The Thesis Committee for Celina Marie Cerf
Certifies that this is the approved version of the following thesis:

Using Rhythm to Teach Spelling to a Child with Autism

APPROVED BY
SUPERVISING COMMITTEE:

Supervisor:

Li Sheng

Jessica Franco, Co-Supervisor

Using Rhythm to Teach Spelling to a Child with Autism

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Celina Marie Cerf, B. Health Sci.

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Abstract

Using Rhythm to Teach Spelling to a Child with Autism

Celina Marie Cerf, M.A.

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Supervisor: Li Sheng

Co-Supervisor: Jessica Franco

The purpose of this study was to develop a multimodal spelling acquisition program (MSAP) for children with autism that capitalizes on sensory perception skills that may be intact with this population to teach early spelling skills. Progress was monitored through seven phases: pre-assessment, baseline probe, acquisition probe, instruction sessions, post-assessment, and maintenance probes of the treatment. MSAP provides for three spelling instructional conditions: (1) instruction with rhythmic auditory feedback in the form of Morse Code presented via speakers at 450 Hz, (2) instruction with rhythmic tactile feedback of Morse Code presented via a bone oscillator, and (3) instruction without feedback. The MSAP program recorded the child's performance for spelling accuracy and rate for each word during the assessment probes. Although the child acquired spelling knowledge of the target words, the statistical analysis revealed no significant difference in the spelling acquisition between the instruction conditions. The computerized instruction did generalize to untaught words. This study's limitations and future directions are discussed.

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INTRODUCTION

The purpose of this study was to develop a computerized spelling program for children with autism, called MSAP, that capitalizes on musical and speech perception skills that maybe intact in children with autism or other developmental disorders to strengthen the attention and encoding skills for spelling tasks (Lai et al., 2012, Lim, 2009). This spelling program investigated the use of the rhythmic quality of Morse code presented via auditory and tactile modalities to teach twelve three-letter words. The fundamental hypothesis underlying this program is that a multi-sensory method of instruction, utilizing rhythm as additional external stimuli, will more effectively facilitate spelling acquisition for individuals learning to spell than the conventional spelling sensory stimuli involving visual presentation of graphemes.

Individuals with autism can face difficulty when perceiving speech, as a result of impaired pitch and temporal pattern processing (Ceponiene et al, 2002; Dellatolas, 2009; Eikeseth & Hayward, 2009; Stevenson et al, 2014; Russo et al., 2008). For example, an event-relate potential (ERP) study by Ceponiene et al. (2002), found that the complex tones that comprise vowels disengage children diagnosed with ASD resulting in poor processing of vowel speech sounds. On a more general processing level, Stevenson et al. (2014) found deficits in multisensory temporal speech processing abilities in high functioning school-age (6-18 years old) individuals on the autism spectrum. In general, nonverbal instrument sounds are easier to comprehend than verbal stimuli (Eikeseth & Hayward, 2009) and musical stimuli paired with speech may be more engaging than spoken stimuli for individuals on the autism spectrum (Simpson, Keen, & Lamb 2013). Thus, a single note or tactile rhythmic sequences pairing with graphemes maybe a more effective way of teaching grapheme sequences to children who have ASD. Therefore, the goal of this study was two fold: (1) to develop a multisensory computerized spelling program in which musical notes could be used to facilitate phonemic awareness and memory of the grapheme order in words the individual is learning to spell and (2) to test the efficacy of using rhythm to teach spelling to individuals with ASD.

MULTI-SENSORY TRAINING

Multisensory learning strategies utilize different types of sensory stimuli, such as visual and auditory stimuli, to naturally facilitate learning unisensory information and skills (Shams & Seitz, 2008). Multisensory learning strategies are believed to be more effective than the unisensory alternatives because the multimodal method of teaching engages the memory and attention of students (Kast et al, 2011). The ability to sustain and switch attention when interpreting new information is critical for learning (May, Rineheart, Wilding, and Cornish, 2013). Difficulties with "attention exacerbates an already compromised cognitive system" for individuals with autism (May, Rineheart, Wilding, and Cornish, 2013). Aberg, Kopp, Berg-Kelley, and Gilbert (2010) demonstrated the effects of poor attention skills on reading comprehension, word decoding, and spelling in eight to seventeen year old children on the autism spectrum and children in the same age range with attention deficit hyperactive disorder (ADHD). Music is one multisensory strategy that could function as an external stimulus that engages children in language learning activities. For example, Simpson, Keen, and Lamb (2013) addressed the inattention of children with autism to speech sounds by singing target words during receptive labeling tasks resulting in fewer challenging behaviors and more consistent engagement than the spoken word condition.

The conceptualization and development of MSAP, the multisensory computerized spelling intervention program, attempted to address the attention impairment often seen in individuals with on the autism spectrum by engaging children with autism in spelling tasks using multi sensory inputs. Studies have shown that while initial reaction times are slower when multisensory stimuli are used (Lehmann & Murray, 2005). Eventually, multisensory stimuli result in faster retrieval of information than unisensory (Lehmann & Murray, 2005, Shams & Seitz, 2008). Multisensory stimulation facilitates learning unisensory information particularly due to the additional sensory cues that aid in future information extraction (Shams & Seitz, 2008). When learning through multisensory training, a larger neural network is activated in response to the stimuli being taught. Effectively, the neurons that activate in response to a certain function or stimulus become regulated by neurons that correspond to another modality augmenting the neural resources used for a certain cognitive task (Shams & Seitz, 2008). Sound is a significant neuromodulating stimulus and the audio-visual training multisensory approach can be more effective at encoding new information than unisensory visual learning (Seitz, 2006). In addition to auditory multisensory learning, Labat et al. (2014) found support for the use of multisensory tactile tasks during phonological exercises more effectively engaged and taught typically developing children between five to six years old teaching the alphabetic principle. Schlosser and Blischak (2004) view multisensory training as essential for the generalization of spelling skills for individuals on the autism spectrum.

CONTROVERSY OVER MUSICAL TO FACILITATE LANGUAGE LEARNING

Recent studies by Fedorenko et al. (2012), Fedorenko, Behr, & Kanwisher (2011) and Rogalsky et al. (2011), have concluded that the neural networks used to process higher level linguistic and music are not correlated with each other. The contrast between this study and the studies of Fedorenko et al. (2012), Fedorenko et al. (2011) and Rogalsky et al. (2011) is that Fedorenko et al. (2012), Fedorenko et al. (2011) and (Rogalsky et al., 2011) were comparing intact and scrambled music processing skills to the ability to process semantic and syntactic associations between words in sentences, which is a higher level of linguistic processing than is required in the three letter spelling tasks used in this study. The spelling tasks in this study involve phonological and grapheme level processing versus process semantic information at the word level. The hypothesized shared neurological networking used for the lower-level acoustic processing of pitch and speech with regard to phonemes and prosody has yet to be disproven (Fedorenko et al., 2012).

SHARED NEURAL NETWORKS BETWEEN LANGUAGE AND MUSIC

Music was a chosen stimulus in this computerized spelling program, because music facilitates cognitive development for all individuals and a growing number of studies demonstrate that music and language share neural resources when processing music and language, despite their independent cortical regions for long-term knowledge storage (Koelsch et al, 2005; Fedorenko et al., 2009; Heaton et al, 2007; Patel et al., 1998; Schön et al., 2010; Wan, 2011). Evidence of neuroplasticity resulting from musical training is seen in subsequent improvement in skills such as memory and auditory functioning (Jäncke, 2009, François, Tillman & Schön, 2012). Enhancing auditory skills may improve speech processing and language comprehension (Jäncke, 2009).

Music and language may share neurological resources due to five main characteristics that they share in common: timber, tones (pitch), vocabulary (notes or words), hierarchical structure (harmony or syntax), and rhythm (Limb, 2006; Besson, Chobert & Marie, 2011; Tillmann, 2012). These similar characteristics may contribute to the bilateral neurological activity seen when processing different aspects of language and music. PET scans by Brown, Martinez, & Parsons (2006) illustrate that when the brain is focused on producing music and language bilateral neural networks are engaged. Specifically, the insula, middle temporal gyrus, superior temporal gyrus, the inferior frontal gyri, and the posterior cingulate affect each other when actively and passively processing speech and music (Schön et al., 2010). The hierarchal structure of music and language contribute to the similarities in processing grammatical information, which is believed to be one of the reasons why bilateral engagement of the inferior frontal cortex has been seen in addition to the superior temporal gyrus and the ventral premotor cortex (Koelsch et al., 2005; Koelsch, 2011).

