RELATIONSHIP BETWEEN WORD STRESS SENSITIVITY AND READING: AN ELECTROPHYSIOLOGICAL INVESTIGATION

by

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ABSTRACT

Prosody, the suprasegmental aspects of phonology, contributes to language acquisition and speech perception. To further analyze this, the present study aims to use a cross-modal priming design in which auditory rhythmic stimuli based on duration were used to prime visually presented trochaic words (i.e., stressed on the first syllable) and iambic words (i.e., stressed on the second syllable). The scalp distribution of Event-Related Potentials (ERPs) indicates rhythmic processing as part of a general rule-based error detection system. In addition, a positive correlation was found between the participants' musical rhythm aptitude and the negativity displayed in response to mismatching iambic words. In line with the previous literature, the results indicated that rhythmic auditory patterns influenced the processing of subsequently presented visual words. The results are in line with previous research suggesting a potential benefit of music training to improve speech rhythm sensitivity.

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CHAPTER I

Introduction

The aim of the present study is to investigate the neural correlates of implicit prosodic processing in silent word reading and whether musical aptitude correlates with individual differences in prosody sensitivity.

Prosody corresponds to the suprasegmental phonological aspects of language. It includes accentuation and intonation patterns affecting anything greater than one phonetic segment such as syllables, words, phrases, and sentences (Cutler, Dahan, & van Donselaar, 1997). The present study particularly focused on the accentuation aspect and meter, the pattern of stressed and unstressed syllables in speech. Stress markers include pitch contour, duration, amplitude, and vowel quality. The metrical segmentation strategy proposed by Cutler and Norris (1988) implicates meter as the aspect of speech that helps us segment language. Cutler and Carter (1987) found 90% of the words in spontaneous speech to be initially stressed. That makes stress an accurate heuristic for segmentation strategies.

Meter closely relates to rhythm, the temporal organization of these metrical patterns. Rhythm and meter may help us overcome one of the greatest issues with human speech, the mash-up, which refers to the fact that words are often not acoustically distinct. This lack of distinction poses a problem during infant language acquisition and helps to explain why individuals learning a new language often say that native speakers talk too fast. However, recent research looking into the use of suprasegmental aspects of language in both children and adults may lend some insight into speech segmentation strategies (Jusczyk, 1999).

Most research examining prosodic processing has focused mainly on prosodic processing in speech. However, prosody seems to play a role in reading as well (Magne & Brock, 2012). In fact, Fodor (2002) proposed the Implicit Prosody Hypothesis stating that a prosodic contour is applied during silent reading. In similar situations, a reader will follow the syntax that is most natural given the structure of the sentence (Fodor, 2002). Thus, studying implicit prosodic processing in silent reading may offer additional insights into the factors influencing reading processes.

It is important to note that rhythm and meter are not restricted to the language domain and are important aspects of music as well. In music, meter is the basic pulse of regular successive beats (Kennedy, 2015). In contrast, rhythm is the actual patterns of notes within a measure (Kennedy, 2015). The explicit nature of meter is generally to keep all musicians on the same page. Rhythm details all of the musical communication of feeling and emotion that the musicians convey to the audience, through various note lengths, ritardandos and accelerandos, and rhythmic variations that bend the rules of stress established by the meter. Since rhythm and meter plays an important role in both music and language, it is thus not surprising that there is an increasing amount of evidence suggesting that linguistic rhythm and musical rhythm are processed by overlapping neural pathways (e.g., Gordon, Magne, & Large, 2010) and that musical expertise is associated with increased speech rhythm sensitivity (e.g., Marie, Magne & Besson, 2010).

Language Acquisition and Speech Segmentation

Over the past 25 years, research into segmentation strategies has blossomed into slowly solidifying insights. By analyzing the way that infants pay attention to novel and familiar words, researchers have been able to understand more about how infants apply increasingly complex segmentation strategies as they develop.

At around 7.5 months of age, infants use stress markers and statistical frequency to segment incoming language. Infants segment words using stress to indicate the start of a word. By 10 months, infants are able to utilize phonotactic and allophonic information as well (Jusczyk, 1999). The importance of stress markers and statistical frequency as the first tools for segmentation are likely indicative of two aspects of development. Statistical frequency is not something that is consciously calculated, but rather an aspect of the general human ability to recognize patterns. While not specifically related to speech, the development of something as complex as language requires all of an infant's newly developing abilities. Stress markers, on the other hand, could relate to the development of specific aspects of language, specifically those suprasegmental aspects of language.

