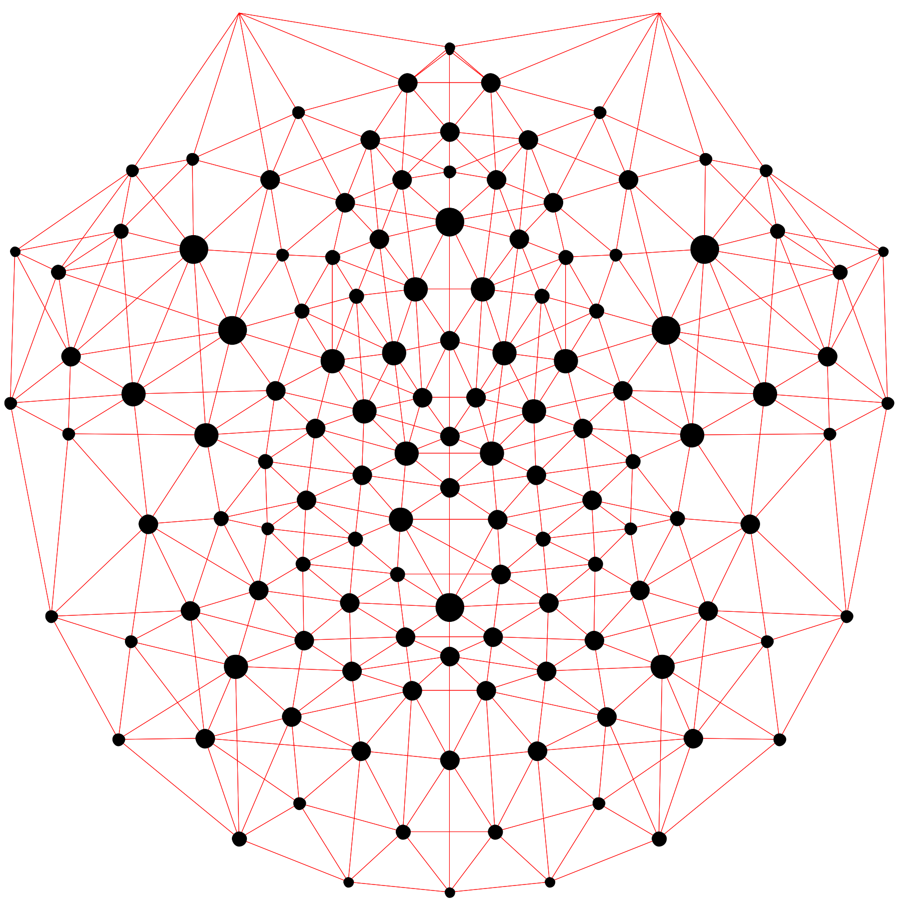

Figure 3. Electrode neighborhood map used for the cluster-based permutation statistics. For each electrode, the diameter of the black disk represents the size of the neighborhood. Red lines connect each electrode with its corresponding neighbors. The front of the head points toward the top of the figure.

Relationship between ERPs and Reading Measures

Prosodic sensitivity indices were calculated to reflect the overall size of the ERP effects in each significant cluster identified for superfluous accents and missing accents. These indices were calculated using the cluster sum approach used by Lense, Gordon, Key and Dykens (2014). First, for each significant cluster found in each planned comparison, the sum of the ERP amplitude at each electrode and at each time point of the significant cluster was calculated separately for each condition. Next, for superfluous accents, the cluster sum value obtained for the unexpectedly accented conditions was subtracted from the value obtained for the expectedly accented conditions. Similarly, for missing accents, the cluster sum value obtained for the unexpectedly unaccented conditions was subtracted from the value obtained for the expectedly unaccented conditions.

To investigate the relationship between vocabulary knowledge, reading skills, phonological awareness, and prosodic sensitivity, a correlation matrix was computed using the standard scores from the standardized measures and the ERP indices described above.

Chapter Four

Results

ERP Data

Figure 4 shows the grand-average ERPs in the four experimental conditions (expectedly accented, unexpectedly accented, expectedly unaccented and unexpectedly unaccented). Within the first 300 ms following the onset of the word *put* (time = 0 ms), N100 and P200 components (also known as the N1/P2 complex) were visible in all conditions. These ERP components, which appear to be similar across conditions, are thought to originate primarily from the auditory cortices in the temporal lobe and reflect primarily perceptual processes (Zouridakis, Simos, & Papanicolaou, 1998; Ross & Tremblay, 2009). Following the N1/P2 complex, the ERP waveforms started to differ across conditions around 300 ms. Cluster-based permutation tests were conducted to identify the time course and scalp distribution of these differences. In particular, the effect of superfluous accents was analyzed by comparing Unexpectedly Accented and Expectedly Accented conditions, while the effect of missing accents was examined by comparing Unexpectedly Unaccented and Expectedly Unaccented conditions.

Effect to superfluous accents. As can be seen on Figure 3, superfluous accents were associated with an increased positivity starting at around 200 ms. This observation was confirmed by results of the cluster-based permutation showing a significant positive cluster between the Unexpectedly Accented *vs* Expectedly Accented conditions (p = 0.001) between 320 and 976 ms post word onset. This difference was significant over a central frontal cluster of electrodes (See Figure 5).

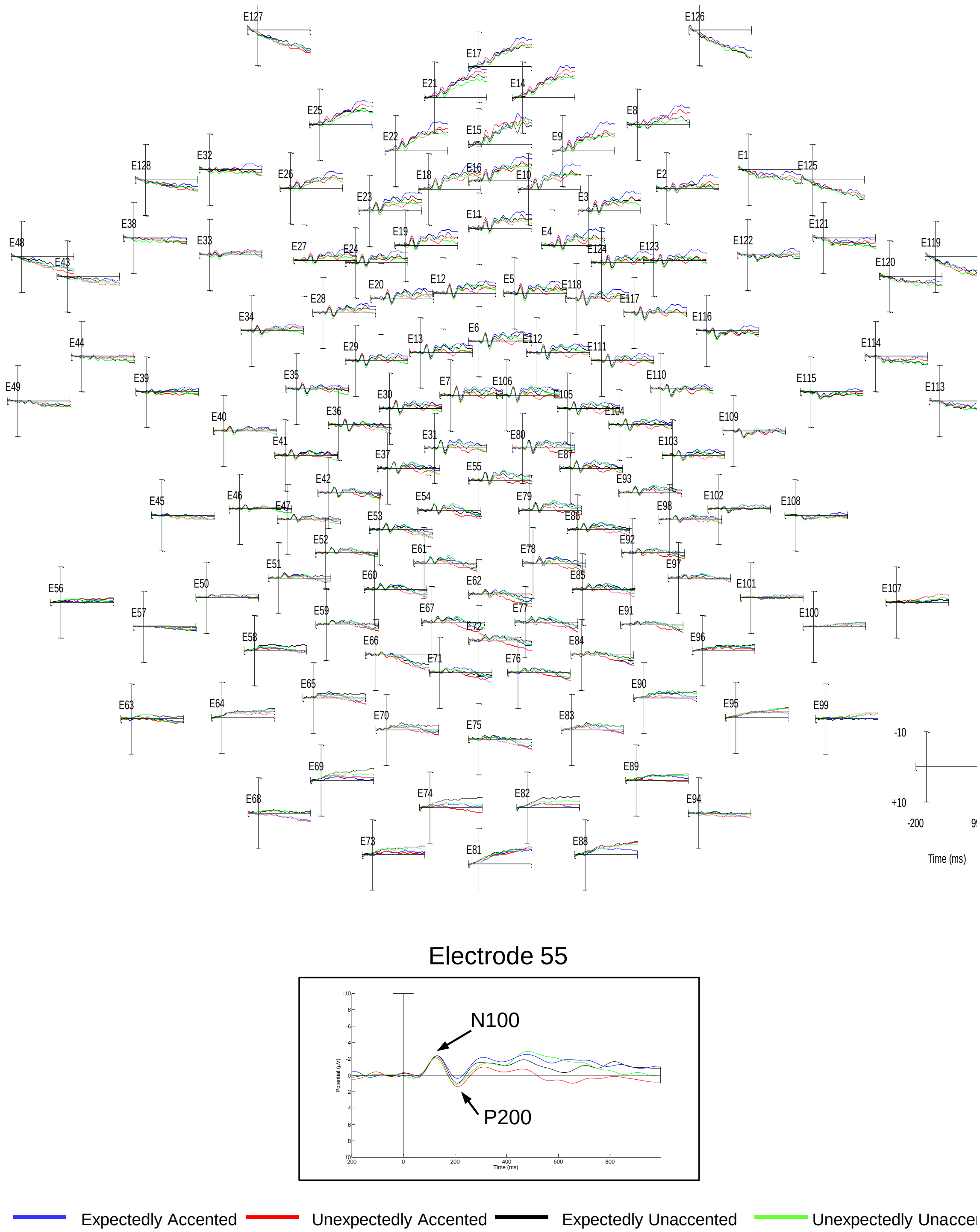

*Figure 4***.** Grand-average ERP elicited by the onset of the word *put* in the four experimental conditions. The top panel represents the waveform for all electrodes and the bottom panel shows a larger view for a representative electrode on the centro-frontal region of the scalp. On this and the following figures, the negative amplitude is indicated upward.