Two of the most fundamental elements of music are pitch and rhythm (Krumhansl, 2000). Previous neurological studies have shown that pitch and rhythm processing are strongly related (Fedorenko et al. 2012; Jones & Boltz, 1989). Like music, speech has particular rhythm (Jones &Boltz, 1989). Music and speech also share pitch patterns used in music to create a melody and in speech for prosody (Lim, 2009). Vuust et al. (2011) found that the pars orbitalis of the IFG is bilaterally activated during rhythm processing while tapping to the rhythm of music. This illustrates that the left pars orbitalis, which is traditionally associated with higher-level linguistic processing, is involved in processing the differences in external stimuli including music, language, and other forms of communication (Vuust et al, 2011). Levitin & Menon (2003) found bilateral neural activity in the left inferior frontal gyrus (LIFG) and the right inferior frontal gyrus (RIFG) when subjects listened to intact musical stimuli that targeted low-level auditory processing skills, which include pitch, loudness, and timbre. A study by Wan et al. (2011) demonstrated that a bilateral white matter network engages between the frontal and temporal regions when processing intonation, which overlaps with pathways used to process language including the arcuate fasciculus (AF) and the uncinate fasciculus (UF). Using diffusion tensor imaging (DTI) and MRI data, Loui, Li and Schlaug (2010) confirmed that the right ventral AF activity is essential for pitch perception and discovered that this white matter pathway is also active while learning non-linguistic grammar, which maybe important for learning language. All together these studies present strong evidence for the *bilateral activation* of white and grey matter in the brain when processing elements of music and language.

The Shared Syntactic Integration Resource Hypothesis (SSIRH) supports the idea that music and language processing share neural resources (Patel, 2003; Koelsch et al., 2005; Levitin & Menon, 2003). The SSIRH infers that a non-domain-specific working memory system is responsible for the syntactic integration and sequencing and music-syntactic and linguistic-syntactic processing demonstrate significant collaboration (Koelsch et al, 2005; Fedorenko et al., 2009; Hoch, Poulin-Charronnat & Tillmann, 2011; Tillmann, 2012). The ERP results in the study by Koelsch et al. (2005) showed that interaction with left anterior negativity (LAN) activity occurs when a person is presented with a syntactically incorrect word and early right anterior negativity (ERAN) activity occurs when the person hears an unharmonious chord. The LAN and ERAN interaction study of Koelsch et al. (2005) provides support for an overlap in the neural resources used to process music and language syntax, because when someone hears an irregular chord while seeing a syntactically incorrect word the LAN amplitude reduces significantly.

Hoch et al. (2011) demonstrated significant similarities between music and linguistic processing during tasks that required the syntactic processing of expected and unexpected tones. Suggesting that the shared neural resources process stimuli structures that follow a consistent pattern and can build upon each other to create a hierarchy (Hoch et al., 2011). These consistent patterns found in music facilitate the recall of the auditory stimulus, because music focuses attention repeated patterns of sound (Buday, 1995).

RIGHT HEMISPHERE DOMINANCE IN CHILDREN WITH AUTISM

Generally in TD individuals language processes is lateralized to the left hemisphere (Knaus et al., 2010). However, white matter microstructure (WMM), MRI, magnetoencephalography (MEG), positron emission tomography (PET), event-related potential (ERP), and functional magnetic resonance imaging (fMRI) studies have shown that children with autism can exhibit right hemisphere dominance while processing language (Dawson et al, 1986; DeFossé et al, 2004; Eyler, Pierce, & Courchesne, 2012; Flagg et al, 2005; Lange et al, 2010; Müller et al, 1999). One area that is associated with auditory association and language processing is the superior temporal gyrus (STG) (Gage et al, 2009). Gage et al. (2009) found right hemisphere dominance in STG activity during language processing in right-handed autistic children. In a study by Lange et al. (2010), WMM of the STG the white matter fibers of the autistic subjects in the STG showed more activity in the right hemisphere versus the left during language processing.

A hypothesis for right hemisphere lateralization during language processing is that children with autism usually have delayed language acquisition, resulting in less left hemisphere activity in early development and right hemisphere neural resources are recruited to aide during language processing (Dawson et al, 1986; Herbert et al, 2005). Another hypothesis is that right hemisphere lateralization during speech processing is the result of a developmental neural pathology occurs in individuals diagnosed with autism (Eyler, Pierce, & Courchesne, 2012).

RHYTHM AIDING LANGUAGE PROCESSING

Rhythm is a salient element of music, which research demonstrates to have a connection with the temporal characteristics of language (Dellatolas, 2009; Overy and Turner, 2009; Slater, Tierney, and Kraus, 2013; Tierney and Kraus 2013). Tierney and Kraus (2013) found that the level of ability to tap to a rhythm correlates to young adults' reading skill level. The connection between rhythm and language lies in the perception of temporal sequences. Sensitivity to and ability to replicate temporal patterns is a foundational skill for phonological awareness, word segmentation, sustained attention, short-term memory, and rapid naming (Carr et al., 2014; Corriveau, Pasquini, and Goswami, 2007; Huss et al., 2011; Marler and Champlin 2005; Tierney and Kraus 2013). For example, Carr et al. (2014) demonstrated that the ability of typically developing emergent readers to synchronize an acoustic beat predicts the accuracy of neural encoding of speech syllables; a skill critical for reading development. Research is showing that this link between rhythm and language has the potential to expand the use of music to facilitate language learning. Slater, Tierney, and Kraus (2013) found that 1year of music training had a positive effect on the ability to maintain rhythm and emerging literary skills for children ages six to nine years old. Dellatolas (2009) demonstrated that the ability for kindergarteners to reproduce rhythm predicts reading skill level in second grade for typically developing and impaired individuals. Thus, perceiving rhythmic acoustic cues is an important element of speech and language development and is evident across languages (Surányi et al., 2009).

PITCH AIDING LANGUAGE PROCESSING

Individuals with autism tend to have less grey matter in regions associated with the MNS, which include the pars opercularis posterior IFG, superior temporal sulcus (STS), ventral premotor cortex (area F5), and the rostral portion of the inferior parietal lobule (IPL) (Hadjikhani et al, 2006; Overy & Molner-Szakacs, 2009). The left inferior frontal gyrus (LIFG), also known to be a component of Broca's area, plays a major role in expressive language and speech stream segmentation (Francois & Schön, 2011; Slumming et al, 2002). Hadjikhani et al. (2006) performed a study that used a Sonata MR Scanner to measure the amount of gray matter in children with autism and found that they had significantly less grey matter in the LIFG than TD children.

Pitch may be able to either facilitate the development of the LIFG or neural recruitment to the RIFG due to the potentially shared neural resources in the IFG used for pitch processing in music and language. Loui, Alsop & Schlaug (2009) found supporting evidence for the right and potentially the left IFG's role in pitch perception in vocal communication through studying the white matter connections in the brain of the arcuate fasciculus (AF) using MRI and diffusion tensor imaging (DTI). Ultimately they concluded that the posterior superior temporal gyrus (STG) and the posterior IFG are essential to pitch discrimination. This conclusion was made by studying the lack of white matter connections to these two areas in individuals who are tone-deaf versus the AF connections in individuals who can perceive pitch (Loui, Aslop, & Schlaug, 2009). According to EEG and fMRI studies musical and linguistic syntax appears to be located in the inferior frontal cortical region of the pars operculum and anterior insula of both hemispheres with dominance in the left hemisphere for language and dominance in the right hemisphere for music (Abrams et al, 2011; Koelsch et al., 2005, Tillmann, Janata & Bharucha, 2003). The IFG is significantly active when processing structure and temporal changes in music and speech, specifically the left pars opercularis, right pars triangularis, and bilateral activity in the pars orbitalis (Abrams et al, 2011). The utilization of the right IFG (RIFG) during music perception training may be able to further the development of the LIFG, because of the sequencing and output analysis required for both music and language in the IFG (Slumming et al, 2002). Gaser and Schlaug (2003) and Slumming et al. (2002) used voxel-based morphometry (VBM) to find that musicians have significantly more grey matter in their LIFG. Thus, incorporating music in therapy session has the potential of improving expressive speech and speech production segmentation by engaging areas of the brain associated with the MNS, as shown through the practice of MIT (Francois & Schön, 2011; Wan et al, 2010).

