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The Effects of Weighted Objects

on Attention, Speech Perception, and Mood

by

Katelyn Smith

A thesis

submitted in partial fulfillment

of the requirements for the degree of

Master of Science in the Department of Speech-Language Pathology and Audiology

Idaho State University

Spring 2019

To the Graduate Faculty:

The members of the committee appointed to examine the thesis of KATELYN SMITH find it satisfactory and recommend that it be accepted.

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RE: regarding study number IRB-FY2018-201 : Behavioral and neural outcomes associated with sensory-based activities

Dear Dr. Cummings:

I have reviewed your request for expedited approval of the new study listed above. This is to confirm that I have approved your application.

Notify the HSC of any adverse events. Serious, unexpected adverse events must be reported in writing within 10 business days.

You may conduct your study as described in your application effective immediately. The study is subject to renewal on or before Jan 23, 2019, unless closed before that date.

Please note that any changes to the study as approved must be promptly reported and approved. Some changes may be approved by expedited review; others require full board review. Contact Tom Bailey (208-282-2179; email humsubj@isu.edu) if you have any questions or require further information.

Sincerely,

Ralph Baergen, PhD, MPH, CIP
Human Subjects Chair

January 2, 2019

Alycia Cummings
College of Rehabilitation Comm Sciences
1311 E. Central Drive
Meridian, ID 83642

RE: Study number IRB-FY2018-201: Behavioral and neural outcomes associated with sensory-based activities

Dear Dr. Cummings:

You are granted permission to continue your study as described effective immediately. The study is next subject to continuing review on or before January 2, 2020, unless closed before that date.

As with the initial approval, changes to the study must be promptly reported and approved. Contact Tom Bailey (208-282-2179, humsubj@isu.edu) if you have any questions or require further information.

Sincerely,

Ralph Baergen, PhD, MPH, CIP
Human Subjects Chair

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The Effects of Weighted Objects on Attention, Speech Perception, and Mood

Thesis Abstract – Idaho State University (2019)

The present study examined weighted objects' influence on mood, speech perception, and attention. Thirty-two adults and ten children were randomly assigned to control (CG) or sensory (SG) groups. All tasks were completed twice, before and after an activity. During the activity, the SG wore a weighted shoulder wrap and lap pad, while the CG wore no weights; all participants colored or completed a puzzle. CG adults showed a pre- to post-activity decrease in the P1 event-related potential (ERP) peak in response to speech syllables, indicating a decrease in perceptual attention. Thus, the weighted objects might have helped sustain SG's attention. SG adults reported feeling calmer and less nervous post-activity than CG adults, suggesting weights decreased anxiety. The partial samples of children demonstrated neural trends similar to adults. Thus, a weighted activity has the potential to improve mood and attention in adults and children.

Key Words: sensory processing, speech perception, attention, mood, EEG, ERP, sensory-based activities, proprioceptive activities, weighted objects

Chapter One: Introduction

People interact with the world around them constantly, and initially it might seem as though those interactions are not very complex. However, many cognitive processes are continually occurring within the brain in order to sort through each and every interaction that takes place. These processes signify sensory processing. While sensory *processing* refers to the way individuals recognize and respond to sensory information around them (Dunn, 2007), sensory *integration* involves taking in sensory information and interacting with the environment as a whole. That is, sensory integration is a neurological process that occurs to effectively perceive, organize, and identify sensory information from the environment (Ayres, 1972).

Two important terms associated with sensory integration are *sensory modulation* and *praxis*. Sensory modulation refers to appropriately responding to sensory information (Noddings, 2017c; Söderback, 2015). For example, when background noise is present, the body interprets that as either being important and something to pay attention to, or not important and something to ignore. When sensory modulation is not occurring properly, sensory processing becomes more difficult; thus, making it harder for the body to decide what to do with the sensory input (e.g, the background noise).

Praxis is the process of thinking, organizing, and executing specific actions based on sensory input (Noddings, 2017c; Söderback, 2015). In the above example, the body decided the background noise was important and something to pay attention to. The brain must then decide what the body needs to do in order to react appropriately to the background noise, which is praxis. For example, if the person is driving and hears sirens in the background, the brain would tell the body to look for the sirens and pull off the road if necessary. Both sensory modulation and praxis are important for processing and organizing the sensory information present in everyday environments.

Sensory processing and sensory integration are similar; however, they differ in their approach. Sensory *integration* focuses more on the process of integrating sensation from the environment, while sensory *processing* focuses more on the individuality in processing the sensory information present throughout daily life. Sensory integration is a dated term that does not address individual differences, while sensory processing is a more current term that accounts for individuality; therefore, this study will focus on sensory processing as the primary theory and terminology throughout.

Sensory Profiles

Sensory processing describes the way in which individuals take in and respond to sensory information (Dunn, 2007). Perception of environmental stimuli can vary from person to person. The brain processes and organizes sensory stimuli differently based on individual needs, and because of this, there is a variety of sensory preferences. These sensory preferences can be grouped into categories referred to as sensory profiles. There are four different types of sensory profiles: sensory seeking, sensory avoidant, sensory sensitivity, and low registration. People can range from low to average to high in each of the profile types (Brown & Dunn, 2002); it is possible to have similar rankings across multiple categories.

Sensory seeking. Individuals who are sensory seeking tend to be unaware of pain, temperature, or the feeling of objects. According to Noddings (2017b), they chew on things that are not edible (e.g., pencils), rub against walls and furniture, or bump into people. This is likely to increase the sensory input they are receiving. People in this profile frequently have a hard time following direction and seem to ignore voices around them. Movement is important for sensory seekers, specifically fast, spinning, or upside-down rides, and they are always moving or fidgeting (Noddings, 2017b). Overall, people who fit this profile are looking for additional sensory stimuli and enjoy the environment and spontaneity (Brown & Dunn, 2002). However, sensory seekers typically become bored easily, and environments with limited sensory stimuli are difficult for them to tolerate.

According to the *Adolescent/Adult Sensory Profile* (Brown & Dunn, 2002), coping strategies to increase sensation might interfere with the execution of daily routines. Since people who fit the sensory seeking profile prefer movement, typical classroom learning and therapy settings can be a challenge for sensory seekers because of the constant in-seat requirements throughout the day. As a result of the challenges sensory seekers experience, sensory-based activities, such as weighted vests, have been examined as a tool to improve such challenges. Weighted objects facilitate more effective learning and performance strategies for children with hypersensitive sensory needs due to the improvement on in-seat and on-task behaviors exhibited following the use of weighted objects (Buckle, Franzsen, & Bester, 2011; Hung-Yu, Posen, Wen-Dien, & Fu-Yuan, 2014). Based on these preliminary findings, clients who are sensory seeking might also benefit from wearing weighted objects during speech and language therapy.

Sensory avoidant. The sensory avoidant profile is essentially the opposite of the sensory seeking profile. People who fit this profile avoid touching or being touched by anything, and produce a fight-or-flight response when touched (Noddings, 2017b). They become anxious when there is too much visual input and frequently cover their eyes and ears. Bright light and excess noise are too stimulating for people fitting this sensory profile. Sensory avoiders do not like certain textures, movement, or heights. They tend to avoid running, climbing, sliding, or swinging, and prefer to remain on the ground. Sensory avoiders are often rigid, tense, stiff, and uncoordinated (Noddings, 2017b). According to the *Adolescent/Adult Sensory Profile* (Brown & Dunn, 2002), it is common for sensory avoiders to have strict routines to create a more predictable sensory environment. Problems arise for people who fit this sensory profile when the environment is too intense or unpredictable, which leads to a decrease in performance on daily activities. It is important for sensory avoiders to have opportunities to take a break (Brown & Dunn, 2002).

Learning in a typical classroom or clinic setting can be challenging for sensory avoiders due to all of the sensory input present in the environment. Effective strategies to facilitate learning and performance based on individual sensory needs could utilize sensory-based activities. For example, clients with a sensory avoiding profile might benefit from wearing weighted objects during therapy sessions to reduce anxiety caused by over-stimulating environments.

Sensory sensitivity. The sensory sensitivity profile is very similar to the sensory avoidant profile; however, over-stimulation and strict structure are less of a concern. According to the *Adolescent/Adult Sensory Profile* (Brown & Dunn, 2002), people who fit this profile typically have a low neurological threshold, which refers to the amount of intensity required from a stimulus to initiate a response from the brain. This means that their brains do not require as much sensory input prior to generating a response. For example, if a low buzzing sound was presented in the environment, people with other sensory profiles might not notice it at all, or the noise might fade away quickly into the background. Alternatively, people who fit the sensory sensitivity profile might notice it immediately and it might never fade into background noise. They will usually notice every stimulus in their environment and get distracted or even uncomfortable from intense stimuli. People who fit this profile typically have a high awareness of their surroundings and pay close attention to detail. Problems arise with this profile when attention to stimuli begins to interfere with the person's ability to focus on completing tasks. People in this profile do best with calm and familiar environments (Brown & Dunn, 2002).

The ideal learning environment for people who fit the sensory sensitive profile would be a quiet place with minimal distractors. It should be noted that weighted materials might not be the best fit for people with sensory sensitivity due to the increased sensory input the weighted materials provide. Thus, since the people who fit this profile become easily overloaded from sensory stimuli, individual therapy sessions, rather than group sessions, might be more beneficial to them. In addition, conducting therapy in a place where stimuli, such as overhead lighting, can be reduced or minimized might increase a client’s attention and focus.

Low registration. According to the *Adolescent/Adult Sensory Profile* (Brown & Dunn, 2002), people with a low registration profile take longer to respond to stimuli, or they might not notice them at all. They have difficulty reacting to stimuli that are presented quickly or with low intensity and are usually the last to understand a joke. People in this profile can focus in noisy environments and are typically more flexible. For people with low registration, problems arise when the environment lacks intensity or change, which is necessary to maintain attention and performance (Brown & Dunn, 2002).

Environments that are constantly changing are best for people who fit this profile. People with low registration constantly seek input. Children with low registration might lose attention quickly in classrooms where they are required to sit still and focus on one thing for an extended period of time. This attention loss is likely due to the lack of new sensory input. Although weighted materials might not be the best fit for people with low registration, it might be beneficial to use tactile-based sensory activities to maintain task engagement.

People can rank high to low in each of the four sensory profiles: sensory seeking, sensory avoidant, sensory sensitivity, and low registration. These rankings are based on their sensory preferences of various everyday stimuli as determined by either the *Child Sensory Profile 2* (Dunn, 2014) or the *Adolescent/Adult Sensory Profile* (Brown & Dunn, 2002). Various activities are available to enhance sensory processing based on the sensory profile a person most identifies with. Activities most commonly used are known as sensory-based activities. Sensory-based activities target three different senses that are associated with sensory processing: tactile, vestibular, and proprioception. To better understand the way sensory-based activities are effective, it is important to first understand the way each sense effects sensory processing.

Associated Senses

There are three senses related to sensory processing: tactile (i.e., touch), vestibular (i.e., balance), and proprioception (i.e., body position) (Kranowitz, 1998; Mauer, 1999). The brain processes the information it receives from these three senses working together and subsequently allows people to respond accordingly to each stimulus around them. A breakdown in this process occurs when the brain or any of these three senses associated with sensory processing do not perceive, process, or organize the surrounding stimuli appropriately (Mauer, 1999). This can occur in a variety of different ways and if the breakdown interferes significantly enough with daily life, this might result in a difficultly processing and incorporating sensation. The major indicators of difficulties processing and integrating sensation are an inability to read cues from surroundings, an inability to consistently take in sensory information, and an inability to adjust behavior according to the environment (Noddings, 2017c).

Tactile. The tactile sense processes information about touch (Kranowitz, 1998). Tactile input is constant and helps keep the body organized and functioning. This sense is activated by anything felt on the skin and generally comes through pain, pressure, temperature, or vibration. Tactile input plays a key role in motor planning, body awareness, learning, emotional security and social skills (Kranowitz, 1998). There can be deficits with the tactile sense, as well. This is known as tactile defensiveness, which refers to difficulty regulating light tactile input. Deep pressure tactile input helps to alleviate defensiveness and increases the amount of input being received by the body. People with tactile defensiveness also avoid certain textures because it might feel irritating to them (Mauer, 1999).

Vestibular. The vestibular sense is thought to be a major organizer of sensory information. This sense coordinates and controls the muscles in the body (Mauer, 1999). According to Kranowitz (1998), the vestibular system processes movement and balance and facilitates efficient body movement. Children with vestibular difficulty tend to lack personal space awareness and stand too close to people because they are unaware of their body in relation to those around them. Additionally, if a child's vestibular system is not functioning appropriately, he or she might experience difficulty learning speech and language (Mauer, 1999). This is likely due to the major role the vestibular system plays in the motor components of speech and the interpretation of body language during interactions with peers. Vestibular difficulty might be an important factor to consider when providing therapy, as incorporating activities designed to target the vestibular system might help improve the motor components of speech or the child's ability to interpret body language (Preis & McKenna, 2014).

Proprioceptive. Proprioception incorporates movement and touch sensations (Kranowitz, 1998). The proprioceptive sense processes and integrates information regarding the body and body position. This sense organizes motor control and motor planning, including fine motor skills (Kranowitz, 1998). Not understanding where the body is in space, often associated with clumsiness, and difficulty manipulating small objects are common characteristics of proprioception difficulty (Mauer, 1999).

Tactile, vestibular, and proprioceptive senses can be difficult to tease apart. This is likely because the three senses work together, and are involuntary, so people have limited control over them (Kranowitz, 1998). While these senses are closely intertwined in what they do during sensory processing, there are key differences between them that can aid in differentiating them, specifically with regards to which part of the body receives information. The tactile sense receives and processes information about touch primarily from the skin. The vestibular sense receives and processes information about movement, gravity, and balance from the inner ear. The proprioceptive sense receives and processes body position mainly through the muscles in the body (Kranowitz, 1998). Together, the three senses work to efficiently integrate the multitude of stimuli present throughout everyday environments. Table 1 describes activities that target these senses.

Table 1

Summary of Sensory Processing Senses and Therapy Activities to Target Each Sense.

Sense	What it Does	Activities
Tactile	Touch	Playing with shaving cream, placing hands in a bean bin, or eating (Preis & McKenna, 2014).
Vestibular	Body movement and balance	Movement activities such as walking, physical activity, or swinging (Preis & McKenna, 2014).
Proprioceptive	Motor control and body position	Fine motor activities such as cutting, writing, coloring, or playing with play dough; doing yoga; wearing weighted objects (Noddings, 2017a; Preis & McKenna, 2014)

Note. Not all clients are appropriate candidates for the use of sensory-based activities.