The primary segmentation strategy that develops around 7.5 months coincides with segmenting initially stressed words. Words that are not initially stressed still appear to be segmented at the stress. When primed with the word "tar", infants will react to the word "guitar" (iambic) in continuous speech. However, when they are primed with the word "guitar", infants show no sign of being able to segment it from continuous speech (Jusczyk, 1999). The secondary segmentation strategies that involve phonotactic and allophonic information may require the use of skills that are also developing around 10 months of age.

Speech Rhythm Sensitivity in Adults

In English, speech heavily favors initially stressed words (~87.6%; both monosyllabic and polysyllabic). However, when comparing bisyllabic nouns and verbs, nouns are mainly initially stressed (about 90% according to Cutler & Carter, 1987) while verbs are more often initially unstressed (about 70% according to Cutler & Carter, 1987). Thus, stress patterns may also help with lexical access. It is particularly relevant to contrast noun/verb stress homographs, in which the nouns and verbs are spelled the same but are initially stressed when used as a noun or initially unstressed when used as a verb (e.g., PERmit *vs* perMIT).

Other research looking at the effects of stress and segmentation have focused on metrical feet. The metrical foot is considered the base metrical unit of speech. The most common metrical feet in English are the iamb (an initially unstressed syllable followed by a stressed syllable), trochee (an initially stressed syllable followed by an unstressed syllable), dactyl (an initially stressed syllable followed by two unstressed syllables), and anapest (an initially unstressed syllable followed by an unstressed syllable and a stressed final syllable) (Baldick, 2008). While the metrical foot is often discussed as a part of poetry, the same concepts apply to natural speech as well. Many studies in German have focused on the metrical foot for a strategy of segmentation (Domahs, Klein, Huber, & Domahs, 2013; Domahs, Wiese, Bornkessel-Schlesewsky, & Schlesewsky, 2008; Knaus, Wiese, & Domahs, 2011). The breakdown of each foot in relation to those around it follows certain patterns. Some patterns are allowable while others, such as the lapse (two unstressed syllables together) and clash (two stressed syllables together), are not allowed (Knaus, Wiese, & Domahs, 2011).

ERP Correlates of Speech Rhythm

Research into the neurophysiological response to meter in speech has been studied using a variety of experimental designs (isolated words vs sentences), tasks (implicit vs explicit) and languages (mainly Dutch, English, French, and German). However, similar results have been found in several studies showing increased negativity between 350 – 450 ms post stimulus onset, in response to spoken words with an incorrect or an unexpected stress pattern (Böcker, Bastiaansen, Vroomen, Brunia, & De Gelder, 1999; Magne et al., 2007; Marie, Magne, & Besson, 2011; Rothermich, Schmidt-Kassow, & Kotz, 2012; Rothermich, Schmidt-Kassow, Schwartze, & Kotz, 2010). The scalp distribution is not consistent, though. A centro-parietal distribution has been found in some studies (Magne et al., 2007; Marie, Magne, & Besson, 2011), suggesting an N400-like effect classically associated with increased lexical and semantic processing difficulties (Kutas & Federmeier, 2011). In others, results revealed a more fronto-central distribution (Böcker, Bastiaansen, Vroomen, Brunia, & De Gelder, 1999), which led some authors to consider those two types of negativity as reflecting distinct functions (Rothermich, Schmidt-Kassow, & Kotz, 2012). Rothermich et al. (2012) concluded that this indicates that rhythm is integrated seperately from lexical access. Another group of studies focused more on the role of metrical feet in speech segmentation in German found increased P300 for altered stress patterns, suggesting that a reevaluation of the metrical foot structure is initiated (Domahs, Klein, Huber, & Domahs, 2013; Domahs, Wiese, Bornkessel-Schlesewsky, & Schlesewsky, 2008).

Recently, Sonja A. Kotz and Michael Schwartze (2010) proposed a theory that moved away from the structuralist view of language and considered that speech perception is opportunistic and makes use of all available information. The brain utilizes time, rhythm, and patterns to establish routines allowing the basal ganglia to act as a corrective agent whenever expected meter is not met by stress while the cerebellum functions as an online processor of incoming information. Research looking at the modulating role of the basal ganglia on expected rhythm in patients with brain lesions supports this temporal theory of speech processing and the role of stress (Kotz, Gunter, & Wonneberger, 2005). Behavioral studies also provide support for the stress/temporal theory of speech organization finding that recognition and recall are stress meter dependent (Robinson, 1977). Lending more support for the temporal approach to speech comprehension is the dynamic attention theory (DAT) proposed by Large and Jones (1999). The theory states that neural entrainment allows attentional processes to sync with outside stimuli. Neural activity is focused at the height of each peak in the oscillation. The purpose of stress in language acts as the outside stimulus to sync neural entrainment in order to facilitate lexical access at certain points in speech.