Furthermore, Lai et al. (2012) used MRI and diffusion tensor imaging (DT) to study the reactivity of neural systems to music and language with low-functioning ASD and typically developing (TD) subjects. Lai et al. found that the neural regions, associated with music and language processing, were more significantly activated during the song condition versus the speech condition. Lai hypothesizes that one reason for speech deficits in the patient populations diagnosed with autism is the low level of activity in the LIFG and song increased activity in the LIFG (Lai et al.). In fact, music can engage the entire MNS, which MIT capitalizes on by using music to improve the neural areas associate with speech and the MNS to facilitate language comprehension and expression (Wan et al, 2010).

These findings inspired the auditory condition of MSAP.

ORTHOGRAPHIC TEACHING METHOD

The spelling tasks in MSAP involve the participant copying the target words twice. The orthographically based teaching method is implemented across all conditions while two conditions are taught with an external stimulus. The effectiveness of orthographic versus phonological spelling strategies depends the decoding and auditory ability of each individual learner (Kwong and Brachman, 2014; McGeown, Medford, and Moxon, 2013). Phonological spelling strategies rely on access to letter-sound knowledge and the phonological segmentation of a word (Share, 1999). On the other hand, orthographic spelling strategies focus primarily on the visual analysis that occurs during the exposure to print. This visual strategy is codependent on existing phonological knowledge. However, the use of phonology as a primary decoding strategy through adulthood is often a reflection of poor spelling skills (Kwong and Brachman, 2014). Thus, novel words are typically first encoded phonologically progressing toward orthographic spelling strategies as novel words increase in familiarity (Ehri 1986; McGeown, Medford, and Moxon, 2013; Share 1999).

MSAP uses a spelling strategy corresponding with an orthographic versus a phonetic spelling strategy to disambiguate the external stimuli presented with the twelve taught CVC words (McGeown, Medford, and Moxon, 2013). The orthographic spelling strategy employed is the same for all MSAP conditions allowing the independent variables (auditory, tactile, and no feedback external stimulus) to differentiate the instructional session conditions.

PREVIOUS LANGUAGE-MUSIC PROGRAMS

Music may be able to improve an individual's speech comprehension by incorporating music in therapies (Wan et al, 2010). Moreover, Music and speech perception skills are believed to be intact for individuals with autism (Lim, 2009). A therapy technique developed to use pitch and rhythm to facilitate speech and language for children with autism is called Auditory – Motor Mapping Training (AMMT). During this therapy, the non-verbal children with ASD sing while taught to play drums that are tuned to certain pitches. The music therapy involving word and phrase intonation coupled with motor movement was very effective at increasing the verbal expression of non-verbal children with ASD (Wan et al. 2011). A subdivision of AMMT is melodic intonation therapy (MIT), which focuses on engaging the auditory, motor, and mirror neuron systems (Wan et al, 2010). The mirror neuron system (MNS) consists of neurons that discharge in response to one's own actions and in response to similar actions of others (Wan et al, 2010). MNS's ability to facilitate learning through the observation of other individuals is the reason why the MNS helps with language representation and evolution (Overy & Molner-Szakacs, 2009; Wan et al, 2010).

In addition to facilitating speech production, elements of music can help to engage in expressive language activities, such as vocabulary acquisition. For example, Buday (1995) taught ten children with autism seven signs in American Sign Language in two conditions: music and rhythm. The rhythm condition used taught sign language using the same rhythm of the melody used in the music condition. The study found that the significantly more signs were learned when taught during the music condition versus the rhythm condition. The authors suggested this was partially because the music condition was more enjoyable (Buday,1995).

Moreover, multisensory teaching techniques foster spelling skills for individuals in various patient populations other than the autism spectrum disorder patient population. For example, Kast et al. (2011) developed and tested a letter and syllable music association multisensory program on children with and without dyslexia. The additional phonological cues provided by the music helped dyslexic children learn spelling skills about as quickly as the children without dyslexia, because the dyslexic subjects had an increase in phonological comprehension and could remember the letter sequences more easily (Kast et al, 2011).

In another study with children diagnosed with dyslexia, Ecalle et al. (2008) studied the efficacy of using visual-audio training to aid spelling comprehension. They used synthetic speech in a computer-aided learning (CAL) program to facilitate phoneme comprehension (Ecalle et al, 2008). They discovered that their audio-visual phoneme discrimination computer activities illustrated the association of the voiced phoneme to the printed graphemes and significantly improved the dyslexic children's phonological skills (Ecalle et al., 2008).

One of the reasons why multimodal teaching techniques involving musical stimuli may be so effective is that musical stimuli, including both pitch and rhythm, are found to be particularly engaging for individuals with autism. For example, Kern, Wakeford, & Aldridge

(2009) found that song was more effective than using just the lyrics during music therapy, because the music more effectively captured the autistic child's attention than speech. More exposure to musical training may also aid skill of focusing attention on pitch variation, which in turn could improve the ability to categorize auditory stimuli including speech and music (Besson et al., 2011; Russo et al., 2008). Neurological evidence for impaired speech perception in autism lies in the brainstem, which play an active role in auditory processing (Chandrasekaran, Skoe, and Kraus 2014; Russo et al., 2008). Exposure to music has the potential to train pitch tracking and improve pitch perception in speech playing a critical role in the development of phonological awareness (Russo et al., 2008).

Furthermore, part of music's educational potential comes from the calming effect of rhythm. Musical stimuli can lower anxiety illustrated decreasing cortisol levels as an individual listens to music (Hillier et al., 2011; Mckinney et al., 1997; Nilsson, Unosson, & Rawal, 2005). Young adults with ASD exhibited lower anxiety and higher self-esteem when listening and composing music (Hillier et al., 2011; Shore, 2003). Hillier et al. (2011) taught children with autism to use a computer program in which the children composed a song that went with a short video skit that they made. They found that the computer technology is an effective way for children with autism to produce music because of the computer's predictable nature, which reduces the children's anxiety.

PREVIOUS SPELLING PROGRAMS FOR INDIVIDUALS WITH AUTISM

Limited research is available on instructional spelling programs for children with autism spectrum disorder. Eby et al. (2010) designed a multiple exemplar instruction that alternated verbal and written response from the participants during the instructional sessions. The sessions took place in the 7 year-old high functioning participant's regular classroom, which employed applied behavior analysis techniques. Eby et al. (2010) found a significant response to treatment with generalization to novel words. The authors posit that the act of saying and writing the target words results in stronger "phonemic control." Tanji, Takahashi, and Noro (2013) designed a computerized spelling program that used both matching-to-sample and constructed-response matching-to-sample techniques. The participants were chronologically 9, 9, and 11 years old with the respective cognitive ages of 2.11, 4.4, and 4.3. The participants chose whether they want to see the word written or hear the word pronounced by touching icons on the computer screen. Once the word was presented, the participants were instructed to place the letter options that are available into the empty slots for the target word by tapping the computer screen. The authors found a significant response to treatment in addition to generalization to within reading and spelling, which supports the findings by Vedora and Stromer (2007) who also used a computerized constructed-response matching-to-sample technique to enhance reading and spelling skills in children with developmental disabilities.

STATEMENT OF PURPOSE

The primary purpose of this study was to develop a computerized spelling program called MSAP for teaching the spelling of single syllable consonant vowel consonant words to children who have autism. The premise underlying this research is that pairing the Morse code rhythm with graphemes presented in auditory and tactile conditions may engage the participants in the spelling tasks and increase the understanding of the orthographic construct of words facilitating spelling acquisition. The computerized spelling program, MSAP, was implemented to compare teaching two conditions: auditory presentation of Morse code at 450 Hz versus a tactile presentation of Morse code and no external stimulus.

METHOD

PROGRAM DEVELOPMENT

MSAP is a computerized method for teaching spelling skills to children with autism by using rhythm presented via auditory and tactile modalities as external stimuli to facilitate spelling acquisition and to allow for comparing the effect of using auditory and tactile stimuli in a multisensory teaching approach on the accuracy and rate of spelling acquisition. The specific features of MSAP are delineated below:

(1) MSAP allows for positive practice that approximates errorless learning. The positive practice method was used to avoid any reinforcement of incorrect associations between the spelling of the target word and the target word's visual or verbal stimulus, thus only facilitating correct stimulus-response associations (Sage & Ellis, 2006).