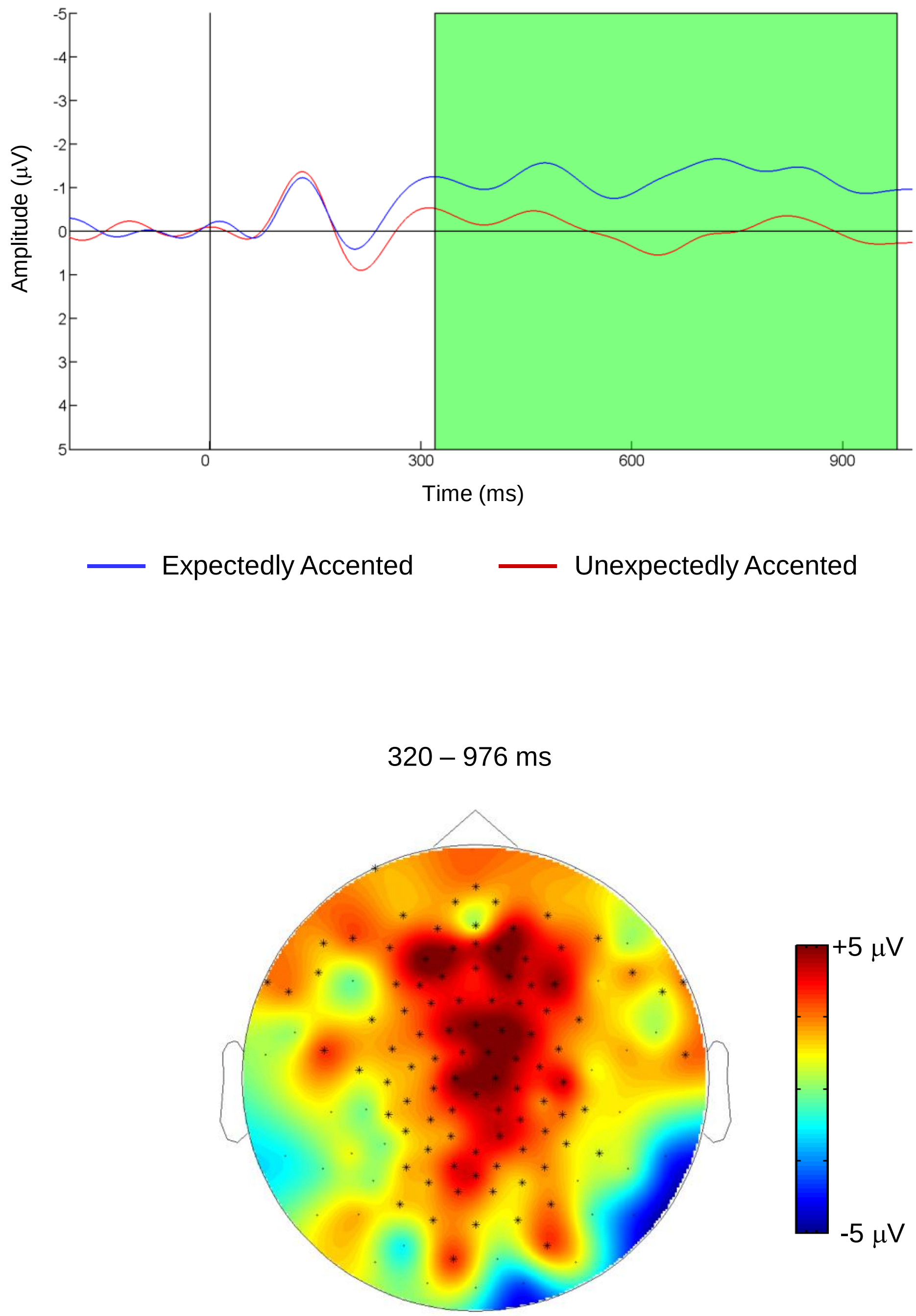

*Figure 5***.** Positive effect elicited by a superfluous accent. (Top panel) Mean waveforms for Unexpectedly Accented (red) and Expectedly Accented (blue) averaged over the electrodes included in the significant positive cluster. The latency range of the significant clusters is indicated by a green rectangle. (Bottom panel) Topographic maps showing mean differences in scalp amplitudes in the latency range of the significant clusters. Electrodes belonging to the cluster are indicated with a *.

Effect to missing accents. The visual inspection of the ERP data suggested that missing accents appeared to be associated with an increased negativity starting at around 400 ms followed by a late positivity starting around 700 ms. A cluster-based permutation test between the Unexpectedly Unaccented *vs* Expectedly Unaccented conditions confirmed a significant negative cluster ($p = 0.038$) with a central scalp distribution between 498 and 652 ms post word onset (See Figure 6). This negative effect was followed by a significant positive cluster ($p = 0.006$) between 772 and 898 ms post word onset over the left parietal, central, and frontal scalp regions (See Figure 7).

Correlations between ERPs and Reading Measures

Table 2 shows the mean and standard deviation scores for the participants on the reading measures in the areas of vocabulary (CREVT-3), phonological awareness (CTOPP-2), word reading (TOWRE-2), and text reading (GORT-5). Mean scores fell within the average range on all measures. However, the mean composite scores in the areas of phonological awareness ($M = 95.08, SD = 14.11$) and text reading ($M = 94.54, SD = 9.00$) fell within the lower end of the average range (i.e., 90 to 110). Within those composites, the mean scores for blending pseudowords ($M = 8.46, SD = 2.84$), one of the phonological awareness subtests, and for comprehension ($M = 8.25, SD = 1.89$), one of the text reading subtests, were barely within the average range (i.e., 8 to 12).