Sensory-based activities have long been used to improve attention and language abilities in occupational therapy; however, their use in speech-language pathology is minimal. This is likely due to the lack of research on this subject relating to its direct impact on the field. In one of the few studies involving communication-related behaviors, Preis and McKenna (2014) demonstrated that sensory-based activities could improve length of utterance and spontaneous speech with disorders associated with difficulty processing sensation, such as autism spectrum disorder (ASD).

It is most important to consider a client's primary sensory deficit before approaching treatment (Dunn, 1997). Using sensory-based activities can be the most effective way to target sensory processing difficulties. Speech-language pathologists (SLPs) can utilize sensory-based activities during speech and language therapy to improve outcomes for clients with sensory processing difficulties. While not much research has been done to examine what SLPs can do to modify their treatment sessions to accommodate clients' sensory processing difficulties, utilizing sensory-based activities that align with a client's diagnosis, sensory profile, and individual needs might be helpful to increase a client's attention and improve treatment outcomes. This study will aim to determine to what extent weighted objects impact attention, speech perception, and mood. Healthy adults and typically developing children will be the focus of this study to determine, understand, and interpret pilot outcomes and prepare the groundwork for future studies to examine populations with attention and/or sensory deficits, such as people with ADHD or ASD.

Chapter Two: Literature Review

Sensory integration is a neurological process where sensory information from the environment is identified, perceived, and organized (Ayres, 1972). Sensory processing refers to individually interpreting and responding to sensory information (Dunn, 2007). The three senses related to sensory processing are tactile, which processes information regarding touch, vestibular, which coordinates balance, and proprioception, which interprets body position (Kranowitz, 1998; Mauer, 1999). A breakdown in sensory processing can occur when any of the three sensory processing senses are not working properly. Sensory-based activities can be used to repair breakdowns in sensory processing. To best determine which sensory-based activities could be most effective for each individual, it is beneficial to consider the sensory profile of that person: sensory seeking, sensory avoiding, sensory sensitive, and low registration.

Improvements in attention have been found following the use of sensory-based activities. Specifically, proprioceptive activities, such as those involving weighted objects, appear to have the greatest impact on attention. For example, significant improvements in attention, processing speed, and in-seat behaviors have been found in children with ADHD wearing weighted vests (Hung-Yu et al., 2014). While sensory-based activities have been used in occupational therapy for many years, these activities could be beneficial for SLPs as well due to the positive effects on in-seat behaviors, attention, and processing speed.

A broad range of sensory-based activities can be used to address sensory processing issues in the tactile, proprioceptive, and vestibular senses. These activities can range from playing with shaving cream to doing yoga to swinging. One of the more commonly known sensory-based activities is the use of weighted materials.

Weighted Materials

Wearing weighted materials is a sensory-based technique used to target the proprioceptive sense. Weighted objects provide deep pressure stimulation. Deep pressure stimulation has shown positive physiological and psychological benefits resembling the effects similar to a firm hug (Mullen, Champagne, Krishnamurty, Dickson, & Gao, 2008). Such effects can decrease anxiety and increase fine motor task attention (Mullen et al., 2008). Weighted objects also increase body awareness and provide feedback regarding body positioning in space. To maximize the benefits of weighted objects, such as decreased anxiety, it is important to follow the proper wearing guidelines that have been established. It is recommended that the weights worn should not exceed 10% of the person's body weight (Buckle et al., 2011; Hung-Yu et al., 2014; Mullen et al., 2008). It is also recommended that the weights be distributed across the person's body.

Wearing weighted materials have been shown to increase children's focus and on-task behaviors. Hung-Yu and colleagues (2014) examined the effects of weighted vests in 110 children with a mean age of 8.6 years diagnosed with ADHD. Using a randomized crossover design, participants were in both the control and experimental groups at different measurement points (i.e., control then experimental, or vice versa). The participants were asked to complete the Conner's Continuous Performance Test (CPT-II; Conners et al., 2000), which measured inattention and impulsivity, at two time points. The group sets were as follows: one wore weights during the task at time one and the other wore weights during the task at time two. The weights were worn for the duration of the CPT-II (Conners et al., 2000), which lasted 14-minutes. Significant improvements were found between groups (weighted and unweighted) across both time points on the participants' inattention (i.e., number of times the individual did not respond to targets), processing and response speed (i.e., how quickly they processed the target and responded to it), off-task (i.e., looking away from the computer), out of seat (i.e., leaving their chair during the task), and fidget behaviors (i.e., extraneous body movements) while wearing the weighted vest, as compared to the group not wearing the weights (Hung-Yu et al., 2014).

Hung-Yu et al.'s (2014) findings support the effectiveness of weighted objects on improving children's attention and behavior. The CPT-II was an appropriate measure for the analysis of attention since it measured variables such as the number of times the participant responded to the presented targets. Blinding and randomization ensured no bias was present, which increased the quality of the study and produced stronger results. While the behavioral outcomes were measured via observation alone, outcomes demonstrated positive effects that weighted objects could have on children with ADHD.

Along with the positive outcomes demonstrated by Hung-Yu and colleagues (2014), a similar study also found improvements on in-seat behavior while children with ADHD wore weighted vests (Buckle et al., 2011). Thirty children diagnosed with ADHD in grades one to three were randomly split into two groups, where each group underwent six phases throughout the crossover treatment study: pre-test, intervention, washout period, two assessment phases, and post-testing. Group A received the intervention and washout period while group B received the two assessment periods and then the crossover occurred, and then the groups switched the two phases. During the intervention phase, the participants wore a weighted vest in the classroom setting for 45-minutes. The participants' in-seat behaviors were observed during each phase using a stopwatch, where researchers recorded how long the children stayed seated in a twenty-minute period of time during each phase.

Buckle and colleagues (2011) observed that while participants stayed seated for longer periods of time while wearing the weighted vests, as compared to when not wearing the vests, the difference was not significant. The measures used by Buckle et al. (2011) might have resulted in the non-significant findings due to the inability of the measurements to detect individual differences within and across participants. Observation as a method of data collection could be useful in showing improvements, as demonstrated by Huny-Yu and colleagues (2014); however, it might not be the most accurate or effective way to evaluate change across time. Such inaccuracies are likely because the measurements might not remain consistent across participants/groups. This suggests that weighted materials could elicit some improvements on in-seat behavior in children with ADHD. Thus, it is possible that with a clear, objective measurement, weighted materials could show significant improvement on in-seat behavior.

Across the two weighted vest studies, there were inconsistencies regarding the appropriate duration of time for the vests to be worn. In Buckle and colleagues (2011), the weights remained on the participants for 45-minutes at a time while in Hung-Yu and colleagues (2014), the weights were worn for 14-minutes at a time. Fatigue might have a quick onset when wearing weighted objects; therefore, wearing the weighted objects for the minimum amount of time required to produce desired results would be optimal as a treatment technique.

It is also important to consider that weighted objects need to be placed on the long axis of the body to improve trunk stability (Gibson-Horn, 2008). Weighted vests might not efficiently displace weight across the long axis and might add extra pressure to the spine. Other forms of weighted objects should also be considered in order to produce more significant results, and to improve trunk stability and spinal support (Gibson-Horn, 2008). For example, shoulder wraps evenly displace weight along the shoulder girdle, while lap pads disperse weight to the lower extremities in the long axis of the body. This study will utilize a shoulder wrap and lap pad to improve trunk stability among participants.

Given the positive outcomes from Hung-Yu et al. (2014) and Buckle et al. (2011), it is important to consider the impacts of weights on behavior and attention. Weighted objects could increase in-seat behaviors in children who have difficulty remaining seated. Additionally, weighted materials might help calm children who have increased anxiety. Improved in-seat behaviors and decreased anxiety could be the result of the deep pressure input the weighted materials provide. Moreover, as an extension, if weighted materials help children maintain attention, they could be used during therapy to enhance children's speech and language learning. Maintained attention is important for children to learn and develop speech and language. When attention is lost for even a brief moment of time, the child can miss short, transitional components of language that are presented briefly in conversation, which can lead to a significant amount of missed information. Without maintained attention, learning language becomes more difficult because children miss important components of language such as morphemes, individual phonemes, syntactical structures, and nonverbal communication being expressed from teachers, parents, peers, and other people in their environment.

Weighted materials can be used to increase clients' in-seat behaviors and attention due to the deep pressure stimulation they provide. Improving such behaviors would likely have positive impacts on clients' speech and language treatment outcomes. Thus, understanding how weighted materials affect clients across multiple domains (e.g., sensory, mood, attention) is both relevant and important given that SLPs' caseloads are continually increasing; therefore, providing the most effective treatment possible is important to manage such large caseloads. Appropriate use of sensory materials could improve treatment outcomes by providing a better learning environment, which could lead to faster, deeper learning and eventually higher dismissal rates.

Assessment Tools

Traditional methods used to assess the outcomes of weighted objects have been primarily behavioral measures and observation. Assessments such as the CPT-II (Conners et al., 2000) and observational rating systems have been used in previous research. Using such methods, some studies have identified significant results regarding attention and behavior (Hung-Yu et al., 2014), while others have not (Buckle et al., 2011). It is likely that the effects of weighted materials are subtle, and such measurements might not have the temporal resolution to capture the differences. This could be because initial changes occur at the neural level within the brain, prior to when overt behaviors can be observed. The brain responds to changes, which subsequently results in overt behavioral changes. Thus, the missing link in sensory-based research could be that the most appropriate measurements have not yet been utilized to accurately measure the changes that occur when participants are engaged in sensory activities.

Electroencephalograms (EEG) and event-related potentials (ERPs). An EEG is a tool used as a direct measure of brain waves and neuronal activity across a given period of time and a range of frequency bandwidths (Lord & Opacka-Juffry, 2016). ERPs are recorded as a part of the EEG and are excellent tools to use when measuring the subtle differences that might occur when wearing weighted materials. Given their attention-independent nature, ERP measures are free of behavioral confounds such as memory and cognition and are a good tool to use with young children who are often non-compliant with behavioral testing. Thus, ERP measures capture the very basic neural responses prior to the participant consciously responding; therefore, they are pure measures of any neural change that occurs. A variety of ERP responses can be produced in an experimental paradigm. The ones most relevant to the present study are the auditory P1, P2, and N2.

The auditory P1, also known as the auditory P50, is a frontocentral positivity that occurs 50-100 ms after the onset of an auditory stimulus, such as a speech syllable (Grunwald et al., 2003; Korzyukov et al., 2007; Potts, Dien, Hartry-Speiser, McDougal, & Tucker, 1998). The physical parameters of an auditory stimulus elicit the response in the temporal lobes, with the information about those parameters subsequently being sent to the frontal lobes for storage. The amplitude of the auditory P1 responses can be modulated by the amount of attention an individual allocates to stimulus processing, with larger P1 responses associated with greater attentional focus (Luck, 1995; Woodman, 2010). Linguistic auditory stimuli can elicit larger P1 responses than nonlinguistic auditory stimuli due to individuals' ability to extract additional meaningful information from the auditory stream (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011). Thus, the P1 is a proven index of attentional focus and extent of auditory processing.

The P2 and N2 waves provide information about the brain's auditory processing abilities and are linked to automatic, low-level responses produced by neurons (Beres, 2017; Čeponienė, Torki, Alku, Koyama, & Townsend, 2008). The P2 wave is a positivity that peaks around 100-250 milliseconds after a presented stimulus (Sur & Sinha, 2009). The P2 response indexes both stimulus detection and identification (Čeponienė et al., 2008). The N2 wave is a negativity that peaks around 200 milliseconds after a stimulus is presented (Sur & Sinha, 2009). The N2 response indexes sound detection and integration (Čeponienė et al., 2008). The P2 and N2 responses together provide insight into the participant's detection of, and response to, auditory information.

The use of ERP as a measurement tool can be a critical element in objectively measuring how sensory activities affect an individual. It is sensitive enough to measure things that behavioral measures cannot. If neural effects are found, then it could be concluded that sensory activities have an effect on an individual, regardless of whether or not behavioral differences are observed. The changes could be brief and/or subtle, which are response characteristics that are not easily measured behaviorally.

Pulse rate. Along with measuring potential sensory-related changes with ERP, changes can also be measured physiologically. Vital signs could provide important information about the impact of wearing weighted materials on the participant's physiological status; specifically monitoring heart rate changes, which can be easily measured and monitored. Heart rate is a volatile vital sign that can change frequently due to subtle changes in a person's environment or mood. Thus, heart rate can be a more sensitive measure than behavioral assessments due to the subtle differences that the heart rate can detect.

A relationship between anxiety, heart rate, and weighted materials has been previously found. Chen and colleagues (2016) compared a group of adults who wore a deep pressure apparatus for the duration of a wisdom tooth extraction procedure to a control group (CG) that did not wear any weights during the procedure. The experimental group had lower heart rate variability during the procedure as compared to the CG. This result could indicate that deep pressure input facilitates regulation of the parasympathetic nervous system and management of anxiety, which in turn contributes to the maintenance of a consistent (and low) heart rate. Thus, heart rate appears to be an important factor to consider and monitor as additional physiological changes that might be occurring when individuals wear weighted materials. Heart rate variability could be an informative tool to use when examining the effects of weighted materials.

Research Question and Hypotheses

While little research has directly examined what SLPs can do to modify their treatment sessions to improve attention, it appears using weighted materials can improve in-seat and on-task behaviors. Adequate attention is necessary for clients to correctly attend to the instructions, directions, and feedback of structured tasks during therapy in order to make significant improvements towards speech and language goals. Maintained attention is crucial for effective speech and language development and learning.

Significant improvements in attention, processing/response speed, reaction time, and generalized behaviors have been found in children with ADHD wearing weighted vests (Hung-Yu et al., 2014). However, previous research done has been criticized for its inconclusive and varying results, which are often anecdotal in nature (Zimmer et al., 2012). Previous research has also shown mixed results on sensory activity effectiveness (Leong, Carter, & Stephenson, 2015). Therefore, it is critical to quantitatively examine the effectiveness of weighted materials using behavioral and electrophysiological approaches sensitive enough to capture subtle differences. Using EEG/ERP additional tools to measure sensory activity outcomes, this study would not rely solely on behavioral measures such as attention and cognition assessments.

While previous research has examined effects on populations with ADHD or ASD, the present study examines the effects from typical populations to inform and predict what might happen in clinical populations. The present study will examine the influence of sensory-based activities on participants' mood, speech perception, processing speed, and attention using standardized behavioral tasks, pulse rate, and electrophysiological methods. Previous research has suggested that weighted materials provide a calming effect on individuals, and increase individuals' attention levels. Thus, it is hypothesized that improvements in attention, mood, and speech perception will be observed in participants who wear weighted shoulder wraps and lap pads, as compared to participants who do not wear weights. It is also hypothesized that heart rate will decrease in participants who wear weighted shoulder wraps and lap pads, as compared to participants who do not wear weights.