The subcortico-cortical framework (Kotz & Schwartze, 2010) and the DAT (Large & Jones, 1999) are not specific to language. The neural networks underlying the temporal predictions are not domain specific but function specific. Therefore, just as the concepts of meter and rhythm are shared between music and language, the neural networks of the proposed theories are shared between music and language. Thus, musical and linguistic abilities share a common rhythmic aptitude that may be influenced by musical training.

Musical Aptitude and Language Processing

Musical ability and music training have been found to correlate with cognitive abilities (Schellenberg, 2005) and language in particular (Besson, Schön, Moreno, Santos, & Magne, 2007). Musicians showed enhanced language processing skills, including pitch percetion (e.g., Magne, Schön, & Besson, 2006; Schön, Magne, &

Besson, 2004) and speech rhythm sensitivity (Marie, Magne, & Besson, 2011). Music training may also facilitate second language learning (Milovanov & Tervaniemi, 2011). In additon, transfer effects from musical training to language abilities have also been found in longitudinal studies using randomized groups of partiicpants assigned to either music training and art classes (Moreno et al., 2009). Evidence for shared neural networks for language and music have been found for pitch processing (Schön, Magne, & Besson, 2004; Magne, Schön, & Besson, 2006) and rhythm perception (Gordon, Magne & Large, 2010).

Cason & Schön (2012) used ERPs to study rhythm auditory primes followed by spoken pseudowords with stress patterns either matching or mismatching the auditory primes. The DAT was the background for their investigation, but they found results more similar to a general error detection strategy rather than a lexical facilitation effect. An increased N100 was displayed for incongruent primes similar to a mismatched negativity. An increased P300 was displayed for target words that were rhythmically misaligned with the preceding stress pattern. The behavioral data showed no noticeable difference between congruent or incongruent target words and primes.

Rautenberg (2015) recently studied the correlates of music aptitude with reading ability as well. Rhythm ability was found to positively correlate with reading accuracy and articulation. Tonal ability, however, was not found to have a significant relationship with any aspect of reading ability, suggesting that segmentation strategies based on rhythm may tranfer to reading ability.

Closely related to the present study, Brochard, Tassin, & Zagar (2013) investigated rhythmic priming on visual word recognition following the DAT in a behavioral study. They used a musical prime for visually presented target words (displayed as syllables). Accordingly, the rhythmic priming should result in entrainment that reaches a peak on each strong beat. Their results indicate that specific processing resources are allocated in rhythm with the priming stimulus indicated by reduced response times for congruently displayed words. An interaction in response time indicates that by allocating processing resources by stress the brain is able to facilitate lexical access and also lacks the necessary resources for incongruently displayed words.

The Present Study

The literature aforementioned clearly suggests that rhythm influences the way we read, but the electrophysiological correlates of this interaction remain largely unexplored. In parallel, research on the effect of music aptitude on cognition largely favors positive transfer effects of training from music to language abilities. Yet, no study has directly investigated the two aspects together. Thus, the present study aims to further analyze the electrophysiological markers of implicit prosody and the potential influence of musical aptitude on sensitivity to implicit prosody. To that end, participants performed a lexical decision task on visually presented bisyllabic words that were either trochaic or iambic. Targets were preceded by a rhythmic tone prime composed of either a long-short tone pattern or a short-long tone pattern. The stress pattern of the visual target either matched or mismatched the rhythmic structure of the auditory prime.

Based on the previous literature on spoken language (e.g., Magne et al., 2007; Marie et al., 2011), an increased centro-frontal negative ERP component was expected around 250-500 ms post word onset when its stress pattern did not match the rhythm of the auditory prime. In addition, musical aptitude was expected to correlate with the negative response to target words with a mismatching stress pattern. At the behavioral level, an increase in response time and error rate was expected for real words with a mismatching stress pattern.

CHAPTER II

Methods

Participants

Eleven native speakers of English (8 females, Mean Age = 21.4 ± 3.2) received course credits for their participation in the study. All participants were right-handed, had normal or corrected-to-normal vision, and had no psychological or neurological history. One was excluded due to a technical error during recording. Ten participants (7 females) remained in the sample. The study was approved by the Institutional Review Board at Middle Tennessee State University and written consent was obtained from all participants. See appendix 1 for the Institutional Review Board approval and appendix 2 for the consent form.