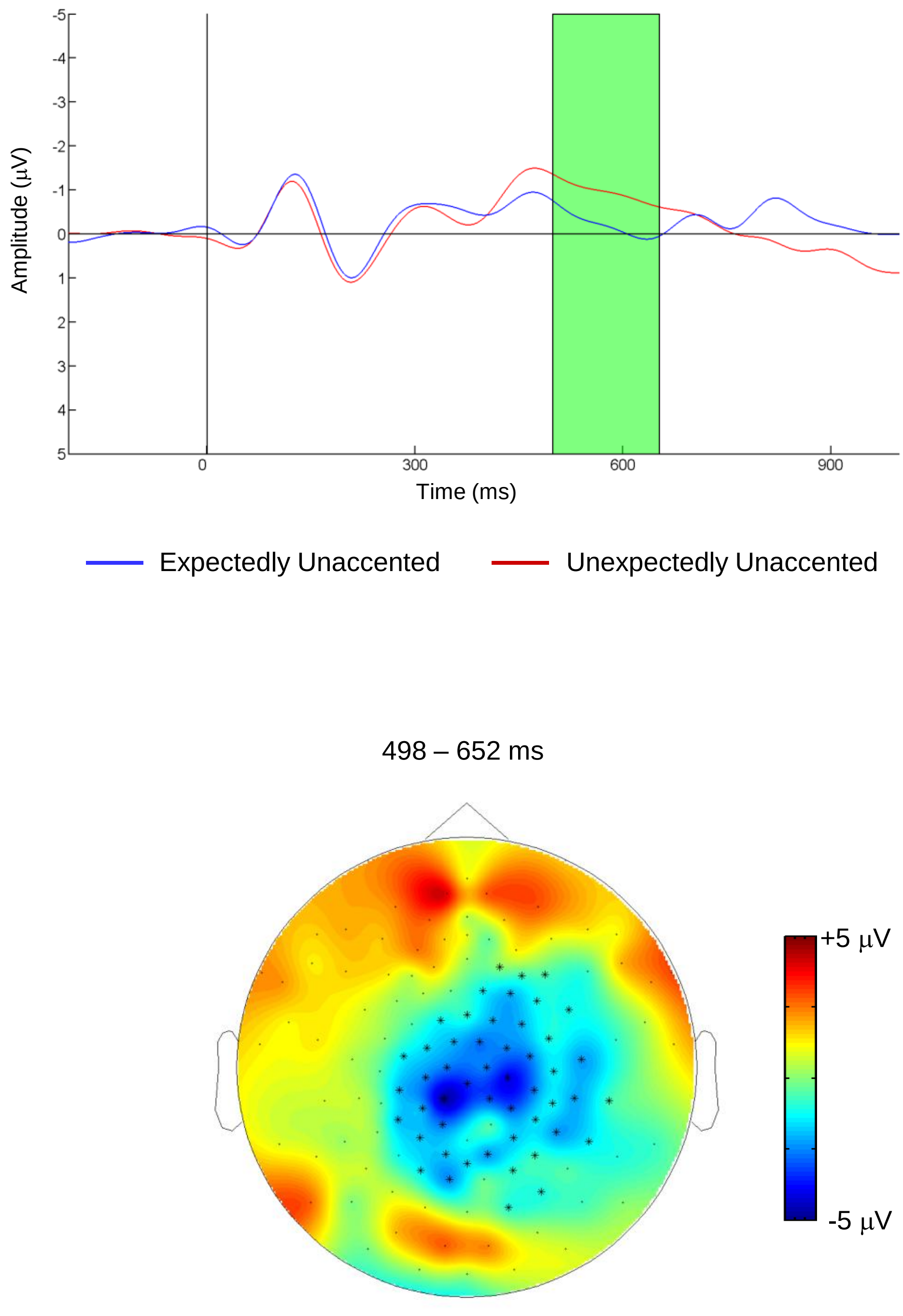

Figure 6. Negative effect elicited by a missing accent. (Top panel) Mean waveforms for Unexpectedly Unaccented (red) and Expectedly Unaccented (blue) averaged over the electrodes included in the significant positive cluster. The latency range of the significant clusters is indicated by a green rectangle. (Bottom panel) Topographic maps showing mean differences in scalp amplitudes in the latency range of the significant clusters. Electrodes belonging to the cluster are indicated with a *.

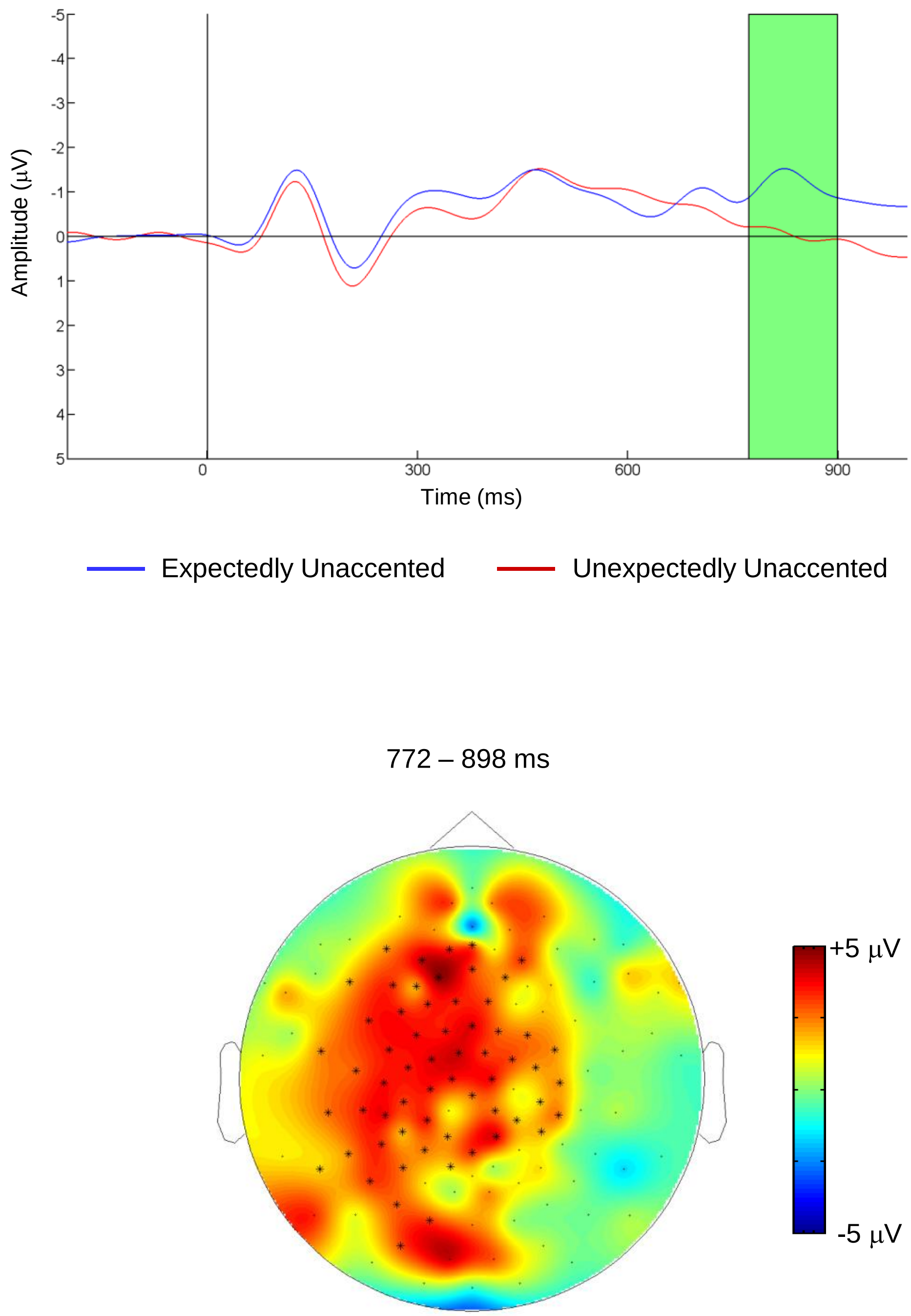

*Figure 7***.** Positive effect elicited by a missing accent. (Top panel) Mean waveforms for Unexpectedly Unaccented (red) and Expectedly Unaccented (blue) averaged over the electrodes included in the significant positive cluster. The latency range of the significant clusters is indicated by a green rectangle. (Bottom panel) Topographic maps showing mean differences in scalp amplitudes in the latency range of the significant clusters. Electrodes belonging to the cluster are indicated with a *.

Table 2

Summary Statistics for the Reading Measures

Measure	Mean	SD
Vocabulary (CREVT-3)	100.50	9.92
PA real words: Elision (CTOPP-2)	9.88	1.60
Alternative phonological awareness (CTOPP-2)	95.08	14.11
Blending pseudowords	8.46	2.84
Segmenting pseudowords	9.67	2.33
Total word (TOWRE-2)	99.92	5.76
Reading real words	102.96	10.98
Decoding pseudowords	99.92	5.76
Total text (GORT-5)	94.54	9.00
Fluency	9.83	1.95
Rate	10.63	2.45
Accuracy	9.04	2.35
Comprehension	8.25	1.89

Note. Alternate phonological awareness is a composite score that comprises the scores for blending pseudowords and segmenting pseudowords. Total word is a composite score that comprises the scores for reading real words and decoding pseudowords. Fluency is a composite score that comprises the scores for rate and accuracy. Total text is a composite score that comprises the scores for fluency and comprehension. Scores for vocabulary, alternative phonological awareness, word reading, reading real words, decoding pseudowords, and text reading are reported as standard scores with a mean of 100 and a standard deviation of ± 15. Scores for PA real words, blending pseudowords, segmenting pseudowords, rate, accuracy, fluency, and comprehension are reported as scaled scores with a mean of 10 and a standard deviation of ± 3.

Table 3 shows the correlation matrix between the reading measures and the significant ERP cluster sum values. As for the reading measures, several correlations were observed in addition to the expected correlations between subtests and composites. The text reading composite (r = .69, p < .001) and the two subtests it comprises, comprehension (r = .69, p < .001) and fluency (r = .53, p = .008), were significantly correlated with vocabulary. Of the two subtests fluency comprises, accuracy (r = .49, p = .02) was found to be significantly related to vocabulary, but not rate. Rate, however, was significantly related to reading real words (r = .59, p = .002) and the word reading composite (r = .62, p = .001), but not decoding pseudowords. Fluency was also significantly correlated with the word reading composite (r = .50, p = .013). Comprehension was significantly correlated with fluency (r = .58, p < .001) and the subtests it comprises, rate (r = .46, p = .023) and accuracy (r = .47, p = .021), which were also significantly related to each other (r = .52, p = .008). In addition, comprehension was significantly related to the alternate phonological awareness composite (r = .43, p < .037).

Significant correlations were also found between the size of the ERP effect to superfluous accents and two of the reading measures. The positivity to superfluous accents significantly correlated with phonological awareness (r = -.48, p <.001) and decoding pseudowords (r = -.45, p <.001). These negative correlations suggest that the greater the difference in response to superfluous accents versus appropriate accents, the lower the performance on the measures of phonological awareness and decoding pseudowords. Several trends toward significance were also observed between the positivity to superfluous accents and vocabulary (r = -.38, p < .069), comprehension (r = -.35, p < .094), and the text reading composite (r = -.38, p < .067). Although these correlations were only approaching significance, their trends were similar to the significant correlations and, again, suggeste an inverse relationship in which larger effects to superfluous accents were associated with lower reading scores. No significant correlations were found between the size of the ERP effects to missing accents and any of the reading measures. In other words, the size of the difference in response to missing accents that were unexpected versus missing accents that were expected did not appear to be related to reading performance in any area.