Chapter Four: Population

Participants

Participants were randomly assigned to a control group (CG) or sensory group (SG). All participants had normal hearing and normal or corrected to normal vision. It is important to note that data from the children and adults were analyzed separately, and tasks varied slightly across child and adult populations, which will be explained in further detail below.

Adults. Thirty-six adults ranging in age from 19- to 38-years-old were recruited to participate in this study (17 sensory; 19 control). The data from four adults did not contain adequate numbers of ERP trials and were eliminated from the final sample of 32 adults (16 sensory; 16 control).

Children. Thirteen typically developing children ranging from ages five years, eleven months to ten years, two months were recruited to participate in this study (7 sensory; 6 control). Due to experimenter error, ERP data from one child in the sensory condition were not recorded. In addition, children in the control condition tended to be older than the children in the sensory condition. Thus, in order to control for age as well as possible, and to have equal sample sizes for this study, a final sample of ten children with five children in each group were included (SG mean age: 7.25 years; CG mean age: 8.25 years)[1].

Sensory Profile

Adults. The *Adolescent/Adult Sensory Profile* (Brown & Dunn, 2002) is a questionnaire that was given to adult participants to fill out at the beginning of the study

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[1] The groups were not significantly different in terms of age ($t(8) = -1.139$, $p < .28$).

prior to any tasks being completed. It contained 60 questions regarding the person's sensory preferences for a number of different items such as taste/smell, movement, visual, touch, auditory processing, and activity level. The participants ranked each statement on a 5-point scale ranging from almost never to almost always. Participants in the SG identified as low registration significantly more than the participants in the CG (SG low registration mean (SD): 34.13 (5.987); CG low registration mean (SD): 28.94 (6.444); $t(30) = 2.159$, $p < .05$).

Children. The *Child Sensory Profile 2* (Dunn, 2014) is a questionnaire that was completed by the child participants' parents at the beginning of the study prior to any tasks being completed. This questionnaire contains 86 questions regarding the child's typical response or behavior in a number of different sensory areas such as auditory, visual, touch, movement, body function, oral sensory processing, conduct, social-emotional, and attentional responses. There were no statistically significant differences in the sensory profiles between the SG and CG.

Sensory profile analysis. The sensory profile questionnaires were blindly and individually scored to determine the sensory profile of each participant. The sensory profiles were then compared across the CG and SG to determine the sensory preferences of the participants in each group. The results from this questionnaire were analyzed and compared to their performance pre- and post-sensory/control activity.

Chapter Five: Methods and Analyses

Experiment Design and Procedure

Two different experiments were conducted as a part of this thesis. Participants over the age of 18-years-old were placed in the adult experiment, while participants between the ages of five and ten years old were placed in child experiment. All electrophysiological, physiological, and behavioral tasks were completed twice, once before and once after the sensory/control activity.

Participants were randomly assigned to either in the control condition or the weighted material sensory condition. Participants in both conditions completed a low-level activity such as completing a puzzle, coloring, or playing with blocks (children only). During the low-level activity, the SG wore both a weighted shoulder wrap and lap pad for 15-minutes while the CG did not wear any weights for the same duration of time. There were three weight options for the each of the weighted shoulder wraps and lap pads: 3 pounds, 5 pounds, and 8 pounds. The amount of weight that was put on the participant was no more than 10% of the participant's total body weight. The 10% standard was used in this study based on the standard that has been set and used in occupational therapy, which has shown positive outcomes and minimal fatigue (Mullen et al., 2008). The weights were purchased from Salt of the Earth® and made out of a fine stone fill, covered in four layers of soft fabric for comfort. Table 2 describes the order of activities for the adult and child participants.

Table 2

Schedule of Events for Each Participant in the Study

Adult	Children
· Sign consent form	· Parent/child sign consent form

· Completion of sensory profile · EEG cap and electrodes are placed on head	· Parent completes sensory profile of child · EEG cap and electrodes are placed on head
· Completion of mood questionnaire · Pulse taken	· Child selects mood on feelings chart · Pulse taken
· Speech perception EEG (7-minutes)	· Speech perception EEG (7-minutes)
· Complete behavioral tasks · Pulse rate taken	· Complete behavioral tasks · Pulse rate taken
· 15-minute sensory/control break paired with low-level activity · Pulse rate taken upon completion	· 15-minute sensory/control break paired with low-level activity · Pulse rate taken upon completion
· Complete mood questionnaire	· Child selects mood on feelings chart
· Speech perception EEG (7-minutes)	· Speech perception EEG (7-minutes)
· Complete behavioral tasks	· Complete behavioral tasks
· Pulse rate taken · EEG cap removed	· Pulse rate taken · EEG cap removed

Electrophysiological Measures

Speech perception task. Three adult-produced English speech syllables (consonant + /ɑ/) were digitized with a 16-bit AD converter at a 44.1 kHz sampling rate: /bɑ/, /dɑ/, and /gɑ/. All syllables were approximately 375 ms in duration. The stimuli were presented via two loudspeakers in one seven-minute block containing 450 stimuli (150 per syllable). Within the seven-minute block, the stimuli were presented with equal probabilities. This task was conducted in the same manner for adults and children. While these syllables were playing, the participants were watching a muted movie of their choice on a computer screen or playing a muted app of their choice on an iPad.

EEG recording, averaging, and data analysis. Sixty-six channels of continuous EEG (DC-128 Hz) were recorded using an ActiveTwo data acquisition system (Biosemi, Inc, Amsterdam, Netherlands) at a sampling rate of 256 Hz. This system provides "active" EEG amplification at the scalp that substantially minimizes movement artifacts. The amplifier gain on this system is fixed, allowing ample input range (-264 to 264 mV) on a wide dynamic range (110 dB) Delta- Sigma (ΔΣ) 24-bit AD converter. Sixty-four channel scalp data were recorded using electrodes mounted in a stretchy cap according to the International 10-20 system. Two additional electrodes were placed on the right and left mastoids. Eye movements were monitored using FP1/FP2 (blinks) and F7/F8 channels (lateral movements, saccades). During data acquisition, all channels were referenced to the system's internal loop (CMS/DRL sensors located in the centro-parietal region), which drives the average potential of a subject (the Common Mode voltage) as close as possible to the Analog-Digital Converter reference voltage (the amplifier "zero"). The DC offsets were kept below 25 microvolts at all channels. Off-line, data were re-referenced to the common average of the 64 scalp electrode tracings. Epochs containing 100 ms pre-auditory stimulus and 800 ms stimulus time were baseline-corrected with respect to the pre-stimulus interval averaged.

Since the data were collected on the same day (pre-activity and post-activity), the data were combined for processing. Data processing followed an EEGLAB (Delorme & Makeig, 2004) processing pipeline described in detail here: https://sccn.ucsd.edu/wiki/Makoto%27s_useful_EEGLAB_code#Example_of_batch_code_to_preprocess_multiple_subjects_.2801.2F27.2F2017_updated.29. Briefly, data were high-pass filtered at 0.5 Hz using a pass-band filter. Line noise was removed using the CleanLine EEGLAB plugin. Bad channels were rejected using the trimOutlier EEGLAB plugin and the removed channels were interpolated.

Source level contributions to channel EEG were decomposed using Adaptive Mixed Model Independent Component Analysis (AMICA) (Palmer, Makeig, Kreutz-Delgado, & Rao, 2008) in EEGLAB (http://www.sccn.ucsd.edu/eeglab). Non-artifact independent component (IC) scalp topographies were modeled as projections of single equivalent dipoles and clustered on the basis of dipole locations. On average, the pre-activity adult individual data contained 148 (SD = 1.8) /bɑ/ syllable epochs (i.e., trials), 148 (SD = 1.9) /dɑ/ standard syllable epochs, and 148 (SD = /gɑ/ deviant syllable epochs. The post-activity Adult individual data contained on average 145 (SD = 7.3) /bɑ/ syllable epochs, 146 (SD = 7.0) /dɑ/ standard syllable epochs, and 146 (SD = 5.8) /gɑ/ deviant syllable epochs. On average, the pre-activity child individual data contained 143 (SD = 5.3) /bɑ/ syllable epochs, 143 (SD = 3.8) /dɑ/ standard syllable epochs, and 142 (SD = 5.2) /gɑ/ deviant syllable epochs. The post-activity child individual data contained on average 142 (SD = 6.1) /bɑ/ syllable epochs, 141 (SD = 10.3) /dɑ/ standard syllable epochs, and 143 (SD = 8.3) /gɑ/ deviant syllable epochs.

ERP measurements. Visual inspection of the grand average waveforms suggested that the P1 appeared at ~100 ms, the N1 appeared at ~150 ms, and the P2 appeared at ~200 ms, and the N2 appeared at ~350 ms post-syllable onset. Fifteen electrodes were selected for all analyses: F3/F4, F1/F2, FC3/FC4, FC1/FC2, C3/C4, C1/C2, Fz, FCz, and Cz. A traditional mean amplitude repeated measure ANOVA analysis was used in the present study.

Mean amplitude measurements of averaged data. Mean amplitudes were measured in 50 ms windows surrounding each ERP peak: P1 (75-125 ms), N1 (125-175 ms), P2 (175-225 ms), and N2 (325-375 ms). Using the ERPLAB Toolbox (Luck & Lopez-Calderon, 2012), mean amplitudes were calculated separately for each of the four ERP peaks taking into account the three sound types and fifteen electrodes during both pre- and post-activity measurements. Differences in mean amplitude were compared separately for each ERP peak using Group (Sensory, Control) x Time (Pre-Activity, Post-Activity) x Sound Type (/bɑ/, /dɑ/, /gɑ/) x Electrode (F3/F4, F1/F2, FC3/FC4, FC1/FC2, C3/C4, C1/C2, Fz, FCz, Cz) repeated measure ANOVAs. Partial eta squared (η^2) effect sizes are also reported for all significant effects and interactions. When applicable, Geiser-Greenhouse corrected p-values are reported.

Pre-post activity difference waves. To control for baseline differences between groups and sounds, pre-post activity difference waves were also created by subtracting the post-activity responses from the pre-activity responses. Thus, these waves represent the changes that occurred from pre- to post-activity. As with the pre- and post-activity measurements, mean amplitudes of the difference waves were measured for each ERP peak: P1, N1, P2, N2. Differences were compared separately for each ERP peak using a Group (Sensory, Control) x Sound Type (/bɑ/, /dɑ/, /gɑ/) x Electrode (F3/F4, F1/F2, FC3/FC4, FC1/FC2, C3/C4, C1/C2, Fz, FCz, Cz) repeated measure ANOVAs.

Physiological Measures

Pulse rate. A heart rate monitor was placed on the participant's finger for approximately one minute at each time point to give the monitor appropriate amount of time to read the participant's heart rate and for the participant's heart rate to normalize. While the electrophysiological and behavioral measures were completed twice throughout the experiment, heart rate variability was monitored at four points throughout the study: beginning of the study, before the sensory/control activity, after the sensory/control activity, and upon completion of the study. These time points were chosen to establish a baseline heart rate and note any potential physiological changes after wearing the weighted objects. Monitoring heart rate variability throughout the current study was beneficial to track physiological changes over time within and between participants.

Pulse rate analysis. Results obtained from pulse rate measurements were analyzed using a 2-between (Group: Sensory, Control) x 2-within (Phase: Pre-Activity, Post-Activity) repeated-measures ANOVA analysis to determine the main effect of the sensory/control condition. Due to the high variability of heart rate among participants upon initial and final heart rate measurement, these values were not included in the final analysis. Adult and child data were analyzed separately and are discussed as separate groups.

Behavioral Measures

Behavioral tasks were selected to measure participants' memory, speech production, attention, mood, and processing speed. It should be noted that while participants were timed for many of the behavioral tasks, analyses were not conducted on reaction times. Changes in reaction time were not considered due to the potential difference in timing accuracy of the experimenters' stopwatch button presses. Table 3 below lists each task, what it assessed, and in which experiment it was used.

All participants.

Memory: Nonword Repetition Task. The Nonword Repetition Task (NRT) created by Dollaghan and Campbell (1998) was used to assess participants' phonological short-term working memory. The NRT contains sixteen nonwords: four 1-syllable, four 2-syllable, four 3-syllable, and four 4-syllable. None of the nonwords on the NRT are related to lexical items. The predictability of phoneme combinations is reduced on the NRT, and early-acquired phonemes are primarily used.

For this study, the words were divided into two sections (A & B), each containing 8 nonwords – two of each syllable length (Appendix A). Participants were asked to repeat each word, one by one, exactly as they heard it. For example, they would hear the nonword “vope” and repeat back to the researcher what they heard, to the best of their ability. This task was administered pre- and post-sensory/control activity, with the order of the A and B sections being randomly assigned.

Trained listeners used the International Phonetic Alphabet (IPA) to narrowly transcribe all NRT samples using the *PHON* computer transcription and data analysis program (https://www.phon.ca/phontrac; Rose & MacWhinney, 2014). Using PHON’s blind transcriber function, 100% of each participant’s NRT samples were reliability-checked by a second transcriber.[2] These transcriptions were used to calculate the percentage of phonemes correct (PPC). A total of 96 phonemes are targeted on the NRT (48 in each section). Each phoneme was point-by-point identified as being correct or incorrect in relation to its target phoneme.

Nonword Repetition Task analysis. Results from the nonword repetition task were analyzed using a 2-between (Group: Sensory, Control) x 2-within (Phase: Pre-Activity, Post-Activity) repeated-measures ANOVA analysis. Adult and child data were analyzed separately and discussed as separate groups.

Attention: Attention Sustained. The *Attention Sustained* subtest from the *Leiter-3* (Roid, Miller, Pomplun, & Koch, 2013) was used as a general attention assessment. The original Attention Sustained task encompassed an entire page of paper. To allow for pre- and post-activity measurements, the visual array was cut into two equal sections (A & B),

[2] Reliability transcription has not been fully completed at the time of this thesis presentation (April, 2019).

and the amount of time allowed for completing the task was halved. Participants were asked to identify and circle as many pictured pattern sets as possible, given a set time limit of 30-seconds. Specifically, both adult and child participants were given a single page containing an array of geometric shapes and asked to circle every pattern set (triangle next to oval) among the array of geometric shapes on one half of the page.

Attention Sustained analysis. Results from the attention sustained task were analyzed using a 2-between (Group: Sensory, Control) x 2-within (Phase: Pre-Activity, Post-Activity) repeated-measures ANOVA analysis. Adult and child data were analyzed separately and discussed as separate groups.

Adult participants.