Stimuli

Target stimuli were comprised of 140 real English bisyllabic nouns and 140 pseudowords. Half of the real words (N = 70) had a trochaic stress pattern (i.e., stressed on the first syllable), while the other half had an iambic stress pattern (i.e., stressed on the second syllable). Both words and pseudowords were selected from the database of the English Lexicon Project (Balota et al., 2007). Iambic and trochaic words were matched in term of lexical frequency using the log HAL frequency (Lund & Burgess, 1996). Pseudowords were matched to the real words in term of syllable count and word length.

Prime sequences consisted of a rhythmic tone pattern of either a long-short or a short-long structure repeated three times. The tones consisted of a 500 Hz sine wave with a 10 ms rise/fall and a duration of either 200 ms (long) or 100 ms (short). In long-short sequences, the long tone and short tone were separated by a silence of 100 ms, and each of the three successive long-short tone pairs was followed by a silence of 200 ms. In short-long sequences, the short tone and long tone were separated by a silence of 50 ms, and each of the three successive short-long tone pairs was followed by a silence of 250 ms.

Short-long and long-short auditory sequences were combined with the iambic and trochaic visual words to create two experimental conditions in which the stress pattern of the target word matched the rhythm of the auditory prime and two experimental conditions in which the stress pattern of the visual word mismatched the rhythm of the auditory prime. (See examples in Table 1 below). In two additional distractor conditions, the pseudowords followed either a long-short or short-long sequence.

Table 1

Examples of Stimuli in Each Experimental Condition

Auditory Prime	Visual Target	
	Match	Mismatch
Long-Short Long-Short Long-Short	BASket	PoLICE
Short-Long Short-Long Short-Long	PoLICE	BASket

Note: Capital letters indicate the stressed syllable. During the actual experiment, only the first letter was always capitalized.

Procedure

Participants were first administered the Advanced Measures of Music Audiation (AMMA; Gordon, 1989). This standardized test of music aptitude consisted of 30 pairs of melodies. Participants were asked to determine whether the two melodies of each pair were the same, tonally different or rhythmically different. As a result, this standardized test provides two subset scores reflecting the participants' ability to differentiate rhythmic and tonal variations.

Following the AMMA administration, participants were seated in an anechoic chamber at approximately 5 feet in front of a computer screen. The presentation of the auditory prime and visual target word was controlled using a Desktop PC and E-Prime (PST, Inc., Pittsburg, PA). The sequence for each trial started with the presentation of a fixation cross in the center of the screen for 500 ms prior to and remaining during the presentation of the auditory prime via headphone. Following the auditory prime, a visual target word was presented in the center of a computer screen. Participants were ask to attend to the target words and decide as fast and accurately as possible whether it was a real word or not in English, by pressing one of two buttons on a response pad. The visual target remained on the screen until a button was pressed or for 2000 ms maximum. After participants gave their answer, a series of Xs appeared on the screen for 2000 ms to let them know that they could relax their eye. Each participant performed a practice block of 10 trials followed by five experimental blocks of 56 trials each. The experimental blocks were counterbalanced across participants, and trials were presented in a random order within each block.

EEG Acquisition and Analysis

EEG was recorded continuously from 129 Ag/AgCL electrodes embedded in sponges in a Hydrocel Geodesic Sensor Net (EGI, Eugene, OR) placed on the scalp, connected to a NetAmps 300 amplifier, and using a MacBook Pro computer. Electrode impedances were kept below 50 kOhm. Data were referenced online to Cz and re-referenced offline to the averaged mastoids. In order to detect the blinks and vertical eye movements, the vertical and horizontal electrooculograms (EOG) were also recorded. The EEG and EOG were digitized at a sampling rate of 500Hz.

EEG preprocessing was carried out with NetStation Viewer and Waveform tools. The EEG was first filtered with a bandpass of 0.1 to 100 Hz. Data time-locked to the onset of the fourth word (target) of each list was then segmented into epochs of 1100 ms, starting with a 100 ms prior to the onset of the fourth words and continuing 1000 ms post-word-onset. Trials containing movements, ocular artifacts, or amplifier saturation were discarded. ERPs were computed separately for each participant and each condition by averaging together the artifact-free EEG segments relative to a 100 ms pre- baseline.