(2) The target words taught in MSAP have direct phoneme-grapheme relationship. As a result, the external stimuli may facilitate the encoding of both phoneme and grapheme sequencing.

(3) MSAP uses rhythmic stimuli. To test the hypothesis that external rhythmic stimuli will most effectively engage the participants in spelling tasks, the external musical stimuli of a rhythmic tones and vibrations paired to phonemes to no external stimuli were compared. To keep the participant's exposure to the stimuli consistent, before the participant is asked to copy the target word into the text box, both forms of external stimuli were presented with the word when the word was displayed on the computer screen with the picture of the word and the text box. Also, the external stimuli were elicited as the child was typing in order to directly associate the external stimuli with each grapheme.

(4) MSAP compares auditory, tactile stimuli, and no external stimuli. To monitor the effectiveness, the auditory, tactile and no stimulus variables were separated into three teaching conditions. A group of target words was consistently taught with one of the three conditions paired to each word group by the researcher. The conditions were randomized during the instructional sessions, as well as, the three groups of target words when they are tested in the acquisition probe to avoid the confounding variable of word order when comparing the learning effects between the different conditions (Grenfall-Essam, Ward & Tan, 2013).

(5) MSAP includes three different programs for the three different types of spelling tests. All of the probes will collect data for the spelling accuracy and rate. The testing program for the pre-assessment is unique, because this program tests the participant's ability to spell more words than will be incorporated into the instructional sessions. The baseline probe only tested the spelling of the target word group and the generalization probes. Although the acquisition probe also only tested the spelling of the target word group and the generalization probes, this test was given directly before each instructional session. Thus, MSAP was designed to have the acquisition probe immediately followed by the instruction session. Thus. MSAP includes three different programs for data collection at different phases of the intervention study to allow for clear data representation in the computerized spelling program's database.

MSAP PROGRAM ELEMENTS

Computerized Spelling Probes

The probes were created so that only the pictures of the word and text box used to enter the target word were present. The pictures were all black and white line drawings (Table 1: Johnson, 1994).

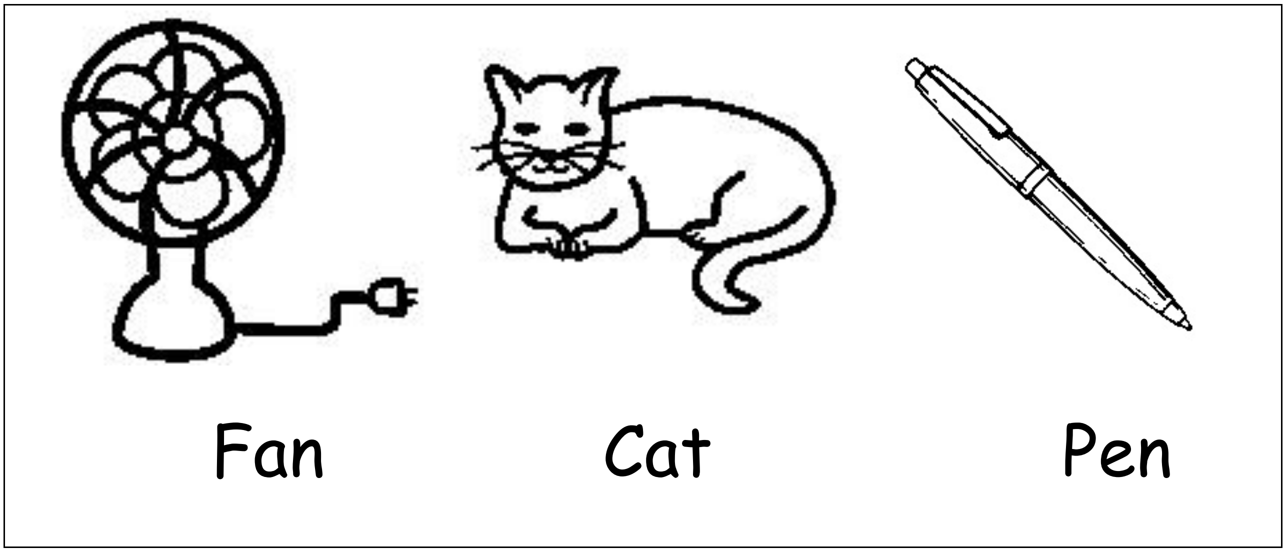

Table 1: Examples of the black and white line drawings paired with the target words

All text is presented in the font type Comic Sans (Table 1: Williams, 2002). If the child takes longer than thirty seconds, the program advances to the next word. The words are tested in three groups and they are grouped according to the feedback condition the words are paired with for the instructional condition. The target word groups are probed in a random order and the program automatically records the word group order during each test. The child was not selectively reinforced when they answer correctly; however, the participant was given arbitrary words of encouragement during the spelling tests. This spelling probe program was used for the pre-assessment, baseline assessment, and acquisition probe.

Figure 1: Probe Display Screen

Computerized Spelling Instruction

The acquisition probe and spelling instruction were given in the same session. After the acquisition probe is given in the beginning of the instructional session, the program pauses allowing the subject to take a 2 minute play break, which was timed with an external timer. Subsequently, the program begins the instructional section after the experimenter returns to the computer and presses a letter key on the computer keyboard. The words were taught in three groups.

The experimenter assigned the target words to a specific feedback group before baseline testing begins. The target word groups are also randomized during the instructional session. During the instruction session every target word was shown in between the picture and the text box (Figure 2).

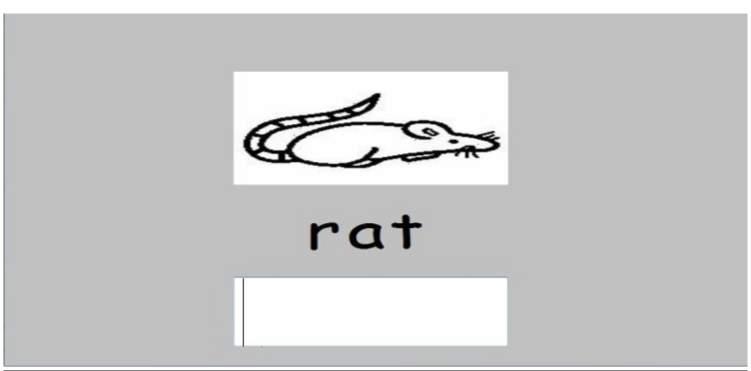

Figure 2: Instructional Session Display Screen

The instructional section was designed to be as close to errorless teaching as possible. The correct spelling of the word was presented to the participant who has to copy each word twice. After the first word is copied program automatically clears the text box under the picture allowing the participant to copy the target word a second time. The experimenter instructed the subject to type the word for the second time once the text box cleared after the first time the subject copied the target word. The program also only displays letters in the text box that are in the target word and in the correct order. Thus, the participant cannot misspell the target word during the instructional section of the computerized spelling program.

Treatment Conditions

1) Auditory rhythmic feedback condition: When the picture, word, and text box appear the Morse Code rhythm (Table 2) associated with each letter will play presented at 450 Hz frequency.

Morse Code					
a	.–	i	..	r	.–.
b	–...	j	.–––	s	...
c	–.–.	k	–.–	t	–
d	–..	l	.–..	u	..–
e	.	m	––	v	...–
		n	–.	w	.––
f	..–.	o	–––	x	–..–
g	––.	p	.––.	y	–.––
h	....	q	––.–	z	––..

Table 2: Morse code ("M.1677 : In ternational Morse code", 2009)

The rhythmic stimuli will also be presented with each letter the participant types in the target words into the text box during the instructional session. The rhythm sequences for the target words are intended to take on the semantics meaning of the word due to the consistent letter and note pairings during each spelling task and provide an additional sensory stimulus to facilitate memory of the grapheme order in each word.

2) Tactile rhythmic feedback condition: A bone oscillator used for routine infant hearing screening tests was used to administer the gentle vibration that the participants felt while holding on to the device with one hand while the participant used the other hand to type. This stimulus exposure mirrors the auditory rhythmic condition.

3) No feedback condition: The computer screen displayed a line drawing image of the word, the word, and a text box. The teacher asks the child to copy the same word into the text box two times.