Mood: Brief Mood Introspection Scale. The *Brief Mood Introspection Scale* (Mayer & Gaschke, 2013) is a questionnaire that addresses 16 positive and negative feelings, which participants rank on a 4-point scale from definitely do not feel to definitely feel (Appendix B). Participants' overall mood was also assessed at the end of the questionnaire using a 20-point rating scale from very unpleasant to very pleasant (-10 to +10). The participant-rated questionnaire was blindly and individually coded to document and analyze current participant mood pre- and post-sensory/control activity. The reported moods were then compared across time points for both the SG and CG to determine mood differences pre- to post-activity. Emotions were not defined for the participants prior to completing the questionnaire; therefore, the emotional ratings were selected based on the participant's interpretation of each specific mood.

Mood analysis. Results from the *Brief Mood Introspection Scale* (Mayer & Gaschke, 2013) were analyzed using a 2-between (Group: Sensory, Control) x 2-within (Phase:

Pre-Activity, Post-Activity) repeated-measures ANOVA analysis. Each emotion was analyzed separately. The questionnaire provided the 4-point scale using Roman Numerals. For the purpose of data analysis, the Roman Numerals were assigned an Arabic numeral (1 to 4). The 20-point scale was assigned only positive values for the purpose of analysis (1 to 20).

Processing speed: Decision Speed. The *Decision Speed* subtest from the *Woodcock-Johnson III* (Woodcock et al., 2001) assessed participants' processing speed. The original *Decision Speed* subtest contained 40 questions/rows. For the purposes of conducting pre- and post-activity assessments, these questions were separated into two sections (A & B) using an odd-even selection with each section containing 20 questions. Participants were asked to identify two semantically-related items among a field of seven given time constraints. For example, one row could have pictures of a moon, hammer, umbrella, house, chair, sun, and flower and the participant decided which two items semantically fit best together; in this case, it is the sun and the moon. The original subtest allowed participants three minutes for task completion. Participants were given 90 seconds to complete each of the two sections.

Decision Speed analysis. Results from the decision speed task were analyzed using a 2-between (Group: Sensory, Control) x 2-within (Phase: Pre-Activity, Post-Activity) repeated-measures ANOVA analysis.

Attention: Pair Cancellation. The *Pair Cancellation* subtest from the *Woodcock-Johnson III* (Woodcock et al., 2001): assessment provided a second measure of participants' attention. Similar to the *Attention Sustained* task, the original *Pair Cancellation* visual array was cut into two equal sections (A & B), and the amount of time allowed for completing the task was halved. Participants were asked to identify a specifically ordered pair of objects in a field of distractors given time constraints. Each adult participant was asked to quickly locate and circle the repeated pattern of a soccer ball and dog, while ignoring a series of similar pictures inserted throughout. For example, they were required to circle the ball and dog together when the ball came before the dog; however, there were many instances when the dog came before the ball.

Pair Cancellation analysis. Results from the pair cancellation task were analyzed using a 2-between (Group: Sensory, Control) x 2-within (Phase: Pre-Activity, Post-Activity) repeated-measures ANOVA analysis.

Child participants.

Mood: Feelings chart. A feelings chart showing 12 cartoon emoji faces associated with common emotions was presented to the child participants (Appendix C). Children were asked to identify which face best represents how they are currently feeling. For example, if a participant was feeling sad they could point to the face that has a frown and a tear coming out of their eye. Emotions were not be defined for the participants prior to selecting their current mood; therefore, the emotion that was selected was based on the participant's interpretation of each mood.

Mood analysis. Faces were pre-determined to be associated with a positive or negative mood (positive: happy, excited, silly, surprised; negative: scared, angry, sad, worried, frustrated). Mood changes were assessed by recording the child's responses pre- and post-activity. If the child identified a negative mood prior to the sensory/control activity and then identified a positive mood following the activity, it was noted as an improvement in mood. A decline in mood was noted if a child identified a positive mood at the beginning of the session, and then selected a negative mood after the sensory/control activity.

Attention: Attention Divided. The *Attention Divided* subtest from the *Leiter-3* (Roid, Miller, Pomplun, & Koch, 2013) task provided a secondary assessment of children's attention abilities. The task was administered exactly as described by the *Leiter-3* during both the pre- and post-activity assessments. The Attention Divided task requires participants to attend to multiple tasks at the same time. Specifically, the children were asked to sort colored manipulatives (red and yellow foam circles) into their corresponding red or yellow buckets while simultaneously watching a set of cards being flipped over by the experimenter. The cards were flipped at the rate of one card per second and the participant was asked to sort the colored foam circles as quickly as they could. When a card containing a red triangle was flipped, they were required to hit the pile of cards, while continuing to sort the colored manipulatives. The task was completed once the final card was flipped over. All of the correctly sorted foam circles and correctly slapped red triangles were counted toward the number of correct items; the number of non-sorted foam circles and incorrect or missed card slaps were counted as errors.

Attention Divided analysis. Differences pre- to post-activity in the number of correct and incorrect items from the attention divided task were analyzed using a 2-between (Group: Sensory, Control) x 2-within (Phase: Pre-Activity, Post-Activity) x 2-within (Measure: Correct, Incorrect) repeated-measures ANOVA analysis.

Table 3

Behavioral Tasks, What was Assessed, and to What Participants They are Administered

Task	**Behavioral Assessment**	**Adults**	**Children**

Brief Mood Introspection Scale	Mood	X	
Feelings Chart	Mood		X
Nonword Repetition	Working Memory	X	X
Decision Speed	Processing Speed	X	
Pair Cancellation	Attention	X	
Attention Divided	Attention		X
Attention Sustained	Attention	X	X

Chapter Six: Adult Participant Results

Mean Amplitude Results

Only significant results are reported in this section. Figure 1 shows adult SG and CG grand average ERP responses from electrode FCz for the three syllables at pre- and post-activity. Appendix D contains all the adult ERP figures.

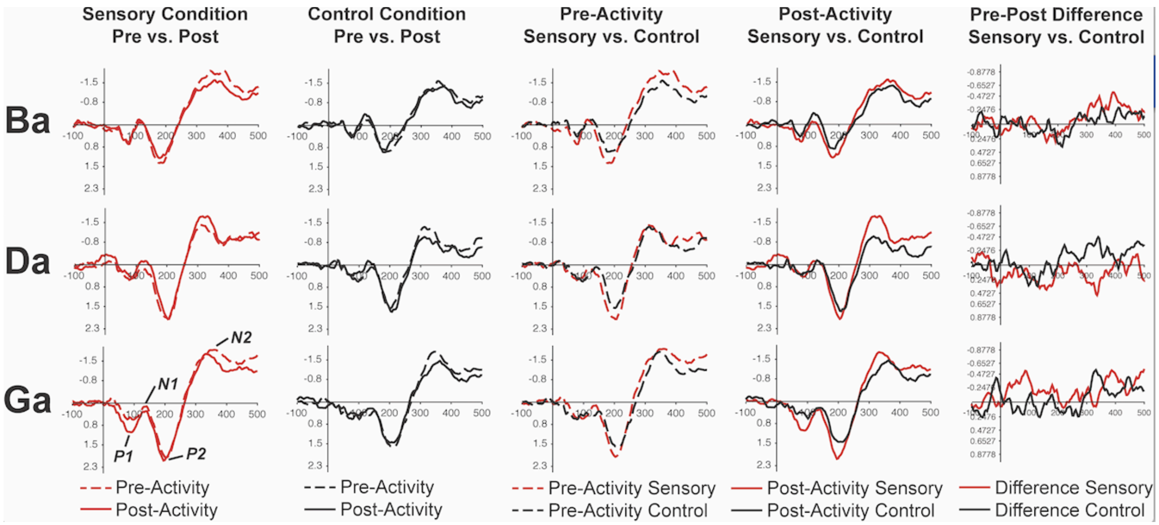

Figure 1. FCz amplitudes of /gɑ/, /bɑ/, and /dɑ/ comparing SG and CG at pre- to post-activity

P1. A significant effect of sound type was found ($F(2,60) = 18.382$, $p < .0001$, $\eta^2 = .380$). Post-hoc pairwise comparisons revealed that /bɑ/ elicited a smaller P1 response than /dɑ/ ($p < .02$) and /gɑ/ ($p < .0001$); /dɑ/ also elicited a smaller P1 response than /gɑ/ ($p < .05$). Thus, /gɑ/ elicited the largest P1 responses across conditions and time points.

A significant group x activity time point interaction was observed ($F(1,30) = 4.469$, $p < .05$, $\eta^2 = .130$). Post-hoc ANOVAs showed that while the SG P1 mean amplitudes did not change from pre- to post-activity, the CG's P1 mean amplitudes tended to be smaller post-activity ($F(1,15) = 3.582$, $p < .08$, $\eta^2 = .193$). Thus, this interaction appeared to be driven by the decreased P1 mean amplitudes of the CG post-activity. Figure 2 shows the mean amplitudes between SG and CG from pre- to post-activity.

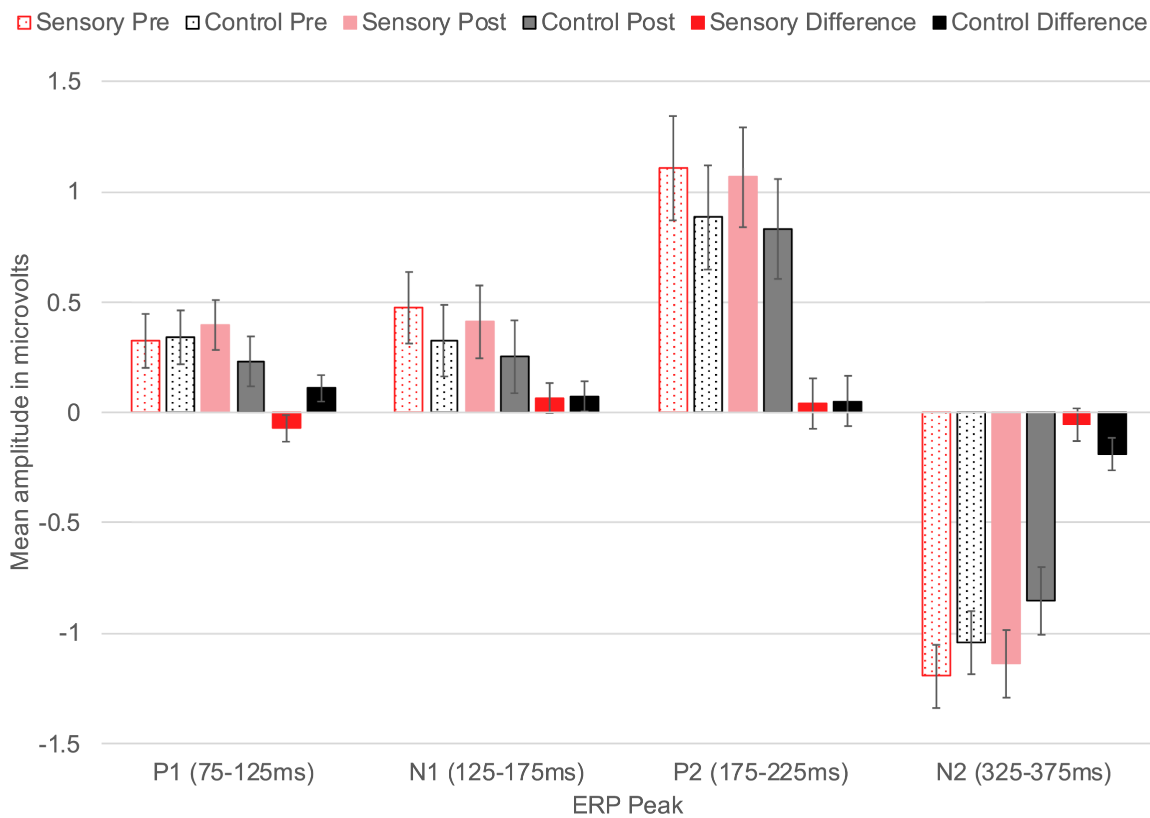

Figure 2. Mean amplitude waves between SG and CG from pre- to post-activity

P2. A significant effect of sound type was found ($F(2,60) = 38.291$, $p < .0001$, $\eta^2 = .561$). Post-hoc pairwise comparisons revealed that /bɑ/ elicited a smaller P2 response than /dɑ/ ($p < .0001$) and /gɑ/ ($p < .0001$).

N2. Post-activity N2 responses were significantly smaller than pre-activity responses across both groups ($F(1,30) = 5.470$, $p < .03$, $\eta^2 = .154$). A significant effect of sound type was found ($F(2,60) = 24.136$, $p < .0001$, $\eta^2 = .446$). Post-hoc pairwise comparisons revealed that /dɑ/ elicited a smaller N2 response than /bɑ/ ($p < .0001$) and /gɑ/ ($p < .0001$).

Pre-Post Activity Difference Waves

P1. When the difference waves were measured, group differences were identified in P1 peak ($F(1,30) = 4.469$, $p < .05$, $\eta^2 = .130$). This is consistent with the Group x Time interaction described above. This group effect was primarily driven by the decreased P1 amplitude in the CG during the post-activity measurement. No other significant effects were identified with the difference wave analysis, suggesting that the sound type syllable differences described above were driven by the baseline differences in activation levels. Figure 3 shows the P1 difference wave between groups, pre- to post-activity.

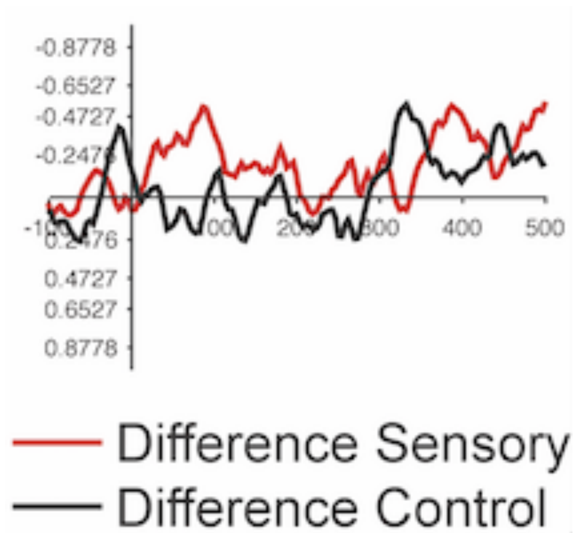

Figure 3. Adult difference waves between SG and CG pre- to post-activity

Pulse Rate

There were no significant differences pre- to post-activity or between the SG and CG found with pulse rate. Due to a delay in equipment ordering, pulse measurements were only completed for the last 14 adult participants (7 Sensory, 7 Control). Table 4 shows the mean and standard deviation of participant heart rate between the SG and CG pre-to post-activity.