Statistical analyses were performed using MATLAB and the FieldTrip open source toolbox (Oostenveld, Fries, Maris, & Schoffelen, 2011). Planned comparisons between pairs of conditions (Long Short Primed Trochaic vs Short Long Primed Trochaic; Short Long Primed Iambic vs Long Short Primed Iambic) were performed using a cluster-based permutation approach. The advantage of this nonparametric data-driven approach is that it does not require the specification of any latency range or region of interest a priori, while also offering a solution to the problem of multiple comparisons (see Maris & Oostenveld, 2007).

To relate the ERP results to the musical aptitude measure, cluster sums were calculated using the approach proposed by Lense, Gordon, Key, and Dykens (2014). For each cluster, amplitude at each time point and electrode were summed together, separately for each condition. Then the cluster sum difference for iambic words was computed by subtracting the cluster sums for the mismatching iambic condition from the matching iambic condition. Similarly, the cluster sum difference for trochaic words was computed by subtracting the cluster sums for the mismatching trochaic condition from the matching trochaic condition. Correlations were then tested between the ERP cluster sum difference (i.e., difference between the cluster sums of each condition) and the participants' scores on the AMMA.

CHAPTER III

Results

Behavioral Data

Table 2 below shows the mean and standard deviation (SD) for the accuracy rate and reaction times of the participants in each experimental condition.

Table 2
Accuracy Rate and Reaction Time per Condition

	Accuracy		Reaction Time	
	Mean	SD	Mean	SD
Long-Short Prime				
Trochaic	99.3%	0.01	579.98	105.34
Iambic	97.4%	0.03	588.10	88.25
Pseudoword	96.9%	0.02	707.67	133.48
Short-Long Prime				
Trochaic	99.3%	0.01	570.34	75.72
Iambic	98.5%	0.02	602.69	107.82
Pseudoword	96.3%	0.04	721.46	130.19

Accuracy rates for correctly identified real and pseudowords were all near 100%. Paired sample t-tests were conducted separately for trochaic and iambic words to assess differences in accuracy and reaction times between mismatching and matching conditions. Statistical analysis revealed no significant differences in either accuracy (Trochaic: $t(9) = 0.00$, $p = 1.00$; Iambic: $t(9) = 1.86$, $p = .081$) or reaction time (Trochaic: $t(9) = 0.64$, $p = .517$; Iambic: $t(9) = 1.58$, $p = .130$).

ERP Data

Figure 2 and Figure 3 present the grand-average ERPs elicited by trochaic and iambic target words. For trochaic words, a visual inspection of the ERP data on Figure 2 suggested an increased negativity between 300 and 700 ms over the centro-frontal regions of the scalp when the target word had an unexpected trochaic stress pattern. This observation was confirmed by the results of the cluster-based permutation tests that revealed significant negative clusters between 200 and 518 ms (t cluster sum = -18225, p = .007) as well as between 522 and 888 ms (t cluster sum = -16067, p = .009).