Table 3

Correlation Matrix between the Reading Measures and ERPs

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.Vocabulary	1															
2. PA Real	.35	1														
3. Blend Pseudo	.28	.40	1													
4. Seg Pseudo	.37	$.56^{**}$	.55	1												
5. PA Pseudo	.37	$.53^{**}$	$.90^{***}$	$.86^{***}$	1											
6. Reading Real	-.23	-.28	-.10	-.20	-.16	1										
7. Dec Pseudo	.35	.29	$.42^{*}$	.27	.28	.16	1									
8. Total Word	-.03	-.10	.09	-.16	-.02	$.90^{***}$	$.57^{**}$	1								
9. Rate	.33	-.26	.18	.23	.12	$.59^{**}$	.26	$.62^{**}$	1							
10. Accuracy	$.49^{*}$	.27	.15	.34	.27	.24	.21	.30	$.52^{**}$	1						
11. Fluency	$.53^{**}$	.09	.19	.23	.24	.40	.36	$.50^{*}$	$.81^{***}$	$.89^{***}$	1					
12. Comp	$.69^{***}$	.36	.34	$.42^{*}$	$.43^{*}$	.06	.27	.17	$.46^{*}$	$.47^{*}$	$.58^{**}$	1				
13. Total Text	$.69^{***}$	.25	.30	.36	.38	.26	.35	.38	$.72^{***}$	$.77^{***}$	$.89^{***}$	$.88^{***}$	1			
14. Sup Acc Pos	-.38	-.36	$-.45^{*}$	-.39	$-.48^{***}$	-.18	$-.45^{*}$	-.34	-.25	-.30	-.34	-.35	-.38	1		
15. Mis Acc Neg	-.05	.001	-.15	-.30	-.25	-.10	.17	-.02	-.15	-.25	-.19	-.06	-.14	-.21	1	
16. Mis Acc Pos	.15	-.03	-.33	-.27	-.34	.30	-.15	.19	.16	.31	.24	.04	.16	.02	.05	1

Note: PA real, Phonological Awareness Real Words; Blend Pseudo, Blending Pseudowords; Seg Pseudo, Segmenting Pseudowords; PA Pseudo, Phonological Awareness Pseudowords; Reading Real, Reading Real Words; Dec Pseudo, Decoding Pseudowords; Total Word includes Reading Real and Dec Pseudo; Fluency includes Rate and Accuracy; Comp, Comprehension; Total Text includes Fluency and Comp; Sup Acc Pos, Superfluous Accent Positive Cluster; Mis Acc Neg, Missing Accent Negative Cluster; Mis Acc Pos, Missing Accent Positive Cluster. $^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$.

Chapter Five

Discussion

The results of the study are twofold. First, unexpected prosody patterns were associated with clear ERP differences. Interestingly, those differences were dependent on the type of prosodic mismatch. Superfluous accents elicited increased positivities while missing accents were associated with an early negativity followed by a late positivity. Second, the response to superfluous accents correlated with the alternate phonological awareness and decoding measures and showed a trend towards significance with the reading comprehension measure. These results will be discussed in light of the previous literature before addressing some of the limitations of the current study and offering potential directions for future research.

ERP Correlates of Prosodic Sensitivity

The first guiding question of this study addressed which ERP component(s) is/are affected by prosodic sensitivity at the discourse level. Overall, the present findings are in line with several previous ERP studies, conducted in French, Dutch, German, Japanese and English, that have explored the interplay between prosody and the processing of information structure. Specifically, the positivities found in the present study are consistent with previous findings regarding positivities elicited by superfluous (Hruska & Alter, 2004; Toepel & Alter, 2004; Magne et al., 2005) and missing (Toepel & Alter, 2004; Magne et al., 2005; Dimitrova et al., in press) accents. Some studies have interpreted such positivities as reflecting attention orientation (Magne et al., 2005) or a stage of repair/reanalysis (e.g., van Herten et al., 2005; Magne et al., 2007).

In the present study, the positivity for superfluous accents occurred around 300 ms and lasted for 600 ms, with a maximum peak that was not clearly defined. Thus, its characteristics are not consistent with the sharp, localized response that is classically attributed to the P300 component (e.g., Sutton et al., 1965). Similarly, for missing accents, the positivity did not start until 700 ms after the onset of the word *put*, and, thus, its latency is not compatible with that of the P300. Taken together, the positivities seen in response to missing and superfluous accents share several features with the P600 related to repair and reanalysis, which has been observed previously for many types of prosodic (e.g., Astésano, Besson & Alter, 2004; Eckstein & Friederici, 2005; Magne et al., 2007; Marie, Magne & Besson, 2011), semantic (e.g., Kim & Osterhout, 2005; van Herten et al., 2005), and syntactic mismatches (e.g., Osterhout & Holcomb, 1992). It should be noted that a positivity known as the Closure Positive Shift (CPS) has also been found in response to accented, focused elements and has been interpreted as reflecting the processing of the intonational phrase boundary that follows the accent (e.g., Steinhauer, Alter & Friederici, 1999). It is, however, unlikely that the positivity observed for superfluous accents in the present study is of this nature because the two conditions that were compared to one another (i.e., Unexpectedly Accented and Expectedly Accented) both contained an accent on the target object. Thus, if a CPS were to be elicited it would be present in both conditions and would not be different for expected and unexpected accents.

An additional ERP effect was observed in the missing accent condition only, in the form of a negativity that was centrally distributed over the scalp and preceded the positivity between 498 and 652 ms. This finding is consistent with other studies that found a negativity in response to missing accents (Hruska et al., 2001; Ito & Garnsey, 2004; Toepel & Alter, 2004; Toepel et al., 2007; Johnson et al., 2003). This negativity has been interpreted as an N400 effect reflecting increased difficulty in semantic integration processes (e.g., Kutas & Federmeier, 2011), which in the present study resulted from the contradicting information provided by the prosody and information structure of the target sentence (i.e., missing accent on information in focus). Such an interpretation would also be in line with previous studies that found increased N400 and lower comprehension for words spoken with an incorrect stress pattern (Magne et al., 2007; Marie et al., 2011).

The differences found in the present study in response to superfluous accents (i.e., positivity only) and missing accents (i.e., N400-like negativity followed by positivity) are not surprising in light of the results of similar studies that found distinct responses to these two types of mismatching prosodic patterns (Toepel & Alter, 2004) and others that found ERP effects for only one pattern or the other (Toepel et al., 2007; Hruska et al., 2001; Johnson et al., 2003; Ito & Garnsey, 2004). However, regardless of the heterogeneity observed in the results across studies, the majority of evidence supports that missing accents and superfluous accents are processed differently by the brain.

At the perceptual level, the increased processing demands suggested by the negativity in response to missing accents are also in line with earlier behavioral studies that explored the effect of accentuation on comprehension. Bock and Mazzella (1983) found faster comprehension times for new information that was accented versus new information that was spoken with a neutral intonation as well as for correct prosodic patterns (new accented and given deaccented) versus incorrect prosodic patterns (new deaccented and given accented). The authors suggested that the greater length of accented words may allow listeners more time for processing, which contributes to the facilitative effect of accented information on comprehension. Birch and Clifton (1995) also found that target sentences with missing accents on new information and superfluous accents on given resulted in lower acceptability ratings and longer reaction times than sentences with appropriate accents on new and given information. Looking specifically at the prosodic incongruities of accented given information versus unaccented new information, Nooteboom and Kruyt (1987) found that target sentences with superfluous accents on given information received higher "acceptability" ratings than those with missing accents on new information, which suggests that the listeners in their study were more tolerant of superfluous accents and, thus, less affected by them. Similarly, Toepel and Alter (2004) and Toepel et al. (2007) found that participants were much more successful in judging sentences with missing accents as inappropriate (i.e., error rates of 19.4% and 9.9%, respectively) than they were at detecting the inappropriateness of sentences with superfluous accents (i.e., error rates of 42.9% and 45.7%, respectively). Again, in both of these studies, participants showed a higher tolerance for superfluous accents. Lastly, the results of Dahan et al. (2002) and Arnold's (2008) eye-tracking studies, which used similar material to the current study, showed a strong bias towards given interpretations of unaccented words but not towards new interpretations of accented words. For instance, in Arnold's study, participants' first looks at target referents were most accurate in the correctly unaccented condition and least accurate in the incorrectly unaccented (missing accent) condition. Their accuracy rates in both accented conditions were higher than in the missing accent condition but lower than in the correctly unaccented condition.