Apparatus

The program must be run on a PC computer. A Lenovo IdeaPad with a 13 inch screen was used for the purpose of this study.

EXPERIMENTAL DESIGN

An alternating treatment experimental single-subject experiment design was used to evaluate the efficacy of using rhythm to teach spelling (Ollendick, Matson, Dawson, & Shapiro, 1980). Three instructional session conditions are alternated while being consistently paired with the same group of target words. The three instruction sections described under ‘MSAP Elements’ include: no feedback, tactile rhythmic feedback, and audio rhythmic feedback.

PROCEDURE

This study included seven phases: parent survey, pre-assessment, baseline probe, acquisition probe, instruction session, post-assessment, and maintenance probes (Figure 3).

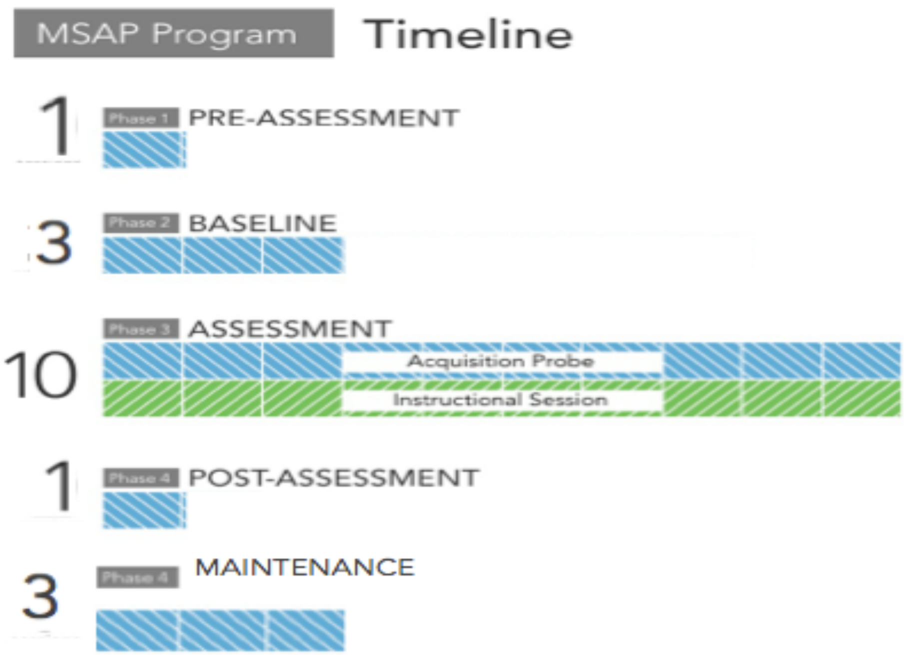

Figure 3: MSAP Timeline

Parent Survey

During the parent survey phase of this procedure, the parent of the child filled out a survey verifying that the subject would be able to understand the instructions to begin the spelling tasks (Schlosser, 2004). The survey asked if the child participated in any previous experiments, can he/she understand the requests to spell and copy, what requests are the child familiar with, what questions the child readily answer, and what stimuli is the child averse to in order to avoid them during the experiment. Finally, the last page includes a list of forty-eight words that the parent uses to circle words that they believe their child does not know how to spell (See table 3). All of the word options consisted of consonant-vowel-consonant letter combinations and scored greater than five hundred for concreteness, familiarity, and imagability according to the MRC psycholinguistic database (Wilson, 1998).

Pre-assessment Phase

Prior to beginning the study, each child would be tested in three areas: word-level spelling, word comprehension, and phonemic awareness tests. In the spelling test the subject was tested on his or her ability to spell eighteen of the words selected by the parent from the master list of three letter consonant vowel consonant words (Schlosser, 2004). Incorrect spelling is defined as no complete and correct letter sequence for the entire word.

Word comprehension of the eighteen words from the pre-assessment spelling test was tested by showing a printed power point with four picture communication symbols (PCS) line drawings of the words on one page and the experimenter will ask the subject, "Point to the picture of the _." After the spelling and word comprehension tests a target pool of twelve target words and four untaught generalization probes was created.

Baseline Probe Phase

MSAP ran three baseline (BL) probes prior to the instruction phase. Prior to the baseline probe, the researcher will establish behavioral momentum with the child. The baseline probe includes 16 words, which include 12 target words and 4 untaught words to assess generalization. During the BL probe child would be unaware if he or she spelled sixteen words correctly or incorrectly. The computer screen will show the picture of the word and the text box is underneath the picture. The child is asked, "Spell [word]". The spelling program will automatically record the participant's reaction time and typed answer.

Acquisition Probe Phase

In this phase, the experimenter probed each subject's ability to spell the twelve target and four untaught words prior to each instructional session to monitor the child's spelling acquisition of taught words and generalization of teaching of untaught words. Prior to the acquisition probe, the researcher established behavioral momentum with the child by telling the participant "It is computer time. Which chair would you like to sit in, the blue chair or the red chair?" During the acquisition probe a picture of each word's image would be presented above the text box and the researcher will say, "Spell [word]". The spelling program would record the participant's reaction time and typed answer automatically.

No feedback was given to indicate a correct or incorrect response. The twelve target words would include: four target words learned with auditory rhythm feedback; four target words learned with tactile rhythmic feedback; and four words learned with visual feedback.

Instructional Phase

The intervention took place individually for one subject one session a day one day a week for a total of ten instructional sessions. Prior to the instructional session, the researcher established behavioral momentum with the child. During the instructional session, the three treatment conditions alternated randomly.

The spelling instruction used a semantic-lexical procedure, in which a black and white PCS line drawing will be visible on the screen above the correct spelling of the target word that the participant is instructed to copy in order to insure semantic understanding and facilitate errorless learning (Sage and Ellis, 2006). Below the word a text box appeared for the subject to copy the target word.

During the condition with no musical feedback, the word appears on the computer screen with the line drawing of the word shown above the written word and the researcher said, "Spell [word]". The subject proceeded to copy the target word into the text box presented below the line drawing and model word. The task of copying the target word occurred consecutively two times. The MSAP program randomized the order of conditions and target word presentation.

In the conditions with rhythmic feedback, the same procedure was used as when teaching spelling during the no feedback condition. However, when the target word was initially presented on the computer's screen and when the child types the words on the keyboard the Morse code corresponding each letter in the target word will play.

Post-Assessment Phase

An acquisition probe was administered with the twelve target words and four untaught generalization probes. The procedure is identical to the acquisition probe administered prior to the instructional session.

Maintenance Probe Phase

Two-four weeks after the post-assessment the subject is probed again on his or her ability to spell the twelve target words trained target words and four generalization probes (Jaspers, 2011). The text box and black and white line-drawn word image would be the only stimulus during the spelling portion of the maintenance probe.

INCLUSIONARY CRITERIA

The participant was recruited by electronic flier distribution to Autism Society of Central Texas. The interested family and the participant then came to the University of Texas Speech and Hearing Center to learn more about the procedure. The inclusionary criteria for this study included that the Participant have:

a) only corrected visual/hearing impairments

b) previously acquired computer typing

c) Ability to match a visual stimulus of a letter to the corresponding key on a computer keyboard

d) a confirmed diagnosis of ASD through the Childhood Autism Rating Scale (CARS-2; Schopler et al. 2010)

e) 5-19 years of age

f) Ability to follow directions

g) Skill criterion for using MSAP should be a score of 75% on an informal test of word copying. On the copying probe, the computer would display an image of a three-letter word, the word, and a text box; then the teacher asks the participant to copy the word into the text box.

PARTICIPANT AND SETTING

The participant is a 5;8 year old Caucasian English speaking male presenting with 1q21.1 microduplication and a diagnosis of autism with no uncorrected vision impairment or hearing loss. The CARS-2 confirmed that the participant has mild-moderate symptoms of autism spectrum disorder (CARS-2; Schopler et al. 2010). The mother's highest level of education is a Bachelor's degree. The participant currently attends a local urban elementary school. Per maternal report the participant seldom used a computer or iPad for recreational and academic work.

The participant passed the skill criterion for using MSAP, which is a score of 75% on an informal test of *word copying*. On the copy test, the computer displays an image of a three-letter word, the word, and a text box; then the child would be asked to copy the word into the text box. Passing this probe confirmed the participant's ability to understand the request to spell and type on a computer keyboard. According to the parent survey the participant had no knowledge of how to correctly spell the 48 three letter words (Table 3).