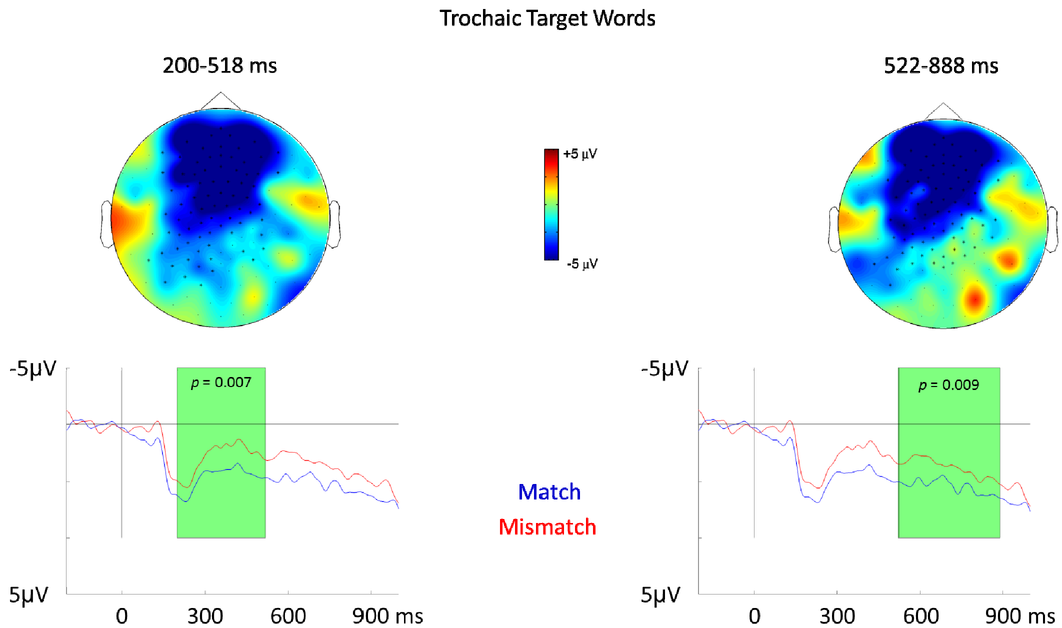

Figure 1. Grand average ERP to trochaic words. Top panel represents the mean scalp distribution of the negative effect (Mismatch - Match) within the cluster. Bottom panel represents the average waveforms (N = 10) elicited by visual iambic words when matching (blue trace) or mismatching (red) the auditory prime sequence. On this figure and the following, the latency ranges of the significant clusters are indicated with a green rectangle. Negative amplitude values are plotted upward.

Regarding iambic words, a visual inspection of the data on Figure 3 suggested that words with a mismatching iambic stress pattern were associated with a more localized increased negativity between 400 and 700 ms over the frontal electrode sites. Though two negative clusters were identified within that time range, none reached significance (516 - 566 ms: *t* cluster sum = -515, p = .370; 590-706 ms: *t* cluster sum = -1331, p = .140).

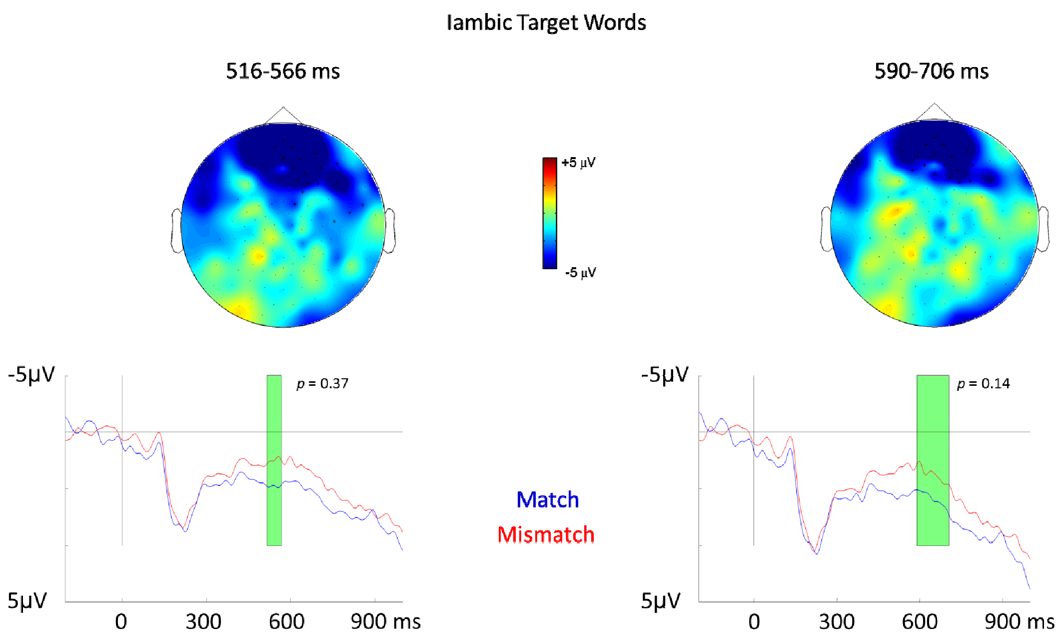

Figure 2. Grand average ERP to iambic words. Top panel represents the mean scalp distribution of the negative effect (Mismatch - Match) within the cluster. Bottom panel represents the average waveforms (N = 10) elicited by visual iambic words when matching (blue trace) or mismatching (red) the auditory prime sequence.

Musical Aptitude

The average total musical aptitude score was 47.90 (*SD* = 7.56) and ranged from 33 to 57. The average tonal and rhythm sections were 23.10 (*SD* = 4.04) and 24.80 (*SD* = 4.08), respectively.

To test the relationship between music aptitude and sensitivity to speech rhythm, cluster sum differences were first computed for each of the negative clusters identified for trochaic and iambic words. Results of the correlations are presented in Table 3 below.