Furthermore, their accuracy rates in the correctly accented condition and the superfluously accented condition were not statistically different. Taken together, the results of these studies support the idea that missing accents are strongly associated with given information. Thus, when participants were presented with new information that was unaccented, they were easily able to detect the violation. However, the detection of violations that occurred as the result of a superfluous accent proved to be more difficult.

The observed difference between missing and superfluous accents is also understandable within the context of the phonological structure of English. Although the focused element that receives a pitch accent is considered the nuclear accent within an intonational phrase, it is acceptable for elements that are in pre-focus to receive pitch accents as well (e.g., Büring, 2007). This structural option is particularly relevant for the current study because the superfluous accents that were analyzed were in the middle of the sentence (i.e., the object word). Thus, when participants encountered a superfluous accent, they may have alternatively considered this accent as marking the end of an intermediary phrase (Beckman & Pierrehumbert, 1986; Selkirk, 1986) rather than the end of an intonational phrase, and they may have waited until the end of the sentence (i.e., the shape word) to determine whether a more prominent accent was going to occur. However, English structure is less flexible with a missing accent. Once the focused information has gone unaccented in the middle of a sentence, opportunities for repair later in an utterance are not the norm.

Correlations between Reading Measures

The second guiding question of the study addressed the relationship between the size of the ERP component reflecting prosodic sensitivity and participants' performance on the reading measures. Before considering this relationship, it is first necessary to consider what the mean scores on the reading measures and correlations between the measures revealed about the sample of the present study. With mean scores that fell within the average range on all measures, the sample appeared to be a relatively average group of readers, which would be expected for a group of undergraduate university students with no known histories of learning disabilities; however, two areas of relative weakness in the sample were apparent. The mean scaled scores for the blending pseudowords subtest and the comprehension subtest fell at the very low end of the average range. The range in comprehension scores from 5, a score within the poor range, to 12, a score at the top of the average range, is understandable given that reading comprehension encompasses a multitude of skills and is greatly affected by the reader's vocabulary and background knowledge, both of which become more variable between readers with age (Stanovich, 1986). Although it is somewhat surprising that none of the participants in the sample scored within the above average range, variation in the reading comprehension abilities of undergraduate students is to be expected.

The variability revealed in the phonological skill of blending pseudowords, however, is puzzling. Although most of the participants scored within the average range on this measure, none scored within the above average range and several scored within the very poor or poor ranges. (Scaled scores ranged from 1 to 12.) Since corrective feedback is provided for the first 12 items of the test and all of the participants were administered anywhere from 7 to 30 (i.e., the maximum possible) items, it is not likely that the low scores on this measure were a result of difficulties with the directions of the task. Considering that phonological awareness skills are characterized as foundational skills that are prerequisites for the acquisition of word-level reading and spelling skills (NICHD, 2000; Scarborough, 2005), the finding that deficits in this area are still apparent in a seemingly average sample of undergraduate students is surprising.

Few studies have explored the reading profiles of adult readers. Furthermore, the studies that have been conducted have focused on adults who have low literacy skills rather than adults who are skilled readers (Mellard, Fall, & Woods, 2010; Braze, Tabor, Shankweller, & Menci, 2007; Sabatini, Shore, Sawaki, & Scarborough, 2010; Mellard, Anthony, & Woods, 2012). One or both of the following models of reading comprehension are typically referenced in these studies: the simple view of reading (Gough & Tunmer, 1986), which explains reading comprehension as the product of decoding/word recognition and language comprehension, and the Direct and Inferential Mediation (DIME) model (Cromley & Azevedo, 2007), which conceptualizes reading comprehension as the result of relationships between background knowledge, strategies, inference, word reading, and reading vocabulary. The difference between the two models is clear: the simple view ascribes a more prominent role to foundational word reading skills, whereas DIME emphasizes the role of higher order thinking skills. As a logical outcome of that difference, the predictive power of the models has been studied in different ages, with the simple view having been found to predict anywhere from 71% to 85% of reading comprehension variance in first through fourth graders (Hoover & Gough, 1990) and 65% of the variance in third through sixth graders (Aaron, Joshi, & Williams, 1999), and DIME having been found to predict 66% of the variance in ninth graders (Cromley & Azevedo, 2007). Although adults are closer in age to ninth graders, the studies that have investigated the reading profiles of adults with low literacy skills tend to focus on how their findings align with the simple view.

The reading measures administered in the present study addressed the five components of reading more so than the use of background knowledge or strategies. In addition, several participants exhibited difficulty with the foundational skills included in the simple view of reading. Thus, it makes sense that, in some ways, the correlations between measures in the present study would resemble the correlations between measures found in studies that have specifically explored the reading profiles of adults with low literacy skills. A few of these correlations are worth discussing in more detail as they have particular bearing on the correlations found between the ERP data and the reading measures.

First, it is interesting to look at the correlations between reading comprehension, the end product according to the simple view, and word reading, one of the components the simple view posits is necessary for comprehension to occur. In the present study, reading comprehension did not correlate with the composite total word score or the individual subtests this composite comprises (i.e., reading real words, also known as word recognition, and decoding pseuodowords, also known as phonemic decoding). This finding is not consistent with the correlations found between word reading and reading comprehension in previous studies (Mellard et al., 2010; Braze et al., 2007; Sabatini et al., 2010). Mellard et al. (2010) and Braze et al. (2007) found moderate to strong correlations between each subtest and reading comprehension and Sabatini et al. (2010) found strong correlations between word recognition and reading comprehension but a weaker association with phonemic decoding. However, in the present study, reading comprehension was correlated with text reading accuracy, which could be considered a reflection of one's word recognition and decoding skills, albeit in text rather than in isolation. The differences between the correlations of the present study and the previous studies cited are likely related to the differences in the reading level ranges of the samples (i.e., low average to average in the present study and below average in the previous studies, although Braze et al.'s sample did include some participants with post-high school reading abilities). All of the participants in the present study scored within the average range on the total word reading composite and each of its subtests, with a few participants scoring in the above average range. In contrast, Mellard et al. (2010) and Sabatini et al. (2010) found mean scores on these measures that were much lower and indicative of individuals who struggle with reading. (Braze et al., 2007, reported only raw scores without descriptors or percentiles.) Thus, the word reading skills of average adults when reading text may be more related to their text comprehension than their skills in reading words in isolation. It should also be noted that the comprehension and accuracy measures of the present study were subtests of the same text reading test.

It is also interesting to consider the correlations between phonological awareness, an area that most certainly affects an individual's acquisition of word reading skills, and the simple view's end product, comprehension. In the present study, comprehension was correlated with both the alternate phonological awareness composite and one of the subtests it comprises, segmenting pseudowords. Interestingly, the blending pseudowords subtest, which had a mean scaled score similar to the mean scaled score of the comprehension subtest, did not correlate with the comprehension measure. The elision subtest, a phonological awareness subtest that uses real words, also did not show a correlation with comprehension. Braze et al. (2007) is the only study of those cited that included a phonological awareness measure; they found a moderate negative correlation between reading comprehension and response times on a spoonerism task, which required participants to exchange the first two letters of a pair of real words to form a pair of pseudowords. The lack of a correlation between the elision subtest and comprehension in the present study may be explained by the fact that this subtest uses real words as opposed to pseudowords. Thus, older individuals who have more experience with print may be able to rely on their knowledge of the way words are spelled rather than solving the items using only phoneme manipulation. In contrast, tasks using unfamiliar pseudowords may be a better indicator of a more experienced reader's phonemic awareness because they are more challenging and, as a result, may show more of a relationship with the complex area of reading comprehension.

Interpreting Correlations between ERPs and Reading Measures

For superfluous accents. In the present study, correlations were found between the positivity elicited in response to superfluous accents and two of the reading measures: the alternate phonological awareness composite and decoding pseudowords. Sensitivity to the patterns of stress in words and in phrases has been found to correlate with word reading and phonological awareness (Holliman, Wood, & Sheehy, 2008, 2010b; Whalley & Hansen, 2006). It has also been shown to be a strong predictor of word reading and fluency at the phrase level (Holliman, Wood, & Sheehy, 2010b). The results of the present study are particularly in line with two recent studies (Holliman et al., 2014; Lochrin, Arciuli, & Sharma, 2014) that have found a specific link between receptive prosody and nonword reading accuracy. While the previously mentioned studies focused on young readers, it is interesting to find in the present study that, not only does such a correlation between prosodic sensitivity and reading exist at the sentence level, it also persists into the college-level years. However, whether sensitivity to discourse-level prosody is important during early literacy development or whether it plays a more prominent role in later reading development remains unclear. Thus, the field of reading education would gain from future studies that address this question.