Table 4

Heart Rate Mean and Standard Deviation of SG and CG Pre- to Post-Activity

	Condition	Mean Beats per Minute (BPM)	Standard Deviation
Pre-Activity	Control	74	7.071
	Sensory	73.71	6.945
Post-Activity	Control	74.71	7.588
	Sensory	72.14	7.313

Behavioral Tasks

Mood. The SG reported feeling significantly calmer ($F(1,30) = 5.400$, $p < .03$, $\eta^2 = .153$) and less nervous ($F(1,30) = 7.723$, $p < .01$, $\eta^2 = .205$) following the activity than the CG. See Table 5 below for the mean and standard deviation of each group pre- to post-activity. These differences suggest that wearing weighted objects improve anxiety related feelings.

Table 5

Mood Mean and Standard Deviation of SG and CG Pre- to Post-Activity

	Condition	Mean Profile Rating	Standard Deviation
Pre-Calm	Control	3.44	0.629
	Sensory	2.75	1.065
Post-Calm	Control	3.44	0.629
	Sensory	3.50	0.632
Pre-Nervous	Control	1.44	0.629
	Sensory	2.38	0.806
Post-Nervous	Control	1.50	0.632
	Sensory	1.75	0.775

Standardized tasks. No significant differences were found on any of the standardized behavioral tasks including: Nonword Repetition Task, Decision Speed, Pair Cancellation, and Attention Sustained. Table 6 shows the mean and standard deviation of each task between SG and CG pre- to post-activity.

Table 6

Standardized Tasks Mean and Standard Deviation of SG and CG Pre- to Post-Activity

	Condition	Mean Accuracy	Standard Deviation
Pre-Nonword Percentage	Control	92	5.86759
	Sensory	91	4.51980
Post-Nonword Percentage	Control	92.9333	4.78788
	Sensory	93.8	3.58967
Pre-Decision Speed Errors	Control	1.75	2.113
	Sensory	0.88	1.258
Post-Decision Speed Errors	Control	2.13	1.544
	Sensory	1	0.816
Pre-Pair Cancellation Errors	Control	1.5	1.155
	Sensory	2.31	2.152
Post-Pair Cancellation Errors	Control	1.44	1.315
	Sensory	2.06	1.879
Pre-Attention Sustained Raw Score	Control	17.13	3.03
	Sensory	19.63	3.423
Post-Attention Sustained Raw Score	Control	19.06	3.108
	Sensory	22.31	3.381

Correlations

Correlation analyses were completed by calculating the pre- to post-activity change in behavioral measurements and ERP mean amplitudes. A correlation between the change in the PPC accuracy of 4-syllable nonwords and /ga/ P1 amplitude was observed ($r(29) = -.429$, $p < .03$, $R^2 = .184$). Adults who demonstrated larger gains in P1 amplitude also tended to have improved PPC scores on the 4-syllable nonwords. No other ERP-behavior correlations were significant. Figure 4 shows the correlation between the nonword repetition task and the P1 amplitude.

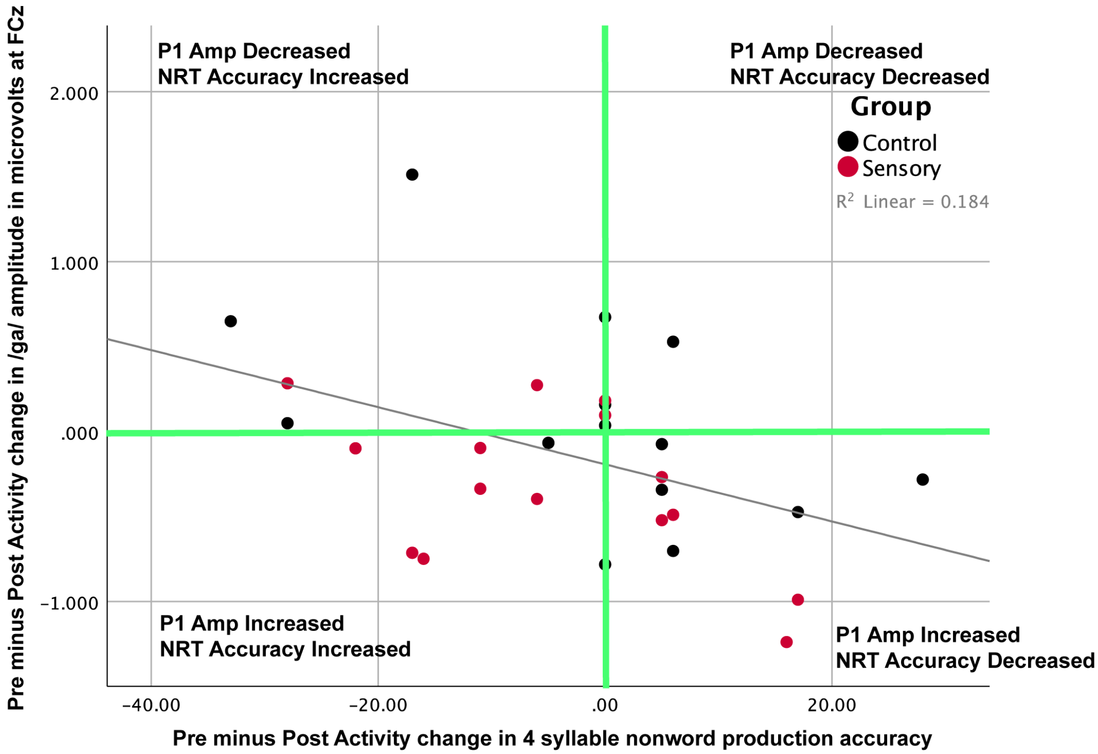

Figure 4. Relationship between NRT accuracy and P1 amplitude

Chapter Seven: Child Participant Results

Electrophysiological Measures

No significant ERP effects were found. Figure 5 shows child SG and CG grand average ERP responses from electrode FCz for the three syllables at pre- and post-activity. Appendix E contains all the child ERP figures.

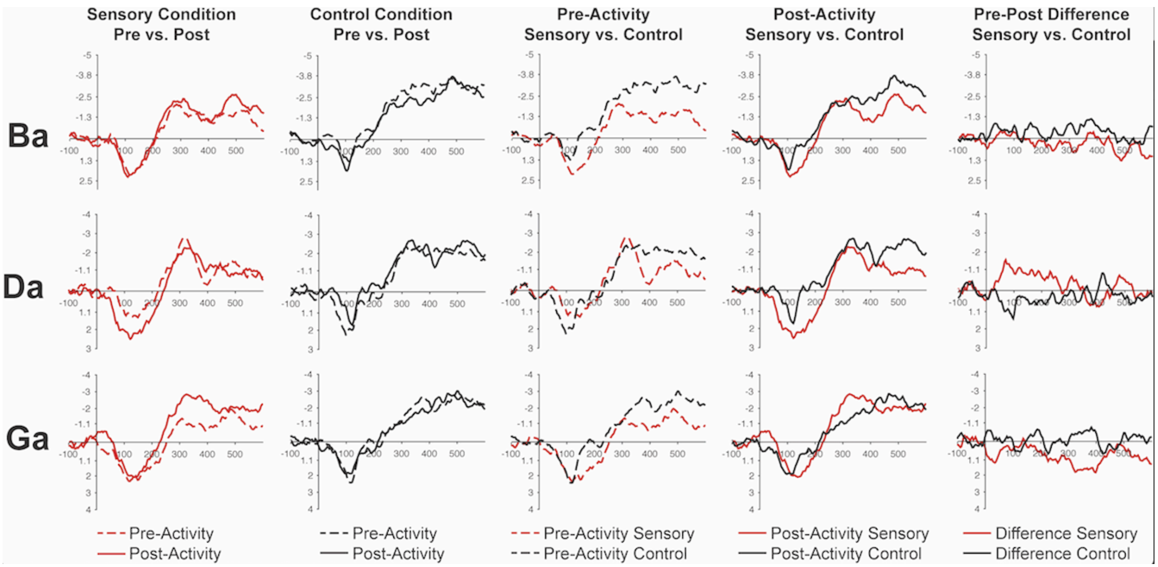

Figure 5. FCz amplitudes of /gɑ/, /bɑ/, and /dɑ/ comparing child SG and CG pre- and post-activity

Visual analysis of the ERP figures suggested that with more participants, significant differences between the sensory and CG could emerge. Specifically, the P1/P2 and N2 peaks in the CG decreased in amplitude post-activity while the SG P1/P2 and N2 peaks maintained or showed slight increases in amplitude post-activity. Figure 6 shows the difference wave between the SG and CG, which shows a similar pattern to the adult difference waves: CG demonstrated a decrease in P1 amplitude peaks post-activity. It is also showing a slight increase in the SG N2 peaks post-activity.

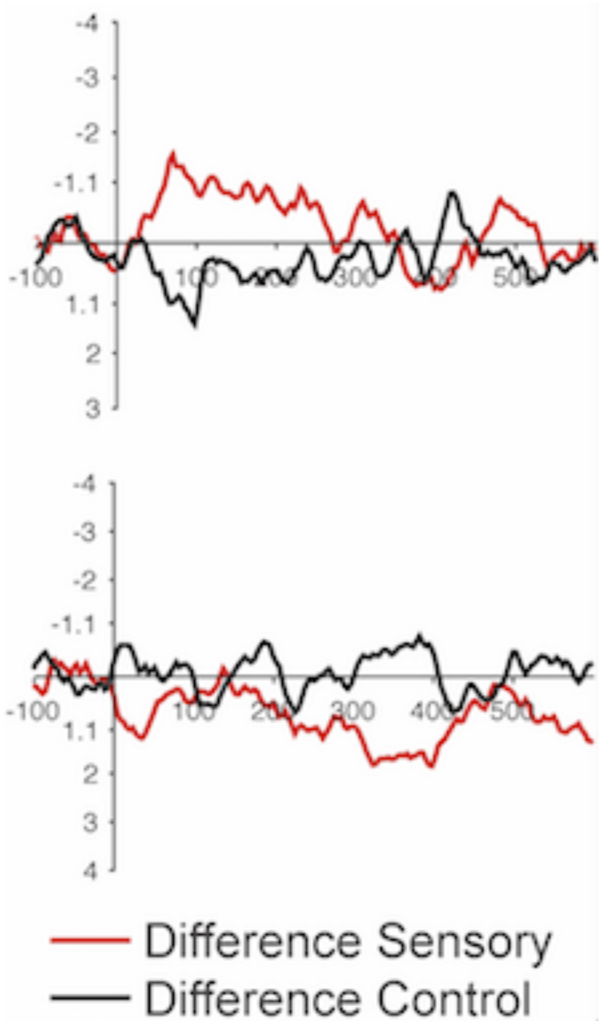

Figure 6. Child ERP difference waves between SG and CG from pre- to post-activity

Pulse Rate

There were no significant differences pre- to post-activity or between the SG and CG found with pulse rate. Table 7 shows the mean and standard deviation of participant heart rate between the SG and CG pre-to post-activity.

Table 7

Heart Rate Mean and Standard Deviation of SG and CG Pre- to Post-Activity

	Condition	Mean BPM	Standard Deviation
Pre-Activity	Control	81.4	13.240
	Sensory	87.2	6.834
Post-Activity	Control	81.8	2.168

	Sensory	87.6	5.857

Behavioral Data

No significant differences were found for any of the behavioral tasks including: Mood, Nonword Repetition Task, Attention Sustained, and Attention Divided. Table 8 shows the means and standard deviations for each behavioral task completed. All children were more accurate in their Attention Sustained responses post-activity, as compared to pre-activity ($F(1,8) = 7.624$, $p < .03$, $\eta^2 = .488$). No Group x Time interaction was observed. Thus, children became more skilled on the task with practice.

Table 8

Behavioral Tasks Mean and Standard Deviation of SG and CG Pre- to Post-Activity

	Condition	Mean Accuracy*	Standard Deviation
Pre-Mood Participant Rating	Control	2	0.000
	Sensory	1.4	0.548
Post-Mood Participant Rating	Control	2	0.000
	Sensory	1.8	0.447
Pre-Nonwords Percentage	Control	88.8	8.585
	Sensory	83.8	6.611
Post-Nonwords Percentage	Control	92.8	5.215
	Sensory	87	12.728
Pre-Attention Sustained Raw Score	Control	8.2	2.280
	Sensory	7.2	2.387
Post-Attention Sustained Raw Score	Control	9.6	2.074
	Sensory	9.4	3.209
Pre-Attention Divided Correct Standard Score	Control	99.4	9.711
	Sensory	97.4	5.857
Pre-Attention Divided Incorrect Standard Score	Control	93.4	15.241
	Sensory	91.6	9.990
Post-Attention Divided Correct	Control	102.6	7.197
	Sensory	93.4	13.126

Standard Score			
Post-Attention Divided Incorrect Standard Score	Control	98.4	10.922
	Sensory	86.6	15.789
*Mood mean and standard deviation is participant rating, not accuracy.			

Chapter Eight: Discussion and Limitations

This study examined behavioral, physiological, and neurophysiological changes that occurred in conjunction with a weighted proprioceptive activity. Adult ERP findings were the most significant results in the study. The CG showed decreased P1 peak amplitudes post-activity compared to the SG who maintained P1 peak amplitudes. The SG reported feeling calmer and less nervous significantly more than the CG that reported minimal-to-no change in mood post-activity. A brain-behavior correlation was also observed, as adults who demonstrated improved accuracy on the four-syllable nonword repetition task post-activity also had increased P1 peak amplitudes. No significant results were found with the child group; however, upon visual analysis of child ERP figures, similar trends to adult ERP findings were noted.

ERP

The consistency across the P1 peak amplitude seen in the SG who wore weights likely indicates maintained attention throughout the study as compared to the CG who did not wear weights and demonstrated a decreased P1 amplitude. The P1 peak is associated with the amount of attention an individual allocates to stimulus processing, with larger P1 responses associated with greater attentional focus (Luck, 1995; Woodman, 2010). Thus, the decreased P1 suggests that the CG was unable to maintain attentional control throughout the course of the study.

Sound-level differences were observed: /gɑ/ elicited the largest response from the P1 peak, /bɑ/ elicited the smallest response from the P2 peak, and /dɑ/ elicited the smallest response from the N2 peak. These effects were not maintained when the difference wave analyses were run. Therefore, it is likely that these sound differences were driven by participants' baseline activation level differences.

N2 responses were significantly smaller post-activity across both groups. The N2 peak is responsible for sound detection and integration (Čeponienė et al., 2008). As the N2 provides insight into participants' detection of, and response to auditory information, the decreased N2 amplitude could indicate habituation to the syllables presented. That is, general habituation of the task resulted in smaller N2 responses, indicating the recruitment of less neural activity during the integration period of speech perception.