Table 3

Music Aptitude and ERP Cluster Sum Differences Correlations

			Pearson Correlations			
			Trochaic		Iambic	
	Mean	*SD*	(200 - 518)	(522 - 888)	(516 - 566)	(590 - 706)
All Participants						
Tonal	23.10	4.04	.023	.145	-.049	.005
Rhythm	24.80	4.08	.159	.083	.366	.192
AMMA Total	47.90	7.56	.098	.122	.171	.106
Removed Participant 4 (Cook's D > 1)						
Tonal	24.11	2.62	.180	.455	.541	.330
Rhythm	25.44	3.75	.248	.193	.750*	.371
AMMA Total	49.56	5.79	.242	.330	.730	.389

*$p < .05$

When all participants were considered for the analysis, none of the correlations reached significance, the largest correlation being between the rhythm subset score and the iambic cluster sum difference in the 516-566 ms time range (significance, $r = .366$, $p = .154$). To identify any potential outlier, Cook's D was calculated. The data from one participant was found to have a Cook's D > 1. Correlations calculated without the data from this participant indicated a significant relationship between the rhythm subset score and the size of the negative effect for mismatching iambic words ($r = .750$, $p = .019$) between 516-566 ms.

CHAPTER IV

Discussion

The results of the present study can be summarized as follows. First, an increased fronto-central negative ERP component was found for incongruently primed bisyllabic trochaic nouns. While the negative effect for iambic words was not significant, its amplitude was highly correlated with musical ability. Finally, no differences in reaction times or accuracy rates were found.

Cross-Modal Priming Effect

The presence of significant ERP differences between target trochaic words that matched and target words that mismatched the auditory rhythmic primes indicates that metrical information of a word is automatically processed even during silent reading. While this negative effect was fronto-central in the present study, the classic N400 associated with lexical and semantic processing is usually centro-parietal (Kutas & Federmeier, 2011). Thus the present negative effect is unlikely to reflect lexical processing per se. This interpretation is also in line with the behavioral data that did not reveal any significant difference between matching and mismatching trochaic words. Thus, regarding the two theories of this negative effect (lexical access vs a general rule-based detection system), the results seem to indicate a general rule-based detection system.

Unlike for trochaic words, the negative effect visible on Figure 3 in response to incongruently primed iambic stimuli did not reach significance. There are two reasons that this may have occurred. The first reason is that the ERPs were segmented from the onset of the word presentation on the screen. The information conveyed from the stress of the second syllable was therefore delayed compared the trochaic target words (where the stress occurs on the first syllable, thus corresponding on the presentation onset). Given the variability in first syllable lengths, the ERPs elicited by the stressed second syllable may have not been properly aligned during the averaging process. The second reason is that the stress of the second syllable requires the implementation of secondary segmentation strategies, as has been suggested for spoken language in infants (Jusczyk, 1999), and these strategies may rely on similar general mechanisms that are involved in rhythm perception in music. The beginning of an answer may emerge when one takes into consideration music abilities.

Relationship between Speech Rhythm Sensitivity and Musical Aptitude

The significant correlation between the size of the negative effect to mismatching iambic words and music rhythm ability suggests that sensitivity to rhythm in music plays a role in the enhanced sensitivity to stress in initially unstressed visual words. This indicates that musical ability and secondary segmentation strategies may co-develop and share aspects of brain potentials. This result also extends the previous literature showing a relationship between music aptitude/training and language processing (e.g., Magne, Schön, & Besson, 2006; Marie, Magne, & Besson, 2011; Schön, Magne, & Besson, 2004). The fact that the iambic negative effect was not significantly correlated with music tonal aptitude suggests that rhyhm (particularly its timing properties) plays a more important role than pitch in stress perception.

The applications of this study extend strongly into language development and reading. Dyslexia has been thought to be caused by various conditions over the years, but some evidence points to a lack in phonological processing and decoding skills (Magne &

Brock, 2012). When a child lacks the phonemes of their language, it becomes very difficult to map those phonemes to symbols (reading). This could potentially result in the developmental issues that are often seen in dyslexia, but musical training and rhythm awareness in particular may be beneficial to building the secondary segmentation strategies, rhythmic error detection, and eventually solidify the phonemes of a child's language through increased sensitivity to phonemic information.

Limitations and Future Directions

While the results shows a role of implicit prosody in reading and the potential relationship between rhythm sensitivity and musical aptitude, it is also important to address some of the limitations of the present study. First, our target stimuli are isolated words. The participants were asked to distinguish between common real words and pseudowords and therefore did not necessarily need to recall the actual meaning of a word. In some situations, identifying the word is familiar may suffice for correct responses. In contrast, greater lexical expectancies are triggered when the words are presented within the context of a sentence or paragraph. In addition, greater resources are required to continually process words and phrases online, and rhythm may play a bigger facilitating role in that process.