Unexpectedly, though, the correlations found in the present study were negative, meaning that the larger positivity in response to superfluous accents was associated with lower reading skills and vice-versa. These results are in conflict with the previous studies mentioned, which found that children who scored better on the prosodic sensitivity measures also scored better in reading. Thus, in the present study, higher prosodic sensitivity to superfluous accents was not necessarily better. However, these results make sense within the context of the aforementioned interpretation of this positivity as reflective of reanalysis/repair. In line with this interpretation, those with higher reading scores may have experienced lower reanalysis/repair costs elicited by the superfluous accent as a result of increased neural efficiency, which manifested as a smaller positive effect. Similar increases in brain processing efficiency (as reflected by lower ERP responses) have been associated with expertise in other domains such as music. For instance, in an auditory sequential learning task, participants with high music aptitudes displayed smaller P300 amplitudes than musicians with low music aptitudes (Emerson, Daltrozzo & Conway, 2014). This finding is also consistent with neuroimaging studies comparing brain activity before and after learning a new skill. The activity in attentional and executive networks of the brain have been found to decrease as training progresses and skills improve, with little or no activity in the individuals once they are considered experts at the learned task (Magne & Kelso, 2008). These results also make sense within the context of the phonological structure of English in which it is acceptable to have several pitch accents located before the focus element of an utterance, as long as the focus element also receives a pitch accent (e.g., Büring, 2007). Thus, it would be expected that individuals with higher language skills would show more flexibility when confronted with an additional/superfluous accent than individuals with lower language skills, who may not be as aware of this generalization. Taken together, the negative correlations between the reading measures and the amplitude of the positivity to superfluous accents could reflect the lower repair/reanalysis cost in the more skilled readers when they encounter superfluous, but not necessarily incongruous, accents in everyday language.

This explanation may also shed light on the relationship between the superfluous positivity and the reading comprehension measure. A negative correlation that trended towards significance was found between these measures. Terken and Nooteboom (1987) found in their behavioral studies that superfluous accents resulted in slower response times, which led them to suggest that accented, given information compels the listener to regard the information as new and to attempt to add it into the discourse representation. This process is redundant because the given information, despite the fact that it is accented, is already a part of the discourse. Perhaps, in the present study, the participants who showed smaller positive amplitudes in response to superfluous accents were more resilient to the disruptive effects of accented, repeated information in that they recognized rather quickly that no integration was necessary. This integration process is also a part of text reading. Reading comprehension requires the continual updating of the situation model constructed during the reading process (Zwaan & Madden, 2004). Thus, it seems logical that readers who are more efficient in determining what needs to be added to the model and what is already present in the model will be able to comprehend more efficiently, without expending unnecessary energy on redundant processes. As a result, they will have more cognitive resources available for deeper comprehension. Although the correlation between smaller amplitudes and higher comprehension scores in the present study was only approaching significance, it would be worthwhile to administer the EEG prosody task and reading measures to additional individuals, particularly those who fall at the higher and lower ends of performance in reading comprehension, to see if this trend continues.

To revisit the simple view of reading, the correlations discussed are most relevant to the word reading component of the simple view in terms of both decoding and the phonological awareness skills that facilitate the decoding process. However, links can also be made to the comprehension product of the model. (It should be noted that Lochrin et al., 2014, suggested a similar link when interpreting their results, which also showed a relationship between receptive prosody and decoding, through the framework of the simple view of reading.) In the present study, the phonological awareness measure that was correlated with the superfluous positivity was also correlated with the comprehension measure and the comprehension measure was nearly correlated with the superfluous positivity. The decoding measure that was correlated with the superfluous positivity did not show a correlation with the comprehension measure; however, the accuracy measure, which could be considered an indicator of how well the participants read words in text, was correlated with comprehension. Although correlations must be interpreted with caution and certainly do not imply any degree of causation, the findings of this study do support that a relationship between prosodic sensitivity, reading foundational skills, and comprehension still exists in adults who are proficient enough readers to be enrolled in a university.

For missing accents. The lack of correlation between the size of the ERP effects to missing accents and the reading measures may be because sensitivity to missing accents is more common. The results of previous behavioral studies that showed participants made fewer errors in judging the inappropriateness of missing accents in comparison to superfluous accents (e.g., Nooteboom & Kruyt, 1987) suggest that missing accents are easier to detect in general. Superfluous accents, on the other hand, were deemed acceptable in these studies more often than missing accents. Again, this is likely related to the prosodic structure of English, which allows additional pitch accents to be present when they are in pre-focus (e.g., Büring, 2007). Thus, the effect of processing superfluous accents may be more subtle and, as a result, lead to more variability in response. If so, then this increased variability could render the response to superfluous accents a more sensitive indicator of prosodic processing. This result is somewhat similar to Magne et al.'s (2010) findings showing larger differences between adult musicians and adult nonmusicians for the least common stress pattern in English (i.e., iambic) than for the most common one (i.e., trochaic). In another series of experiments in adults (Schön, Magne & Besson, 2004) and children, Magne, Schön & Besson (2006) found larger differences between musicians and non-musicians for small/subtle pitch changes compared to large/obvious pitch changes in speech. Together, these results suggest that small deviations in language (i.e., those that are more difficult to detect) are more sensitive measures of expertise.

An alternative interpretation of the lack of correlation between the ERPs for missing accents and the reading measures could be that the negativity and positivity elicited in response to missing accents were partially overlapping. For example, on some posterior electrodes, even though the negative cluster was significant until 652 ms and the significance for the positive cluster started at 772 ms, visual inspection of the data shown in Figure 3 clearly shows an overlapping of the negative and positive effects between 600 and 700 ms on several electrodes. During this time window, the negativity lasted longer on some anterior electrodes and the positivity started earlier on some posterior electrodes. Thus, a negativity and positivity occurring at the same time may partially cancel each other out, depending on the relative size of each, particularly if they share overlapping time windows and scalp distribution. As a result, the two effects may be partially masking each other, rendering it difficult to uncover their true sizes, or amplitudes. Thus, a correlation between the ERP effect to missing accent and the reading measures may not have been found because a key piece of information cannot be observed. Using other analysis tools such as independent component analysis (ICA; Comon, 1994) could theoretically help to separate the different sources on the scalp that are contributing to the EEG, which would allow for the isolation of the unique contributions to the negativity and the positivity.

Limitations and Future Directions

Several limitations regarding the implementation of this study in addition to opportunities for future directions should be considered. The first limitation concerns the issue of time. Two separate sessions were required of every participant for a total time commitment of approximately four hours. Scheduling two separate sessions proved to be difficult with college students, especially at certain times of the semester such as mid-terms and finals. Several participants came to the first session but were unable to find the time to participate in the second session. The EEG prosody task was also quite long, which interfered with how many participants could be tested in one day. Both of these time-related issues had an effect on the number of participants in the study. Reducing the time requirement in one or both sessions should be considered for future studies. If the prosody task were shortened, it might be possible to administer it and the reading measures in one session. However, the reading measures were challenging, and doing both parts in one day could be too taxing for the participants.

Regarding the reading measures, the fluency scores from the oral reading measure may not have revealed the most complete picture of these adult readers. The decision to include a fluency measure was based on previous studies that have shown a link between prosodic oral reading and reading comprehension. The results of this study did show a correlation between fluency and comprehension; however, the prosodic quality of the participants' oral reading was not a factor in the fluency score, which comprised only a participant's rate and accuracy scores. Thus, an opportunity for future research lies in the evaluation of the participant's oral reading using both qualitative measures (Klauda & Guthrie, 2008; Rasinski, Rikli, & Johnston, 2009; Paige, Rasinski, & Magpuri-Lavell, 2012; Zutell & Rasinski, 1991; Rasinski, 2010; Rasinski & Padak, 2005a, 2005b) and the more technical approach of spectrographic measurement (Schwanenflugel, Hamilton, Kuhn, Wisenbaker, & Stahl, 2004; Miller & Schwanenflugel, 2006). Since the participants' oral reading was recorded, a spectrographic analysis would be possible with the current data. It could be particularly interesting to extract two sentences in which the new/given distinction is apparent and analyze the accentuation used across participants to see if differences are evident. An additional opportunity for analyzing prosodic production lies in participants' oral reading of specific words with stressed syllables. Many participants made errors in stress placement when reading multisyllabic words, which had an effect on their accuracy scores. It would be interesting to see if a correlation exists between the number of stress placement errors an individual made on the oral reading measure and the size of their amplitudes to missing and superfluous accents on the prosody task. Both of these analyses would allow for an investigation of the relationships between sentence-level and word-level prosody production and sentence-level prosody perception in the same individuals.