Child participants followed a pattern similar to that of the adult participants. Upon visual analysis of the ERP figures, participants in the SG maintained and/or increased P1 and N2 amplitudes post-activity, while the CG P1 and N2 responses decreased in amplitude post-activity. This suggests that with an increased number of participants, there might be significant results similar to those of the adult group. These similar trends in children indicate that wearing weighted objects can have similar effects on attention in typically developing children.

Pulse Rate

Pulse rate did not show significant differences for both the adult and child groups. It is important note that due to a delay in equipment ordering, pulse measurements were only taken in seven adult participants in each group. The small group numbers could have affected the group-level variations in SG and CG. Moreover, deep pressure has been found to lower heart rate variability (Chen et al., 2016). The lack in pulse rate differences between groups could be due to the type of deep pressure used in this study compared to previous studies. Another variable to consider is that the pulse rate monitor may not have been medical quality, thus it might not have been sensitive enough to detect subtle pulse changes. As pulse rate might not have been a sensitive enough measure to capture physiological changes, an alternative response to document could be variations in blood pressure.

Mood

Improved mood reported by the SG adults, feeling calmer and less nervous, was likely due to the impact that weights have on anxiety (Chen et al., 2016; Mullen et al., 2008). The improved mood reported by the SG could be due to the effect weights have on the proprioceptive system by increasing body awareness and decreasing anxiety. Thus, a weighted activity has the potential to improve mood in adults. While no significant results were found in the child group, the measure used to assess mood was different than the measure used for adults. Due to the surface-level measurement of emotion in the feelings chart compared to the adult, which is more an in-depth analysis, the measurement might not be specific enough to capture the differences in mood change pre- to post-activity.

Standardized Tasks

Standardized behavioral tasks did not elicit significant differences for both the adult and child groups. A larger sample might be required to result in any significant differences when using behavioral tasks like the ones used in this study. Interestingly, the behavioral tasks that measured attention did not yield significant results, while the ERP peak that measures attention did yield significant results. Significant differences on the standardized tasks might not have been seen due to the lack in temporal resolution of the measurements, while ERP measurements have high temporal resolution. Thus, the standardized measures were not sensitive enough to result in significant change.

Another factor to consider with regards to the lack of outcomes throughout most of the tasks is that the SG adult participants identified as the low registration sensory profile significantly more than participants in the CG. Sensory processing differences might have been interacting with condition effects. Future directions could include providing participants with a sensory profile to fill out and return prior to participating in the study. If participants' sensory profiles are known beforehand, they could be more evenly distributed between SG and CG. Comparing sensory profiles between group outcomes might provide insight into the impact sensory preferences have on performance. For example, it is predicted that participants who fit the sensory avoiding and sensory seeking profiles would perform better after wearing the weighted materials. Therefore, distributing people with these sensory profiles evenly between the groups would ensure that neither group was skewed in their electrophysiological or behavioral responses.

Overall, ERP results from the adult group were the most significant findings in this study. Similar neural trends were observed in both child and adult data, though P1 amplitude changes were only observed in the adults. Anxiety-related moods in adults significantly improved with weight-wearing. Future studies should include larger participant groups and consider sensory preferences a priori.

Limitations

It is important to consider current limitations of this study and point to future directions. This study required a large time commitment from each participant, which made recruitment for children participants challenging. It also required coordination of multiple schedules, which resulted in increased difficulty scheduling appropriate times. It is important to consider that the study was designed to be completed in one session so that children would not be required to return for a second testing visit, which improved scheduling; however, reducing the number or types of tasks in order to decrease the total experiment time might be an important consideration for future extensions of this work.

Mood ratings across the child and adult studies were not consistent, as the Feelings Chart was used for the child group while the Emotion Questionnaire was used with the adult group. Different mood ratings were used for the child group because the Emotion Questionnaire involved rating moods on a continuum, which might have been difficult for younger children to complete without prompting. The adult questionnaire was extensive and assessed a range of different emotions, while the Feelings Chart only had the child select the mood they were feeling best represented by a cartoon face. This way of assessing the child's mood may not have accurately identified the current feelings the way the questionnaire did for the adult group. Thus, there was a significant increase in mood for adults, while there was virtually no change for children. A more sensitive measure may be necessary to more accurately determine changes in child participant's mood.

This study contributes to the existing literature on sensory-based activities and also extends the research. Previous studies have examined the use of weighted objects on children with ADHD and their improvement on in-seat and on-task behaviors. This study extends the possibility of using weighted materials by using cognitive processes that would likely be important to speech and language therapy. Sensory-based activities can be an effective therapy tool for both occupational therapists and speech-language pathologists due to the positive outcomes they have on attention and mood.

Chapter Nine: Clinical Relevance

Sensory processing is important for taking in information from the environment and organizing and responding to that information appropriately. Previous research has shown that weighted materials positively impact attention and in-seat behaviors (Buckle et al., 2011; Hung-Yu et al., 2014) and reduce anxiety (Chen et al., 2016). The results of the current study are consistent with these previous findings as neural indices of maintained attention and improved participant-reported anxiety-related feelings were observed. Using weighted objects can affect change among attention and mood, which can be beneficial to the field of speech-language pathology by utilizing weighted objects to employ these changes during therapy.

Based on the current results of this study, the use of weighted objects might be advantageous in the clinical setting for the development of effective treatment plans based on the client's individual needs and sensory profile. By considering the client's sensory preferences, appropriate sensory-based activities can be utilized to improve the client's performance during therapy. With activities that facilitate sensory processing for the client, progress in therapy will likely improve because the child can maintain attention to the tasks, which will promote a deeper, quicker understanding of the material.

Weighted materials can be easily implemented as a noninvasive tool to help keep clients in their seat and on-task during speech activities (Buckle et al., 2011; Hung-Yu et al., 2014), as well as maintain attention to specific tasks. It is beneficial for clients to remain on-task because therapy time is limited. In order to make efficient gains towards the client's goals, therapy time is better spent on productive speech and language activities rather than behavior management. The use of weighted objects might increase productivity and reduce the amount of time spent on behavior management during a session. Increased productivity during a session will likely occur because of the impacts weighted materials have shown to have on attention and anxiety.

The present study combines positive outcomes previously found on in-seat and on-task behaviors with practical implications to speech-language pathology by incorporating cognitive processes important to speech and language treatment, such as speech perception. Based on the findings of this study, weighted objects show maintained attention and improved mood in adult participants, with child participants demonstrating similar trends. Weighted shoulder wraps and lap pads can facilitate attention and mood changes that can benefit treatment outcomes in speech-language pathology.

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Appendix A
Split Nonword Repetition Task Part A and B Respectively

Dollaghan & Campbell (1998) Nonwords	
naɪb	
taʊdʒ	
teɪvak	
vætʃaɪp	
tʃinɔɪtaʊb	
dɔɪtaʊvæb	
veɪtatʃaɪdɔɪp	
naɪtʃɔɪtaʊvub	
voʊp	
dɔɪf	
tʃoʊvæg	
nɔɪtaʊf	
naɪtʃoʊveɪb	
teɪvɔɪtʃaɪg	
dævoʊnɔɪtʃig	
tævatʃinaɪg	

Appendix B
Brief Mood Introspection Scale Given to Adult Participants

Brief Mood Introspection Scale (BMIS)
by John D. Mayer

INSTRUCTIONS: Circle the response on the scale below that indicates how well each adjective or phrase describes your present mood.

(definitely do not feel) (do not feel) (slightly feel) (definitely feel)

XX X V VV

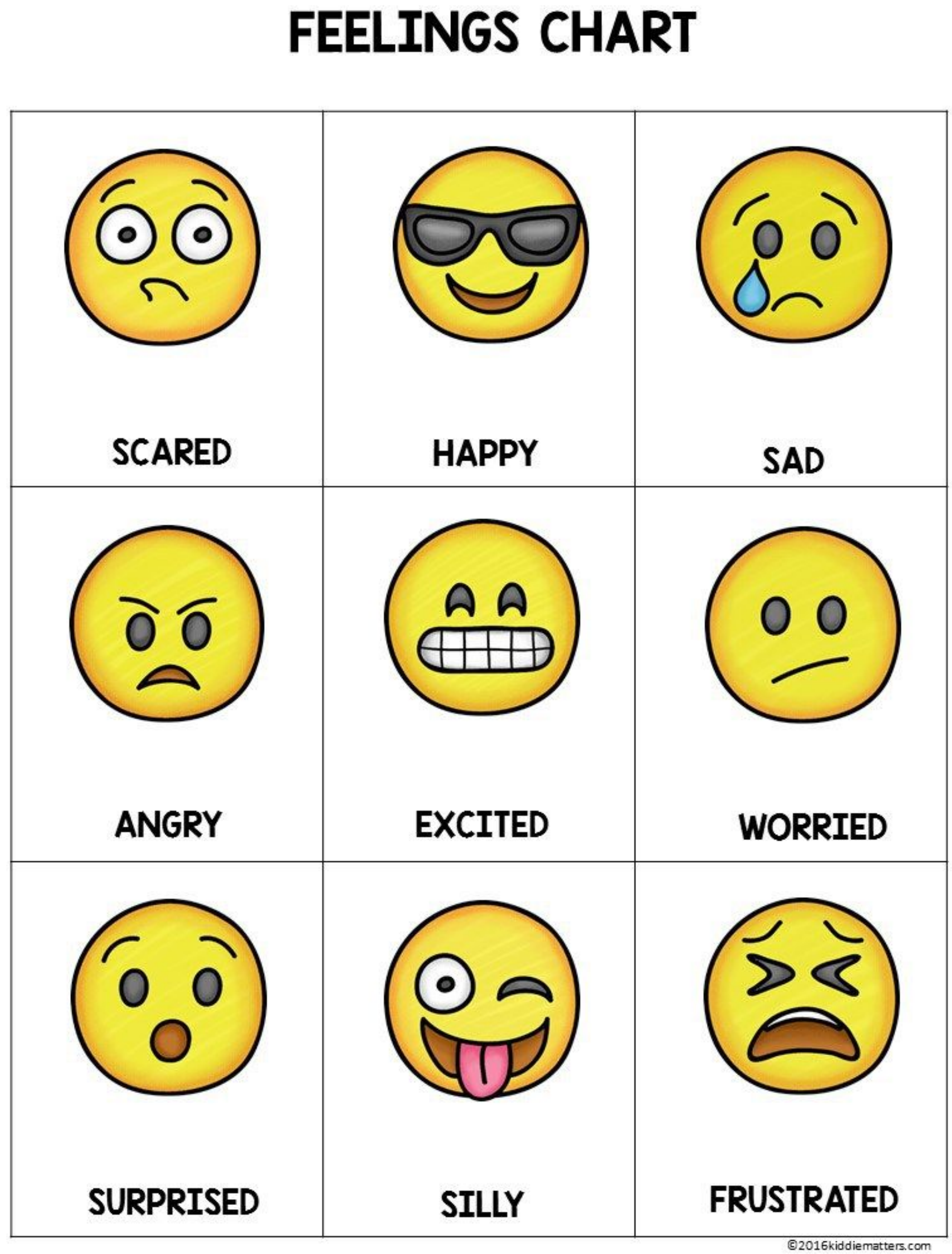
Lively	XX X V VV	Drowsy	XX X V VV
Happy	XX X V VV	Grouchy	XX X V VV
Sad	XX X V VV	Peppy	XX X V VV
Tired	XX X V VV	Nervous	XX X V VV
Caring	XX X V VV	Calm	XX X V VV
Content	XX X V VV	Loving	XX X V VV
Gloomy	XX X V VV	Fed up	XX X V VV
Jittery	XX X V VV	Active	XX X V VV

Overall, my mood is:

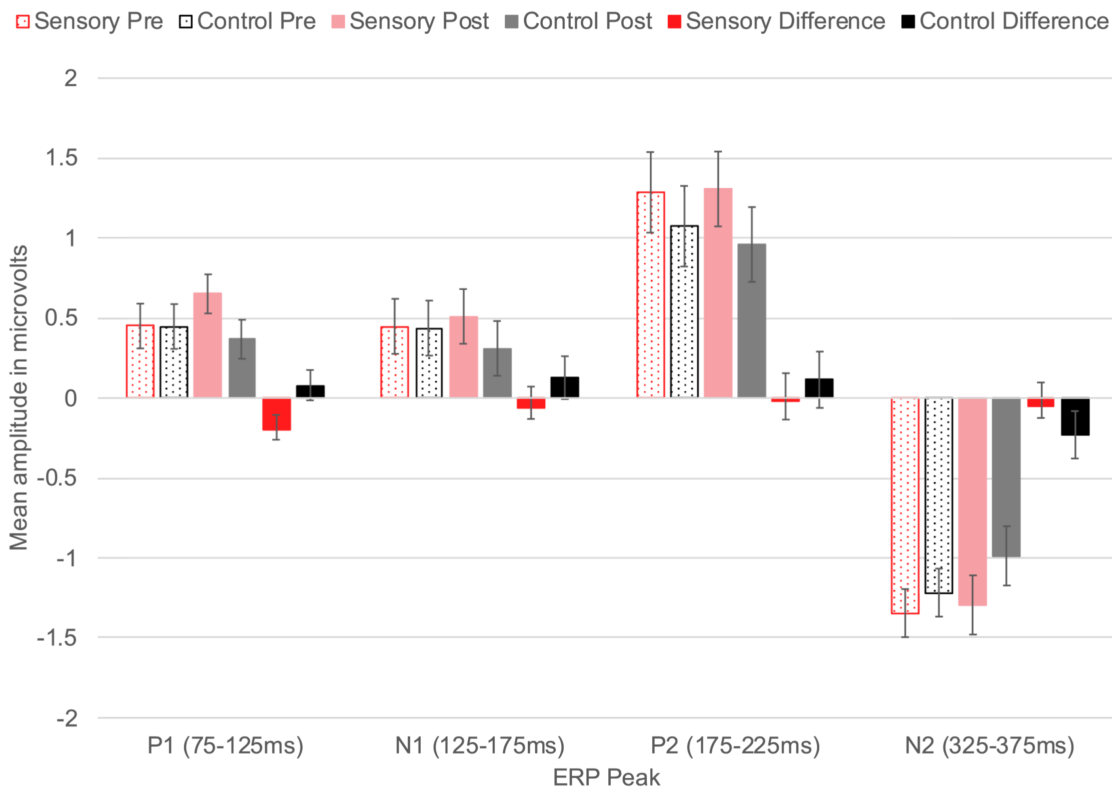
Very Unpleasant — Very Pleasant

-10 –9 –8 –7 –6 –5 –4 –3 –2 –1 0 1 2 3 4 5 6 7 8 9 10

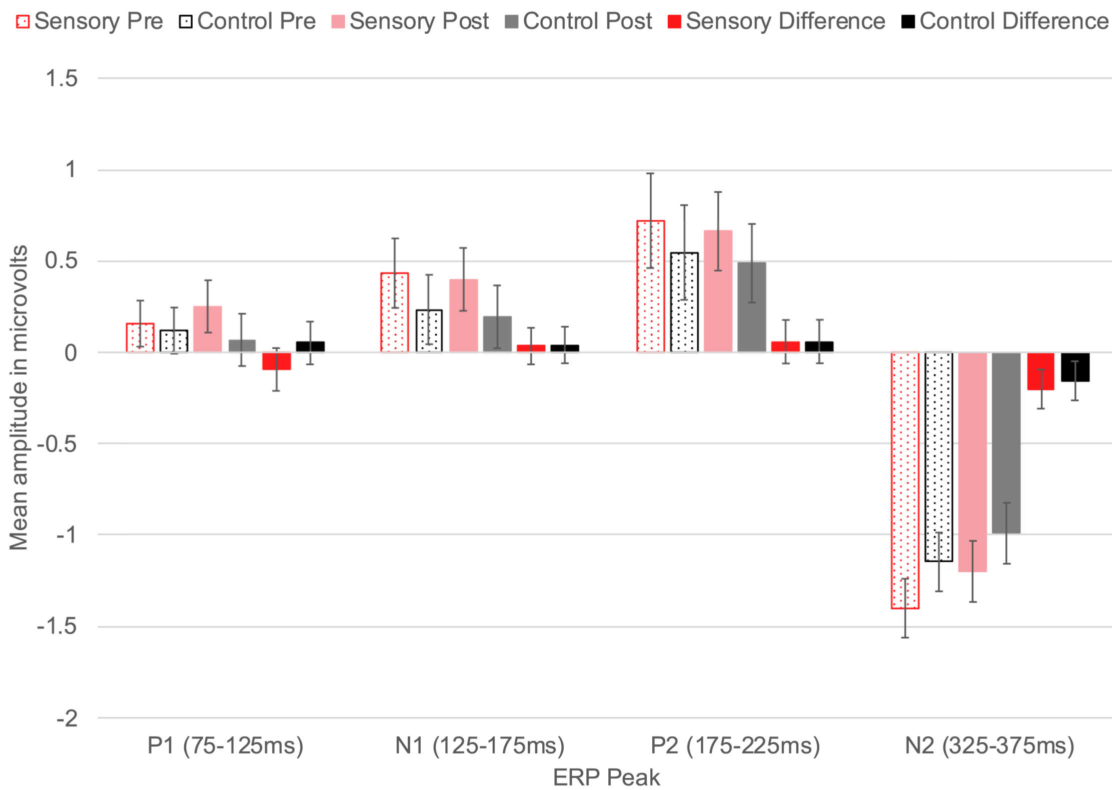
Appendix C
Feelings Chart Given to Child Participants



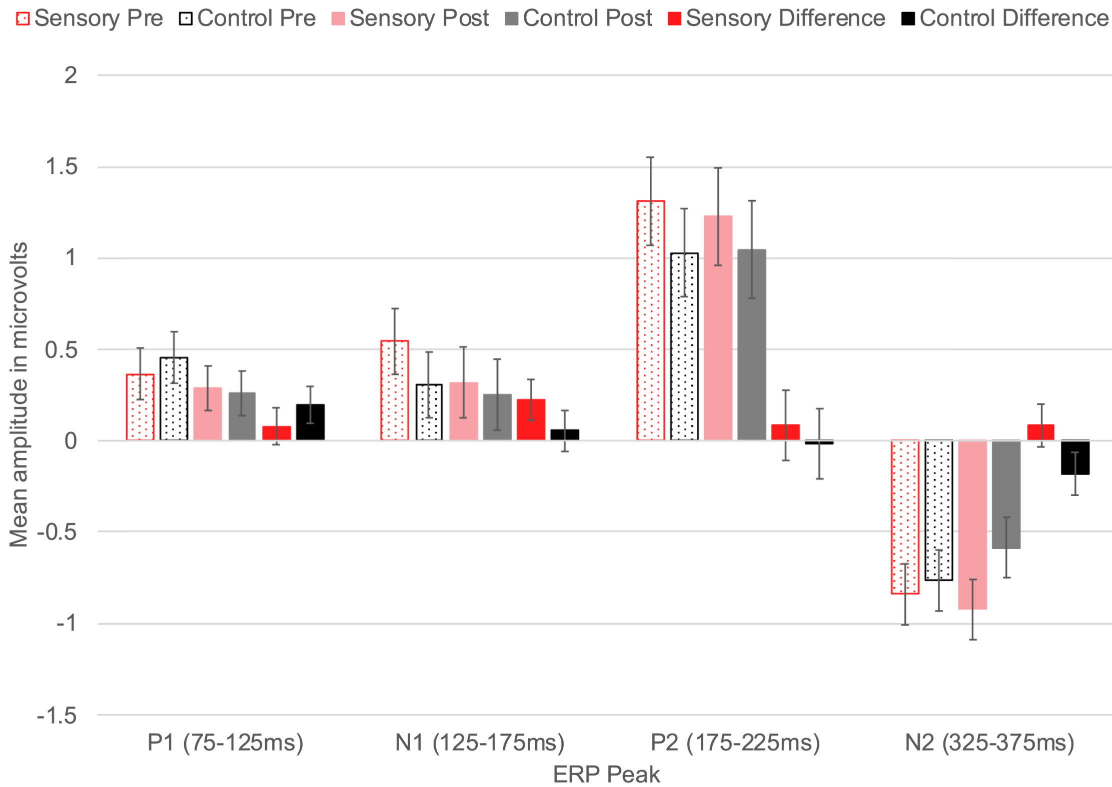
Appendix D
Adult ERP Figures and Peak Mean Amplitudes



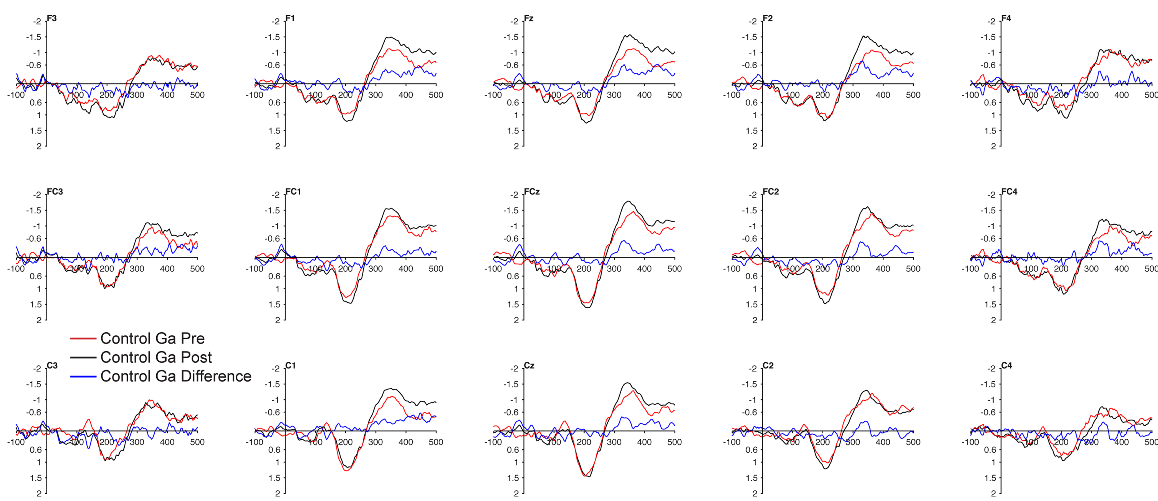
D1: Peak Mean Amplitudes for /gɑ/



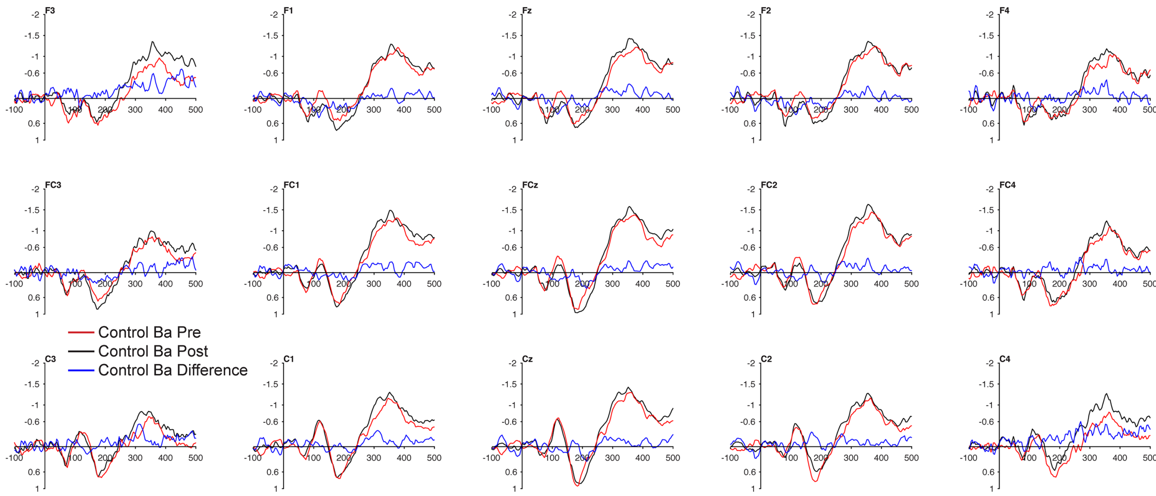
D2: Peak Mean Amplitudes for /bɑ/



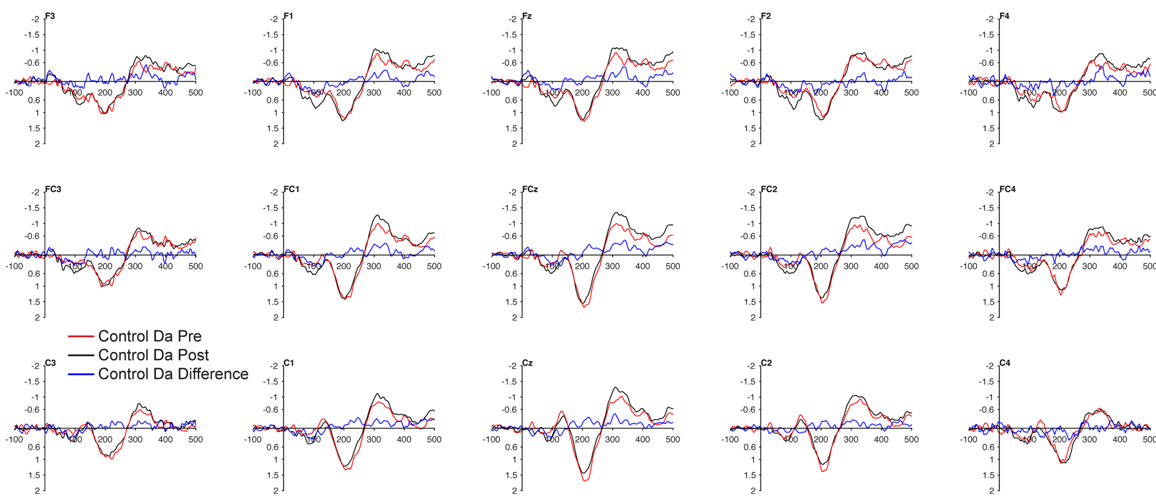
D3: Peak Mean Amplitude for /dɑ/



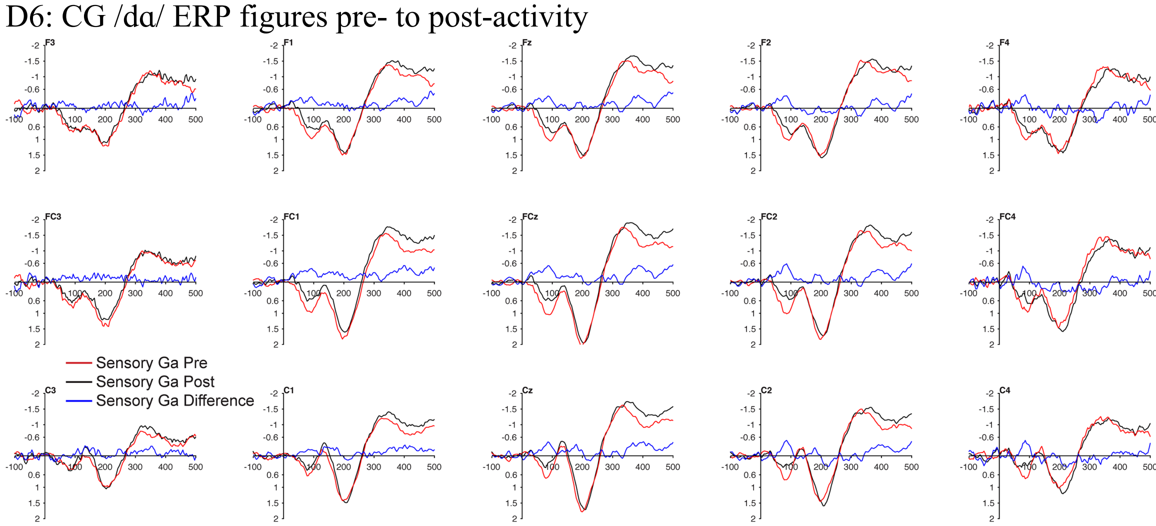
D4: CG /gɑ/ ERP figures pre- to post-activity



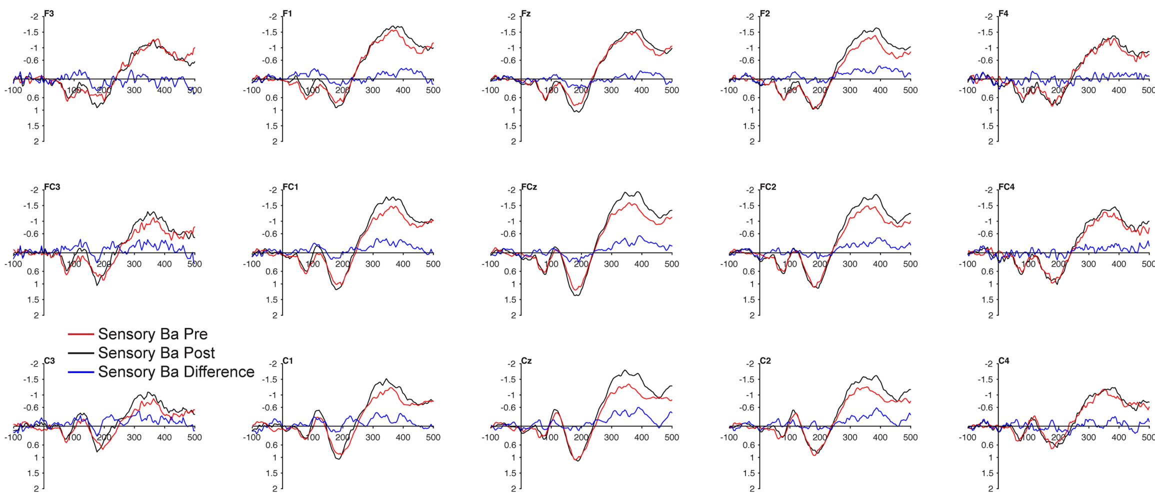
D5: CG /bɑ/ ERP figures pre- to post-activity