CVC Word Bank				
mat	hat	rat	fat	cat
bed	red			
pig	dig	wig		
boy	toy			
box	fox			
cap	map			
bar	jar			
cow	bow			
cup				
dad				
dog	fog	hog		
dot	hot	pot		
leg				
mom				
pan	fan	man	van	
pin	bin	tin		
sun				
rug	bug	mug		
pen	ten			
jaw	saw			
bag				
tub				
gas				

Table 3: The 16 taught and untaught words are chosen from this list of 48 words.

The pre-test probe confirmed this statement by testing 18 of the 48 words. The participant correctly produced the initial letter of 11/18 words. No other letters were correctly produced in the participant's responses qualifying the pre-test words for the study. The participant demonstrated semantic knowledge of the pre-test words by correctly pointing to 100% of the black and white images.

The study took place at the University of Texas Speech and Hearing Center once a week in a quiet clinic room.

TREATMENT FEDILITY

A Masters Student Clinician and the Examiner used a Treatment Integrity Recording Sheet during 3 of the 10 instructional sessions to collect treatment fidelity data. A maximum of 17 points could be earned for each instructional session. The three treatment sessions obtained an average treatment fidelity percentage of 90%.

RESULTS

MSAP DATA COLLECTION

MSAP automatically records the user input as the participant is completing the spelling probes, including the pre-assessment, baseline probe and acquisition probe. The results are recoded in four columns: Word, User Answer, User Input, and Time. The Word column includes all of the words that the participant will be asked to spell. The User Answer column states whether the typed word is correct or incorrect. If the answer is incorrect, the program records every letter that the participant types in response to the picture and spelling prompt in the User Input column. Finally, the Time column is where the recorded time taken to spell the word in milliseconds is located.

BEHAVIORAL MEASURES

Average Number of Letters

This measure assessed the number of letters that the participant used to spell the three letter CVC words across condition probes. This measure illustrates how the participant made a gradual progression toward knowing the accurate number of graphemes used in each target word irrespective of the accuracy of the type of grapheme used. During the baseline probes (BL) the participant used only one letter to spell the CVC words. The participant demonstrated increased orthographic knowledge one week after the first instructional session by using an average of 2 letters in the tactile condition, 1.67 letters in the untaught words condition, 1.5 letters for the no external stimulus condition, and 1 letter in the auditory condition. The average number of letters used gradually increases in spelling acquisition with a period of decreased accuracy on instructional sessions 7 and 8. Scheduling conflicts caused a two week break between these two sessions. On the 9^{th} instructional session, the participant accurately entered 3 letters for all 12 of the taught CVC words. Subsequently, on the 10th instructional session, the participant accurately entered 3 letters for both taught and untaught CVC words. Thus, responding with the correct number of letters generalized to the untaught three-letter probes. The participant maintained the knowledge of the correct number of letters in the post-assessment taken 1 week after the last instructional session and the three maintenance probes taken 1 month after the last instructional session.

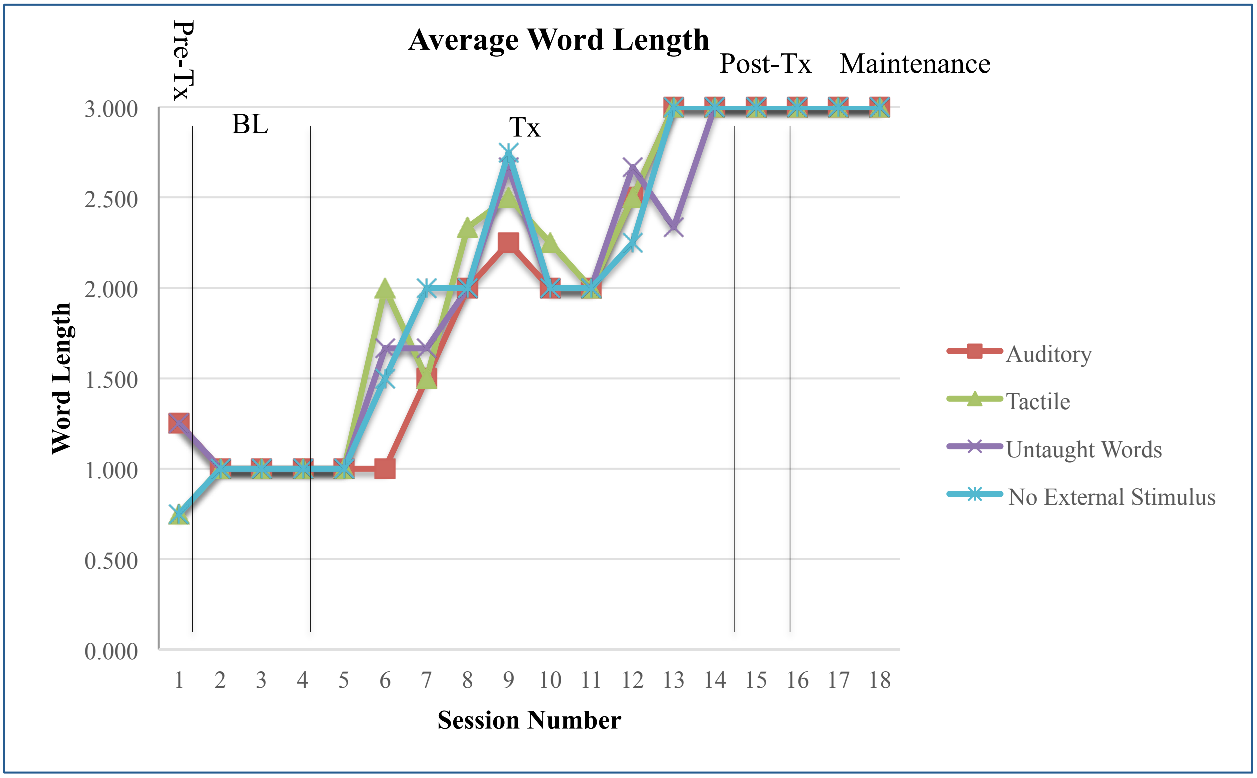

Table 4: Depicts the Average Word Length results

Percent of correct letters in correct position

This measure assesses the participant's ability to type the letters of target words in the correct order from the pre-assessment to the last maintenance probe. Learning which letters go in the correct position was the most challenging concept for the participant to grasp. The initial consonant was the first consonant to be learned followed by final consonant, but without the vowel. If the final consonant followed the initial consonant without a vowel the position of the experimenters marked the final consonant as incorrect. If the initial letter is in the initial position, the participant used an incorrect vowel, and the final letter is in the final position then 2/3 letters are marked accurate with regard to position and with letter accuracy. Not until the maintenance probe did the participant demonstrate understanding regarding the position of the vowel in the word. The participant put every letter in the correct position when spelling the words taught with no external stimulus and tactile feedback. The participant spelled the words in the untaught and auditory conditions with 80% percent accuracy during the last 2 maintenance probes.