It may also be helpful to look at the participants' word level decoding and text reading accuracy at a deeper level to look for subtle differences that have not been captured by participants' overall scores. For example, some participants read two-syllable pseudowords on the decoding measure with a weak-strong pattern rather than the strong-weak pattern that is typical in English. These pronunciations were counted as correct because, as long as the correct sounds are produced, any stress placement is acceptable. However, since the ERP effect to superfluous accents was correlated with the decoding measure, looking at the data from this angle may provide additional insight. Individual differences are also possible in the text reading accuracy measure. The particular measure used in this study considers any deviation from the printed text to be an error. Thus, some participants' may have made more insertions, self-corrections, and repetitions than others. Also, because all of these deviations contributed to the participants' accuracy scores, this measure may not be the best reflection of their actual word reading and decoding skills in text. It may be beneficial to analyze the data according to the total number of word reading and decoding errors participants made, excluding repetitions, self-corrections, and insertions.

The scoring of the reading comprehension measure was another limitation. Because the participants verbally responded to the questions, there was quite a bit of variability in their answers. This variability led to difficulties in scoring. Although examples of acceptable responses are printed in the protocol next to each item, these examples did not encompass all of the responses given by the participants. Furthermore, many of the participants' responses were neither clearly correct nor clearly incorrect. Thus, the scoring of some items was more subjective than objective. Great care was taken to ensure that consistency in scoring was applied across all participants for each item. In addition, responses that were difficult to score were transcribed and submitted to the technical advisor of the test's publishing company. However, this process took time. In future studies, the selection process for assessments should be based on how long the measures will take to administer as well as how long they will take to score.

Some of the questions on the reading comprehension measure also posed a problem. A few questions could be interpreted differently depending on the word that received the accent in the question. For example, the question "Which of the people's needs has been provided for in this story?" could be interpreted as referring to a specific group of people, if it were asked as "**Which** of the people's needs has been provided for in this story?" or as referring to the specific need that has been provided, if it were asked as “Which of the people’s **needs** has been provided for in this story?” Similarly, the question “Why were the cattle driven on trails in this story?” could be asked as “**Why** were the cattle driven on trails in this story?” or “Why were the cattle driven on **trails** in this story?” Although questions like these were asked with the accent placement that corresponded to the answer in the protocol, some participants still responded with an answer that would be more fitting for an alternative accent placement. Since such errors provide an indication of an individual’s ability to use accent to determine focus, it might be interesting to see if any links exist between participants’ responses on these questions and their ERP responses to missing and superfluous accents.

The reading comprehension measure exposed another limitation: the lack of information regarding participants’ working memory abilities. Since the passages that the comprehension questions were based on were removed from the participants’ view before the questions were asked, individual variations in memory abilities most likely had an influence on participants’ success, or lack of success, in answering the questions. Not being able to refer to the passage was disconcerting for many participants, and several participants shared their frustration with comments like “I don’t remember anything I just read” or “There were so many words, I have no idea.” Likewise, the prosody task consisted of pairs of instructions separated by a lapse of time during which participants moved objects on shapes. It is important to note that no limit was imposed on the time they were allowed to take to move the object, and some participants were clearly slower than others in performing the task. Thus, differences in working memory capacity could have affected the perception of givenness/newness on the objects in the target sentence. Adding a working memory measure to the assessment battery of future studies would be in line with other studies that have investigated the reading profiles of adults (Braze et al., 2007; Mellard et al., 2010).

Another limitation of the study was the lack of behavioral data to accompany the ERP data on the prosody task. Although the stimuli were very simple and straightforward, participants did occasionally make errors in moving objects to shapes. Recording such errors in a systematic way would allow for comparisons between ERP responses and the number of errors per condition as well as comparisons between errors per participant and scores on the reading measures. Reaction times would be another interesting piece of data to record; however, acquiring this data in the current design of the study would not make sense because a wait-time was imposed on the participants after the presentation of each sentence in order to reduce noise in the EEG recording. Thus, true reaction times to the stimuli were not possible. Revising the design of the study, perhaps by incorporating a computerized version and an eye-tracking measure, may allow for the recording of behavioral measures (i.e., both accuracy and reaction times).

Lastly, the small size of the sample was a major limitation. Since a sizeable amount of data was generated from the 128 electrodes that recorded the EEG of each participant, the sample size for the EEG part of the study was adequate. However, the correlations found between the ERP data and the reading measures should be interpreted with caution because of the limited amount of reading data. The small sample size may have also restricted the range on several measures, which may have been why correlations between some measures were not found. Increasing the sample size in future studies may result in more variability between the participants, which may provide a more accurate picture of the relationships between measures. In future studies, it will be important to include enough adults that are below and above average to see if the correlation between sensitivity to superfluous accents and reading skills remains. In addition, conducting a step-wise hierarchical regression analysis would allow for a more precise understanding of the unique contribution of discourse level prosody to reading skills. Since the positivity to superfluous accents was correlated with phonological awareness, it will be important to see if suprasegmental phonology (i.e., prosody) makes additional contributions to reading performance after controlling for segmental phonology (i.e., phonological awareness) in adults, as has been found in studies with children (Holliman, Wood, & Sheehy, 2008; Whalley & Hansen, 2006; Clin, Wade-Wooley, & Heggie, 2009).

Conclusion

The findings of this study provide evidence of a relationship between prosodic sensitivity at the discourse level and certain reading skills in adults. Thus, in response to Ashby's (2006) question of whether or not "prosody is processed at the end point of reading development" (p.318), the present results suggest that the answer is yes. In addition, these findings show that cognitive neuroscience techniques, such as ERP, can provide information that enriches an individual's reading profile, which has strong implications for the field of education. Similar studies in children of various ages could help to build a developmental continuum that shows how prosodic sensitivity at the discourse level changes over time and how that sensitivity is related to reading performance at different grade levels. Knowledge of the particular dynamics of this relationship over time could have implications for educational practice by illuminating which prosodic skills should be highlighted in instruction at different grade levels. Furthermore, studies that focus specifically on children with learning disabilities could help to distinguish the relationship between prosodic sensitivity at the discourse level and reading in children with basic word reading difficulties (i.e., dyslexia) and children with specific reading comprehension difficulties.

The results of these studies could have major implications for the interventions implemented within the Response to Intervention framework as well as for the accommodations recommended for the students served by those interventions. For example, knowledge that superfluous accents have more of a disruptive effect on children with reading difficulties could have implications for speech-to-text technology, which is often provided to struggling readers to assist them with accessing grade level content. In fact, Nooteboom and Kruyt (1987) addressed this issue years ago when behavioral studies on the processing of accents were still quite new and text-to-speech technologies were referred to as “speaking machines” (p. 1521). Thus, accounting for research findings in the development of these technologies could increase their benefits for struggling students. In sum, the results and implications of the present study support previous findings that prosody does, indeed, hold an important place on the reading path.

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APPENDICES

APPENDIX A

IRB Approval Letter and Consent Form

MIDDLE TENNESSEE STATE UNIVERSITY

September 17, 2013
Melissa Brock
Literacy Studies and Psychology
Melissa.Brock@mtsu.edu Cyrille.Magne@mtsu.edu

Protocol Title: ***Relationship between Spoken Language Comprehension and Reading Skills***

Protocol Number: **14-021**

Dear Ms. Brock:

The MTSU Institutional Review Board, or a representative of the IRB, has reviewed the research proposal identified above. The MTSU IRB or its representative has determined that the study poses minimal risk to participants and qualifies for an expedited review under the 45 CFR 46.110 Category 2, 4, and 7.

Approval is granted for one (1) year from the date of this letter for no more than 80 participants.

According to MTSU Policy, a researcher is defined as anyone who works with data or has contact with participants. Anyone meeting this definition needs to be listed on the protocol and needs to provide a certificate of training to the Office of Compliance. **If you add researchers to an approved project, please forward an updated list of researchers and their certificates of training to the Office of Compliance (Box 134) before they begin to work on the project.** Any change to the protocol must be submitted to the IRB before implementing this change.

Please note that any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615) 494-8918.

You will need to submit an end-of-project form to the Office of Compliance upon completion of your research located on the IRB website. Complete research means that you have finished collecting and analyzing data. **Should you not finish your research within the one (1) year period, you must submit a Progress Report and request a continuation prior to the expiration date.** Please allow time for review and requested revisions. Your study expires September 17, 2014.

Also, all research materials must be retained by the PI or faculty advisor (if the PI is a student) for at least three (3) years after study completion. Should you have any questions or need additional information, please do not hesitate to contact me.

Sincerely,

Beverly J. Boulware

Beverly J. Boulware, Ed.D.
IRB Committee
Middle Tennessee State University

Middle Tennessee State University Institutional Review Board
Informed Consent Document for Research

Principal Investigator: Melissa Brock
Study Title: Relationship between Spoken Language Comprehension and Reading Skills
Institution: Middle Tennessee State University

Name of participant: ____ Age: _________

The following information is provided to inform you about the research project and your participation in it. Please read this form carefully and feel free to ask any questions you may have about this study and the information given below. You will be given an opportunity to ask questions, and your questions will be answered. Also, you will be given a copy of this consent form.