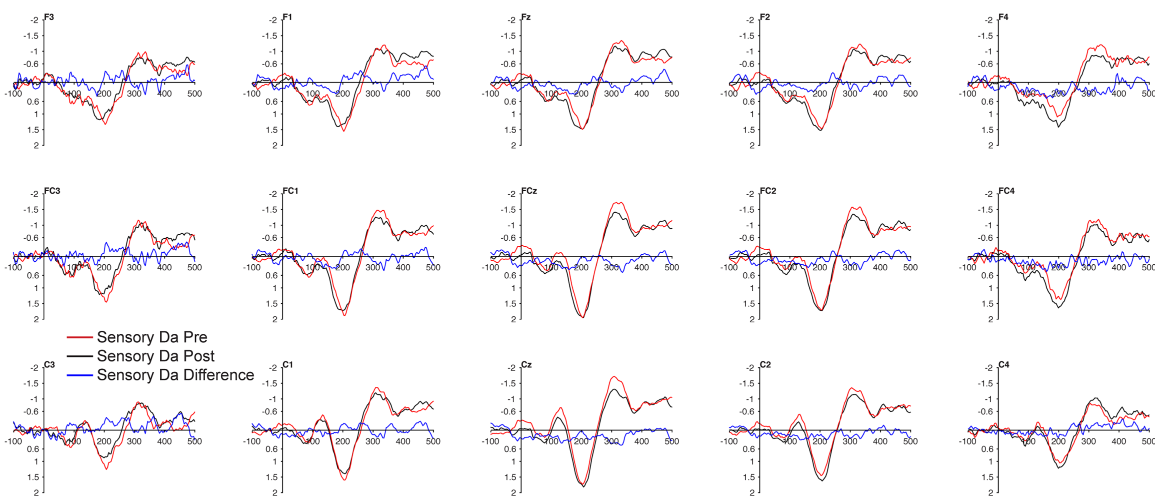
D6: CG /dɑ/ ERP figures pre- to post-activity



D7: SG /gɑ/ ERP figures pre- to post-activity

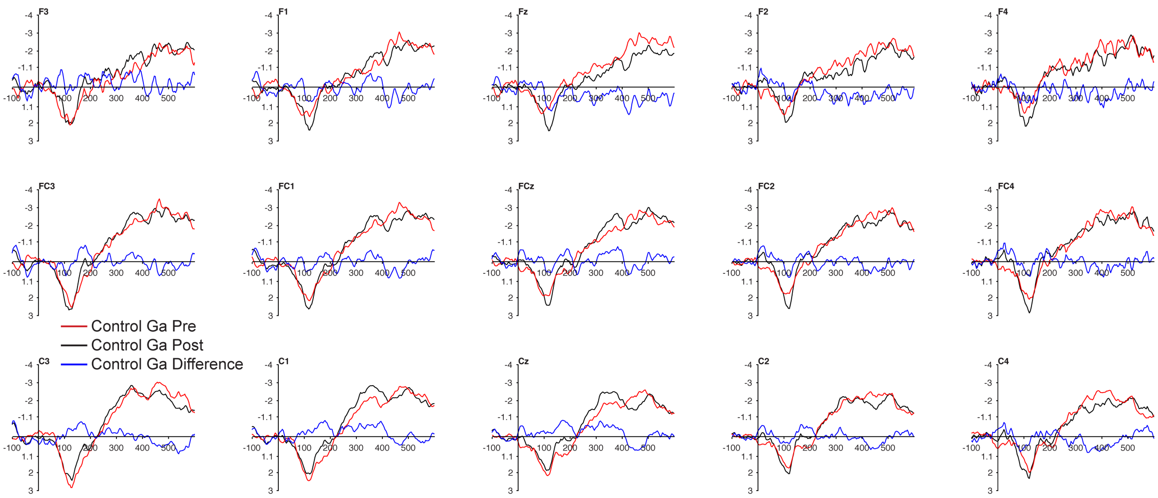


D8: SG /bɑ/ ERP figures pre- to post-activity

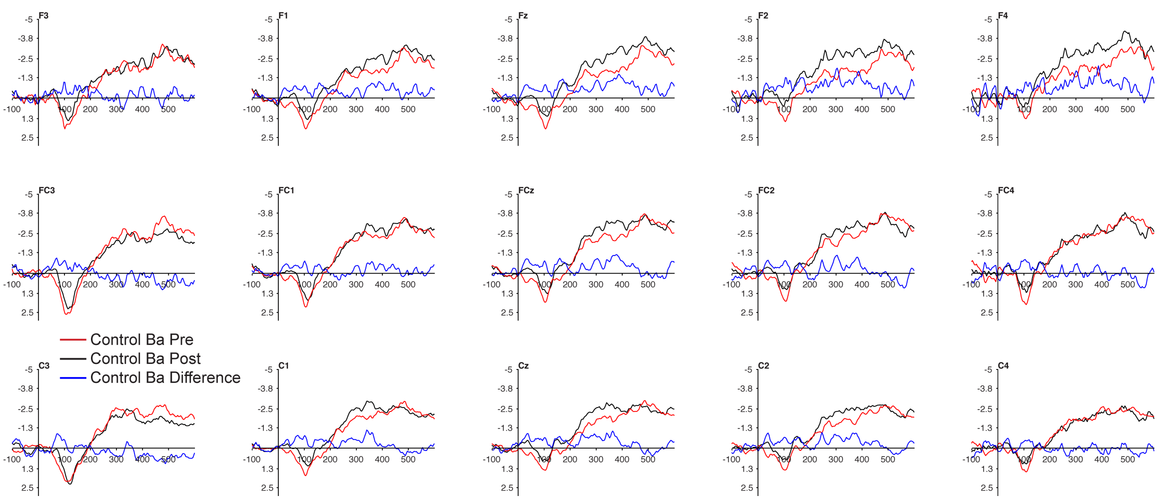


D9: SG /dɑ/ ERP figures pre- to post-activity

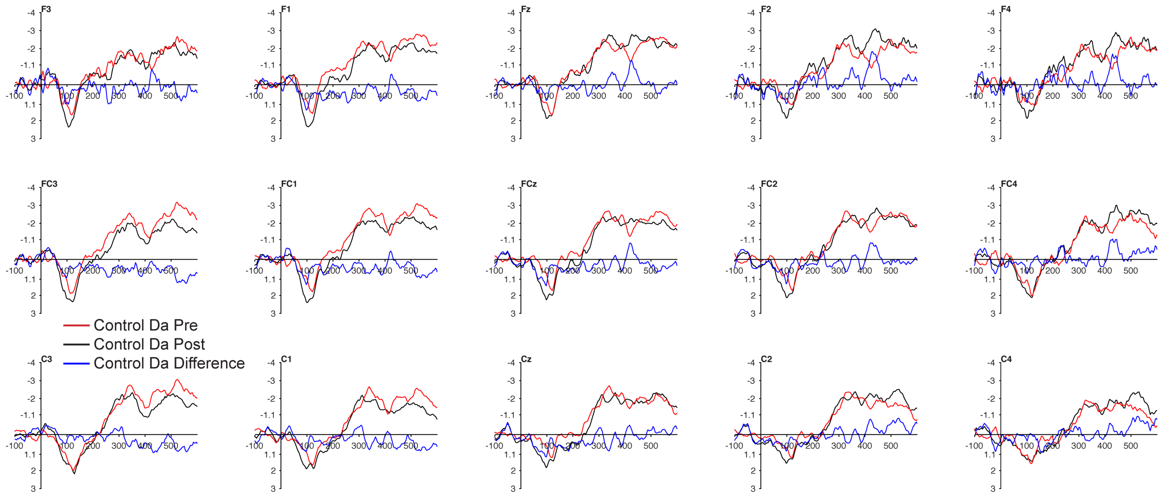
Appendix E
Child ERP Figures



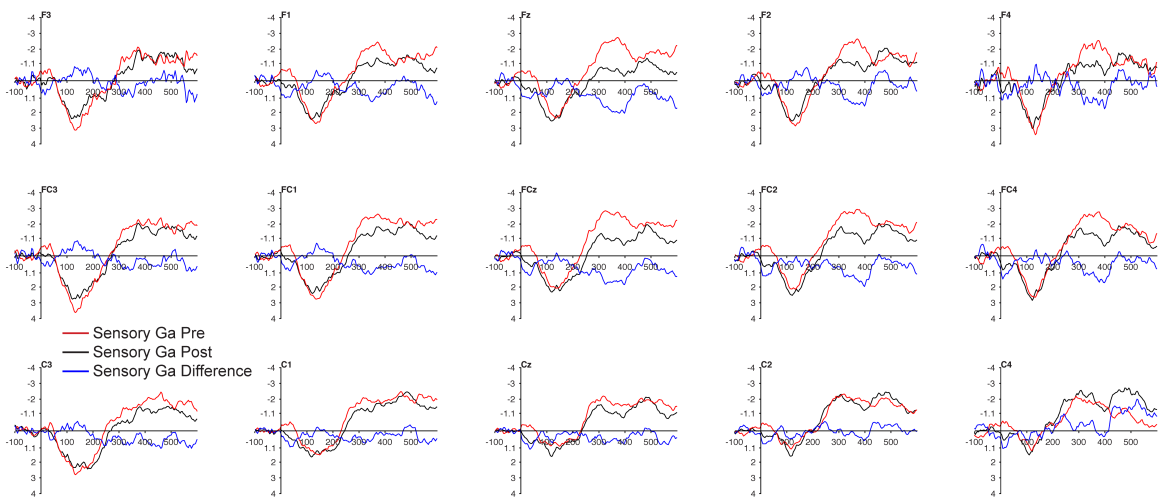
E1: CG /gɑ/ ERP figures pre- to post-activity



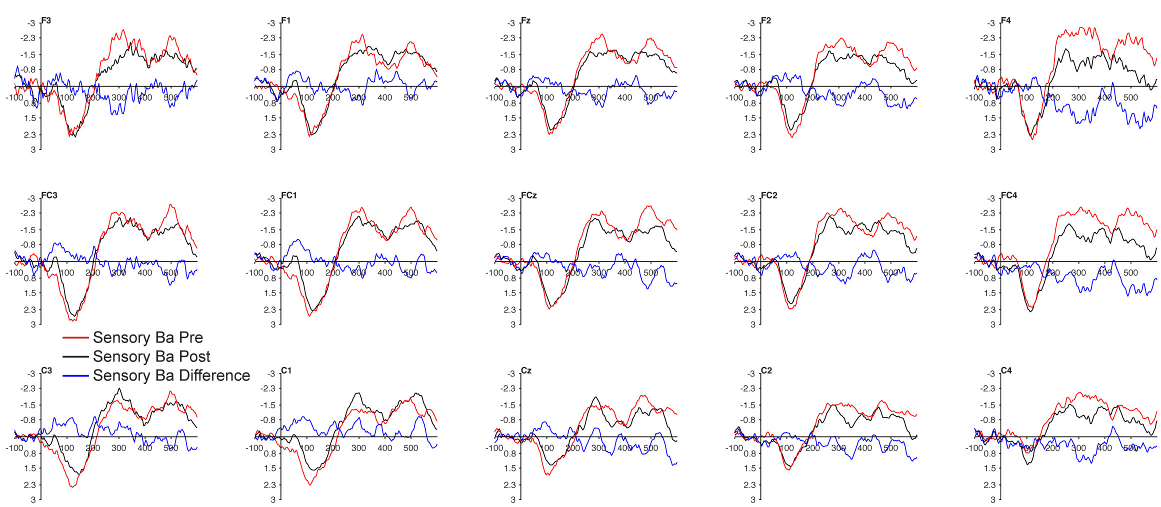
E2: CG /bɑ/ ERP figures pre- to post-activity



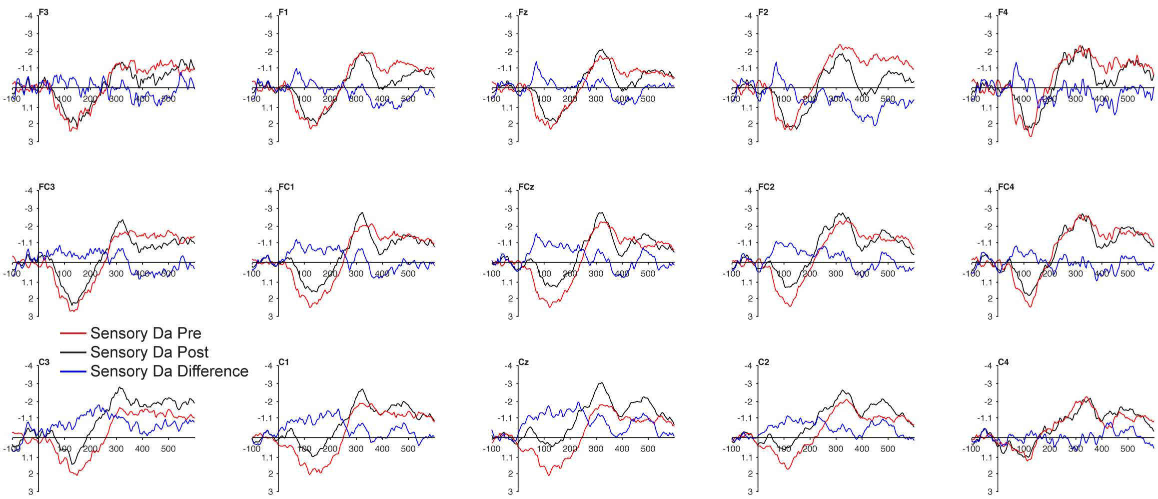
E3: CG /dɑ/ ERP figures pre- to post-activity



E4: SG /gɑ/ ERP figures pre- to post-activity



E5: SG /bɑ/ ERP figures pre- to post-activity



E6: SG /dɑ/ ERP figures pre- to post-activity