The acoustic correlate of stress marking that was manipulated in the auditory prime for the present study was the duration. Other stress markers like pitch and intensity may be more important for lexical access while duration indicates peripheral online information about where to expect amplitude, intonation, or vowel quality changes. Thus duration would successfully elicit entrainment and issue a response in the general rule-based error detection system, but not interfere with lexical access.

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APPENDICES

APPENDIX A: IRB APPROVAL LETTER

April 16, 2013

Nicole Brunas, Matthew Harris, Jessica Burns, Michael Prodmore, Dr. Cyrille Magne
Protocol Title: Relationship between word stress sensitivity and reading: An electrophysiological investigation
Protocol Number: 13-312

Dear Investigator(s),

The MTSU Institutional Review Board or its representative has reviewed the research proposal identified above. The MTSU IRB or its representative has determined that the study meets the criteria for approval under 45 CFR 46.110 and 21 CFR 56.110, and you have satisfactorily addressed all of the points brought up during the review.

Approval is granted for one (1) year from the date of this letter for **100** participants. **Please use the version of the consent form with the compliance office stamp on it that will be emailed to you shortly**.

Please note that any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615) 494-8918. Any change to the protocol must be submitted to the IRB before implementing this change.

You will need to submit an end-of-project report to the Office of Compliance upon completion of your research. 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. Failure to submit a Progress Report and request for continuation will automatically result in cancellation of your research study. Therefore, you will NOT be able to use any data and/or collect any data.

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 (c/o Emily Born, Box 134) before they begin to work on the project.
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 and then destroyed in a manner that maintains confidentiality and anonymity.

Sincerely,

Aleka Blackwell
Member, MTSU Institutional Review Board

April 8, 2014

Hershel Eason, Cyrille Magne
Department of Psychology
hje2b@mtmail.mtsu.edu; Cyrille.Magne@mtsu.edu

Protocol Title: "Relationship between Word Stress Sensitivity and Reading: An Electrophysiological investigation"

Protocol Number: **13-312**

Dear Investigator(s),

I have reviewed your research proposal identified above and your request for continuation and your requested changes. Approval for continuation is granted for one (1) year from the date of this letter. Any changes to the originally approved protocol must be provided to and approved by the research compliance office.

You will need to submit an end-of-project report to the Office of Compliance upon completion of your research. Should the research not be complete by the expiration date, **April 8, 2015**, please submit a Progress Report for continued review prior to the expiration date.

According to MTSU Policy and Procedure, a researcher is defined as anyone who works with data or has contact with participants. Therefore, should **any individuals be added to the protocol that would constitute them as being a researcher, please identify them and provide their certificate of training to the Office of Compliance**. Any change to the protocol must be submitted to the IRB before implementing this change.

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

Also, all research materials must be retained in a secure location 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,

Kellie Hilker
Compliance Officer
Research Compliance Office
494-8918
Compliance@mtsu.edu

APPENDIX B: APPROVED CONSENT FORM

Principal Investigator: Hershel Eason
Study Title: Relationship between Word Stress Sensitivity and Reading: An Electrophysiological investigation
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 reading processing.

2. **Description of procedures to be followed and approximate duration of the study:**

   Prior to the start of the experiment, 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.

   While the electrode net is being setup, you will perform a short music aptitude test during which you will make judgments on pairs of melodies.

   During the experiment, you will hear tones and read words on a computer screen and decide whether they are real English words or not. Both your responses and brain electrical activity will be recorded on a computer. At the end of the experimental session, pictures of your head will be taken in order to determine the exact position of the sensor on the surface of your scalp. The pictures will then be discarded. Afterwards the experimenter will answer any additional questions you have regarding the experiment. The entire session lasts approximately 2 hours, including several planned rest periods.

   We are also requesting access to your ACT scores to determine if there is any relationship between them and your performances on the music task and during the experiment. Please note that your name and any identifying information will not be linked to your ACT scores in our records.

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 towels for your convenience. The experimenter will be in constant contact with you, and the experiment can be discontinued at any time.

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

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

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

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 reading processes.

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

9. **Compensation for participation:**
   n/a.

10. **Circumstances under which the Principal Investigator may withdraw you from study participation:**
    If you are visually impaired, have hearing deficits, have had psychology or neurological disorders, or are not native speaker of English, 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 negative consequences; that withdrawal would not in any way affect your standing with the University.

12. **Contact Information.** If you should have any questions about this research study or possibly 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. De-identified version of your behavioral and EEG data may be made publicly available or shared with other researchers for research purpose only.

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

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Printed Name and Title