Your participation in this research study is voluntary. You are also free to withdraw from this study at any time. In the event new information becomes available that may affect the risks or benefits associated with this research study or your willingness to participate in it, you will be notified so that you can make an informed decision whether or not to continue your participation in this study.

For additional information about giving consent or your rights as a participant in this study, please feel free to contact the Office of Compliance at (615) 494-8918.

1. **Purpose of the study:**
   You are being asked to participate in a research study to address fundamental questions regarding the brain mechanisms underlying speech comprehension and how those relate to your reading skills.

2. **Description of procedures to be followed and approximate duration of the study:**
   The study involves two experimental sessions taking place on two different days. During one experimental session, you will complete a series of small standard tests aimed at evaluating your reading skills. Your voice will be audio recorded during the administration of the reading measures to ensure accurate scoring, but your name will not be associated with the recordings to preserve your identity. This session lasts approximately 1.5 hours.

   During the second experimental session, you will perform a discourse comprehension task while your brain activity is being recorded non-invasively. Prior to the start of the discourse comprehension task, an electrode net with small metal sensors will be gently placed on your head. The sensors will allow us to record the activity from the nerve cells located under your scalp. The sensors are embedded in sponges pre-soaked with an electrolyte solution (water and potassium chloride) to improve the contact with your scalp. The application does not hurt and usually takes about 40 minutes. Once the test starts, you will listen to pairs of short sentences containing instructions asking you to move toys onto particular shapes printed on a desk in front of you. Your hands will be video recorded as you complete the experiment, but your face will not be shown to preserve your identity. Afterwards the experimenter will answer any additional questions you have regarding the experiment. This EEG session lasts approximately 2 hours, including several planned rest periods.

3. **Expected costs:**
   There will be no cost to you for the data collected for this study. Your insurance company or other third-party payers will not be charged for the research or the examinations required specifically for this study.

4. **Description of the discomforts, inconveniences, and/or risks that can be reasonably expected as a result of participation in this study:**
   The risk involved is minimal. It is no more than one would experience in daily life activities. You will have to sit relatively still for 10 minutes at a time, which might be tiring or annoying. Your hair may be damp at the end of the session from the water-based solution used to lubricate the electrodes, so we will provide you with a hair dryer and towel for your convenience. The experimenter will be in constant contact with the subject, and the experiment can be discontinued at any time.

5. **Unforeseeable risks:** n/a

6. **Compensation in case of study-related injury:** n/a

Middle Tennessee State University Institutional Review Board
Informed Consent Document for Research

7. **Anticipated benefits from this study:**
   This study does not provide you with any health care. The study is strictly for research purposes and will have no direct health or medical benefit to you as an individual. The proposed experiments will enable us to address fundamental questions regarding the brain mechanisms underlying speech perception and language comprehension.

8. **Alternative treatments available:**
   n/a

9. **Compensation for participation:**
   If you are currently enrolled in PSY4240-003 at MTSU, you may receive 15 points of course credit for your participation. If you are a student currently enrolled in PSY1410 (General Psychology), you will receive 4 credits for your participation. Other volunteer participants will receive a $20 gift card.

10. **Circumstances under which the Principal Investigator may withdraw you from study participation:**
    If you are hearing impaired, have had psychological or neurological disorders, you may be withdrawn from participating in the study.

11. **What happens if you choose to withdraw from study participation:**
    You may decline to join this study or withdraw from this study at any time without prejudice; that withdrawal would not in any way affect your standing with the University. If you withdraw after the experiment has begun, you will still receive compensation.

12. **Contact Information.** If you should have any questions about this research study or possible injury, please feel free to contact Dr. Cyrille Magne at 615-898-5599.

13. **Confidentiality.** All efforts, within reason, will be made to keep the personal information in your research record private but total privacy cannot be promised. Your identity will remain confidential. You will be assigned an ID code, and completed forms will be stored in locked files to which only the Principal Investigator will have access. All computer data files pertaining to you will be accessible by subject ID code only. Your information may be shared with MTSU or the government, such as the Middle Tennessee State University Institutional Review Board, Federal Government Office for Human Research Protections, if you or someone else is in danger or if we are required to do so by law.

14. **STATEMENT BY PERSON AGREEING TO PARTICIPATE IN THIS STUDY**
    I have read this informed consent document and the material contained in it has been explained to me verbally. I understand each part of the document, all my questions have been answered, and I freely and voluntarily choose to participate in this study.

________________ ________________________________
Date Signature of patient/volunteer

Consent obtained by:

________________ ________________________________
Date Signature

____
Printed Name and Title

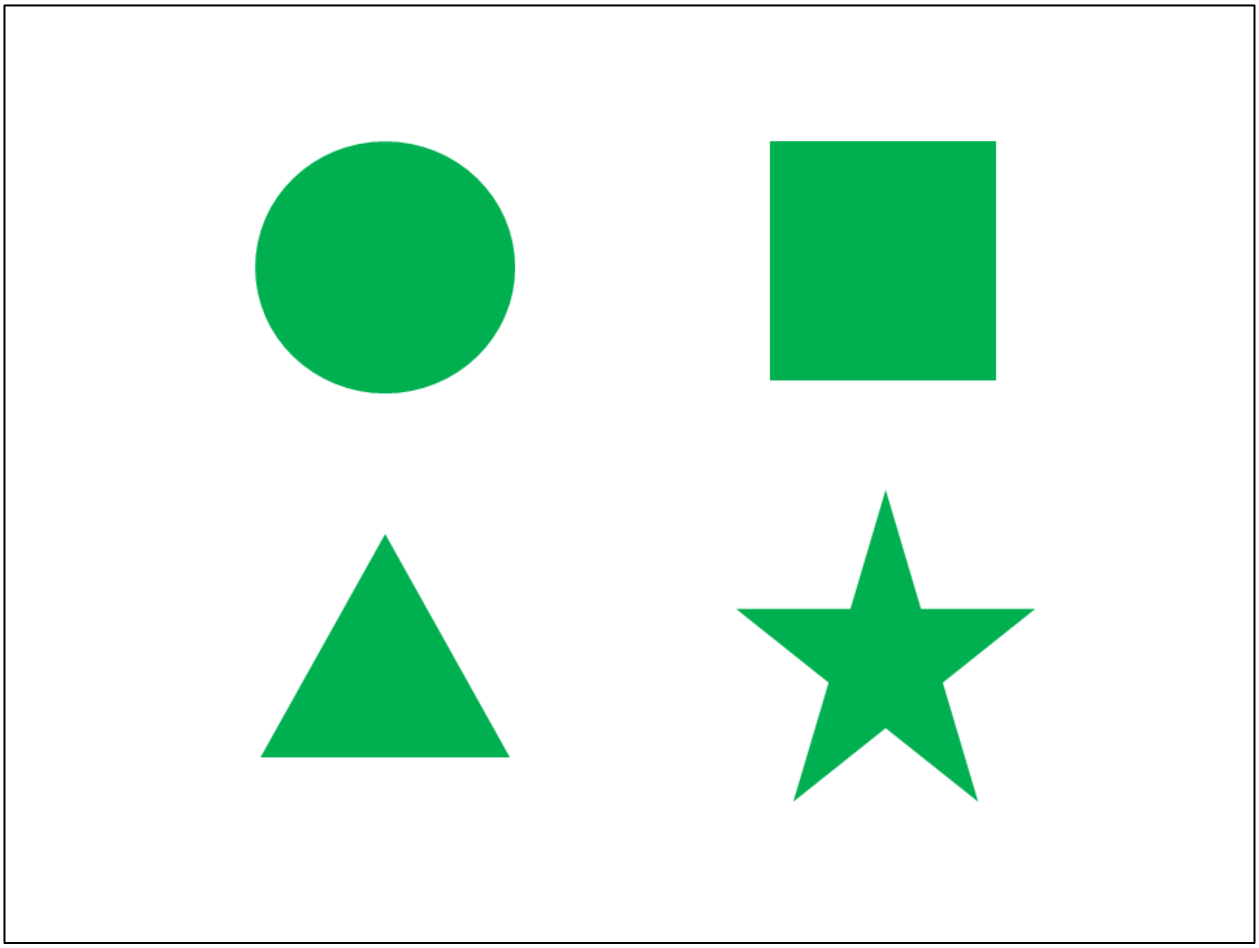
APPENDIX B

Objects and Shapes for Prosody Task

Animals	Manufactured Objects	Shapes
ant	ball	circle
bat	boat	diamond
bear	boot	heart
bee	car	square
bird	coin	star
cat	cup	triangle
cow	doll	
deer	hat	
dog	key	
duck	nail	
fish	plane	
fly	pot	
fox	rock	
frog	spoon	
goat	train	
horse	truck	
mouse		
pig		
shark		
sheep		
snail		
snake		
worm		

APPENDIX C

Display of Shape Mat for Prosody Task



APPENDIX D

Electrode Layout on the Scalp