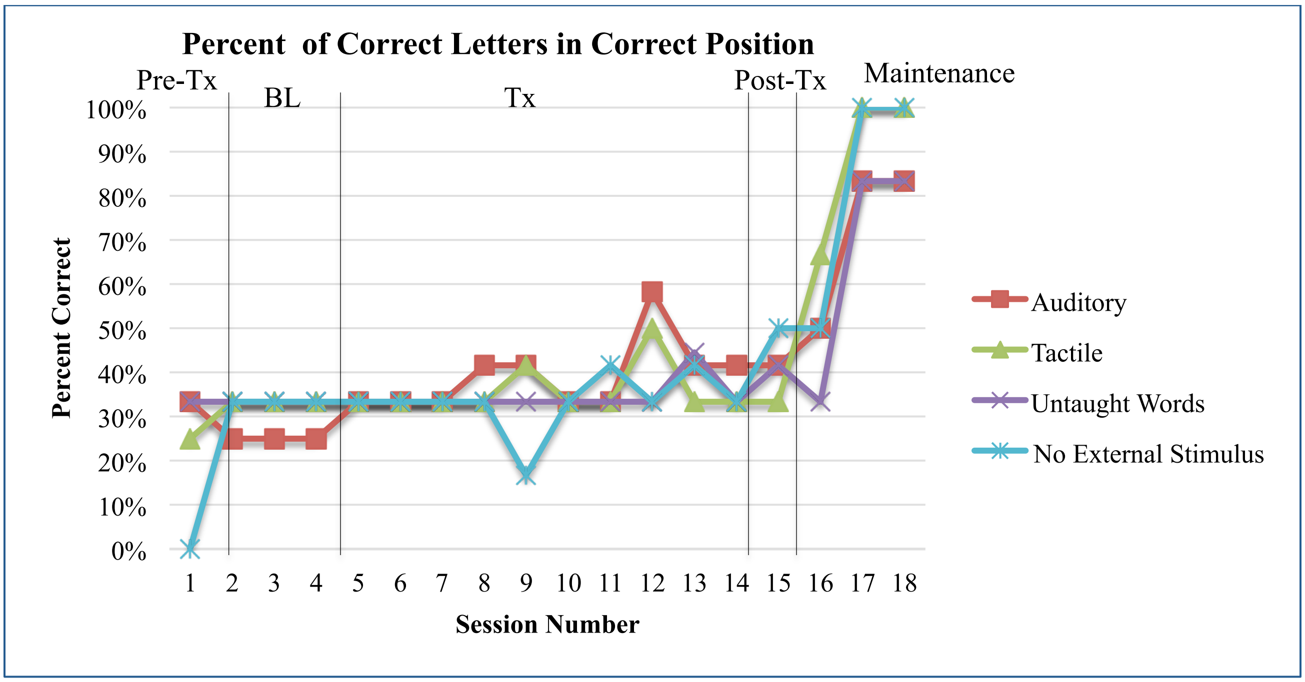

Table 5: Depicts the Percent of Correct Letters in the Correct Position

Percent of letters correct

This measure assess the percent of correct letters that the participant uses to spell the three letter CVC words irrespective of the order they occur from the pre-assessment to the last maintenance probe. This measure depicts a gradual increase in spelling acquisition with a period of decreased accuracy on instructional sessions 10 and 11. This decrease in accuracy reflects the scheduling conflicts that caused the instructional sessions to occur once every other week versus once every week.

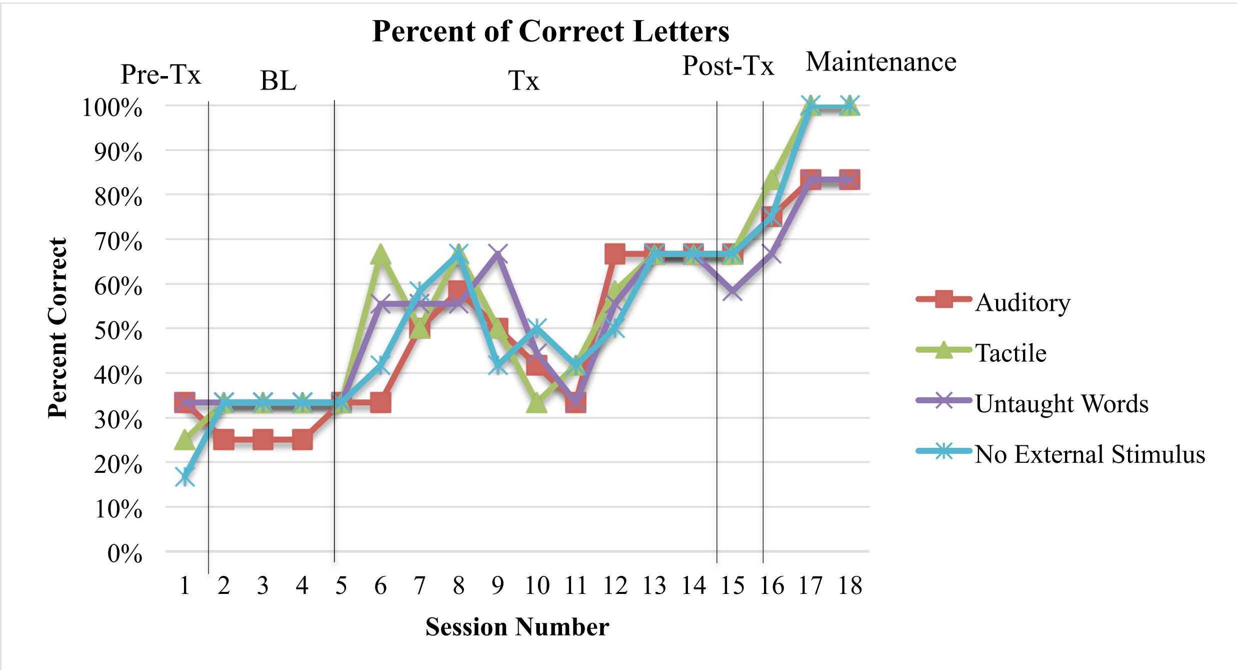

Table 6: Depicts the Percent of Correct Letters

Time taken to complete spelling response after stimulus onset

The computer program automatically recorded the time in seconds the participant used to respond to each instruction to spell. The reaction times displayed in figure_ show how much time the participant used when copying the target words during the instructional session and when spelling the target words with 100% accuracy irrespective of the instructional condition. The time the participant used to spell words with 100% accuracy rapidly decreased from session 12, which is a 1-week post the Participant's 7th instructional session, to the 3 maintenance probes taken 1 month post-intervention.

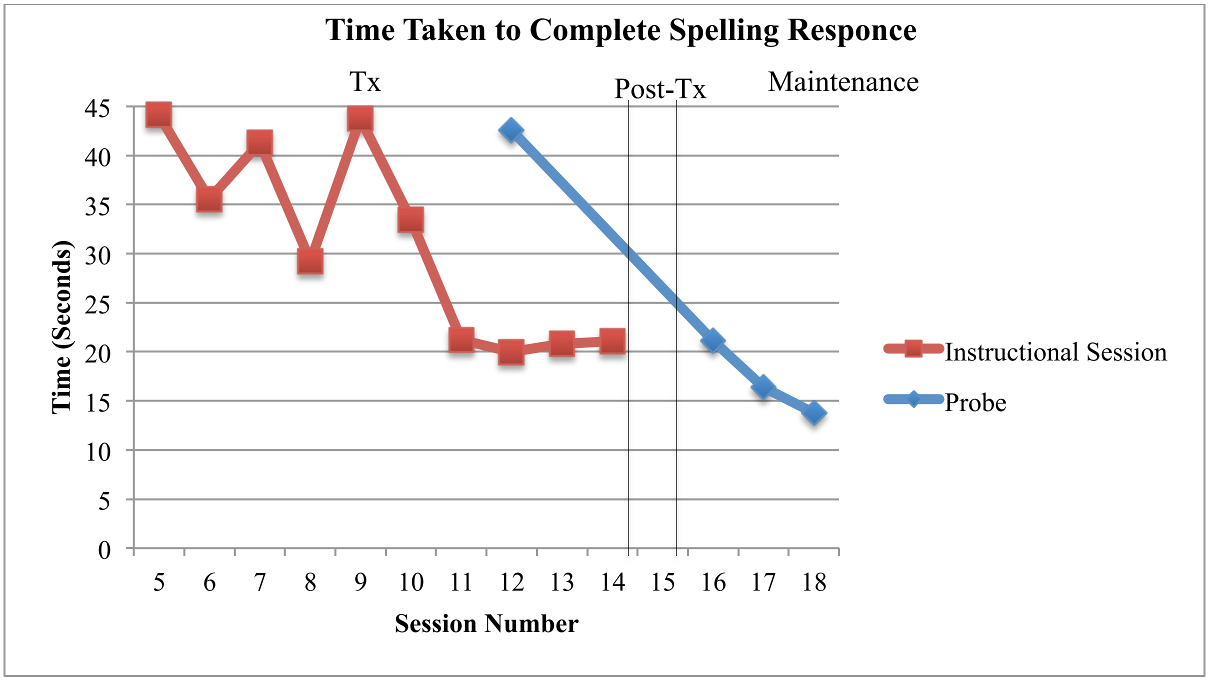

Table 7: Depicts the time taken to complete spelling response after stimulus onset

STATISTICAL ANALYSIS

The participant's spelling acquisition did not show a significant difference between the instructional conditions when tested using a two-way time (pre-treatment versus post-treatment) by condition (Tactile versus Auditory versus No External Stimulus) ANOVA. This is true for the percent of letters correct, $F(3,12)= 0.98$, $p < 0.432$, as well as, the percent of correct letters in the correct position, $F(3,12)= 2.89$, $p < 0.833$. No significant difference was found between the spelling acquisition of the target words taught in three different instructional conditions.

DISCUSSION

MSAP was designed to test whether an auditory or tactile presentation of a rhythm in concert with graphemes in a target word on a computerized spelling program would facilitate the spelling acquisition of CVC words more effectively than a computerized spelling program with no external stimuli. The spelling program to taught twelve words in three different conditions using an orthographic spelling task involving the correct spelling of a target word while assessing the effect of tactile and auditory rhythm to letter pairing has on learning how to spell novel words. Four measures were used to manipulate the raw data: average number of letters used in a spelling attempt, letter accuracy, percent of accurate letters in the correct letter position, and time taken to respond. A two-way ANOVA calculation was performed on the average number of letters used in a spelling attempt and letter accuracy to identify any significant differences in spelling acquisition between the 3 instructional conditions.

INTERPRETATION OF FINDINGS

Average Number of Letters and Percent of Correct Letters

The participant demonstrated gradual acquisition of accurate number of letters used in spelling attempts and letter accuracy for taught and untaught novel three letter CVC words in every teaching condition. No significant difference was found between the different instructional conditions. A possible reason for seeing a similar rate of spelling acquisition for all taught words is that there was a carryover effect, also known as a contextual effect (Barlow & Hayes, 1979). Even though the taught words are consistently paired with an instructional condition the participant is exposed to all three conditions in every instructional session due to the rapid alternating treatment design. A carry over effect occurs when 2 or more alternating treatments influence the treatment results irrespective of the order in which the treatments were presented

(Barlow & Hayes, 1979). However, the results do demonstrate that the external stimuli did not hinder the spelling acquisition and the tactile condition seemed to be slightly more effective for teaching word form. Thus, the possibility remains that musical elements may have the ability to aid language acquisition for individuals with autism by engaging them in spelling tasks.

Percent of Correct Letters In Correct Position

The Participant's low accuracy level until the higher level of accuracy during the post-test and maintenance probes demonstrates a memory consolidation effect. Memory consolidation refers to the phenomenon of novel concepts gradually being strengthened and acquiring permanence (Squire 1992; Stickgold & Walker 2013). Memory consolidation can occur during the week between instructional sessions (Storkel, 2015) and at least one month after the last instructional session occurs (Bosshardt et al., 2005; Norbury, Griffiths, & Nation, 2010). Allowing time for memory consolidation for 6-8 year-olds can improve the linguistic representation of novel words (Brown, 2012; Norbury et al., 2010). The dual systems theory explains the mechanics of memory consolidation postulating that initial memory acquisition primarily involves the hippocampus and as the memories stabilize the neo-cortex increases activation during memory retrieval, while other theories believe that there are linkages between the hippocampus and neo-cortex (Bosshardt et al., 2005; Davis, 2008). This process of strengthening novel phonological and orthographic information post-instructional sessions may account for the improved performance seen for the Participant 1 week and 1 month post-training. In addition to memory consolidation playing a role in the increased spelling accuracy one week and one month post-treatment, the Participant spontaneously integrated MSAP's external stimuli with phonological spelling techniques during the last 2 maintenance probes. The Participant would verbally sound out each letter prior to typing. This may be correlated with improvement in Participant's spelling accuracy during the last 2 maintenance probes.

Time Taken to Complete Spelling Response After Stimulus Onset

The MSAP program automatically recorded the time from stimulus presentation to the completion of the spelling attempt. The results demonstrate that less time was required for the Participant to copy the words during the positive practice in the instructional condition indicating increased comfort with typing on the computer and knowledge of the target words. Also, when the time taken during the positive practice began to plateau the first 100% accurate spelling response occurred during an acquisition probe. The Participant's consolidation of spelling knowledge was further demonstrated by the decreased time used to respond during the maintenance probes.

LIMITATIONS

The experimental design presented with the inherent limitation that the participant was exposed to all conditions during the same session resulting in a possibility of a Carryover effect. The Carryover effect may have reduced any significant difference in spelling acquisition between the instruction conditions. In addition, an Autism Diagnosis Observation Schedule (ADOS) trained professional did not confirm the diagnosis of autism spectrum disorder with administration of the ADOS (ADOS; Lord et al., 2000). Moreover, this pilot study used one participant limiting the power of the results. Furthermore, scheduling conflicts caused sessions 10 and 11 to occur every other week versus once every week. As a result, the experiment deviated from the schedule of the designed experimental method. Finally, technical difficulties were experienced with this beta MSAP program. These included the program shutting down at the beginning of an instructional session. The experimenter would then need to restart the program and return to the condition(s) that the participant did not complete.

FUTURE DIRECTIONS FOR MSAP

Patient Population

The computerized spelling program developed in this study could be run with TD children in kindergarten and first grade to observe the programs effects on beginning spellers with no language learning impairment (Ehri 1987, Davis & Drouin, 2010). A comparison between the multimodal intervention on the spelling abilities of individuals who are TD and diagnosed with autism could clarify cognitive processing similarities and differences between the two different populations. In order to make valid comparisons between the two populations, all of the participant's cognitive level of functioning should be evaluated, so that the comparisons can give an accurate depiction on the effects the external rhythmic stimuli have on spelling acquisition.

Target Words

Future studies could include words of varying length and grapheme to phoneme correspondence.

Musical Stimuli

The program could be designed with a multimodal condition that combines phonemic-music note and grapheme-Morse code pairing. Meaning every letter has a rhythm and every sound has a corresponding phoneme. The music notes would correspond to the perceived pitch of phonemes. This would demonstrate how using elements of music to approximate English speech and language could engage individuals with autism in spelling tasks.

Data Collection & Analysis

Phonemic Awareness

A previous study by Ehri (1989) demonstrates in a posttest that individuals with spelling training have greater reading and phonetic segmentation abilities than individuals who have yet to be trained. Increasing phonemic awareness and the ability to comprehend the phoneme-grapheme correspondence is essential for developing reading and spelling skills (Gauger, 2013; Wimmer, Landerl, Linortner, & Hummer, 1991). If this program has significant effects on phonemic awareness, future studies should examine this intervention's affect on the reading and speech skills of individual who are TD, diagnosed with autism, and other developmental disorders.

Assessing the participant's phonemic awareness and reading abilities before and after the intervention with this spelling program would be useful to evaluate if any improved phonetic and reading abilities. This assessment may need to be performed in a separate study with a control group unexposed to the rhythm conditions and without a visual feedback condition in order to properly assess the effects of the musical note-phoneme and rhythm to grapheme pairing on phonemic awareness and reading ability. Observing the interventions effects on reading would require the creation of a different acquisition probe that would monitor the participants reading abilities.

Neuroimaging

The relationship between the neural networks used to process the various elements of speech, language, and music are continuously being investigated in hopes of discovering a way to facilitate speech and language learning. Although, many studies have found evidence for shared neural resources during speech, language, and music processing more research needs to be done to definitively establish functional correlations in neural anatomy used to process them. Electroencephalography (EEG) could be used to measure neural activity during spelling tasks and fMRI imaging could be used to look at what areas of the brain are engaged when tactile and auditory tones and rhythms are presented in conjunction with the spelling tasks. Identifying the neural interaction between speech, language, and music processing would allow for the development of a potentially effective multi-modal speech and language teaching intervention.

Spelling Teaching Technique

Positive Practice

The positive practice teaching method of copying the words on the computer twice each session was effective; however, different teaching techniques should be examined in conjunction with the auditory and tactile stimuli to see how error knowledge facilitates spelling acquisition with the external stimuli. Moreover, positive practice can be more effective when joined with positive reinforcement (Ollendick et al, 1980). In addition, Ollendick et al. 1980, demonstrated that positive practice may be most effective when used only for words that the participants spell incorrectly. Using the positive practice technique for every word during every session may slow the individuals learning progress, because the speller becomes comfortable with every input on the spelling probes irrespective of the practice accurate spellings of the target words during the instructional sessions.

Orthographic Spelling Tasks

To increase the rate of learning orthographic spelling strategy could be used in conjunction with a phonological spelling approach, because phonological knowledge is typically the first step to decoding unfamiliar words (Share, 1999). The phonological approach could be employed when the participant is copying the taught words after the computer presents the external tactile or auditory stimulus with the target word. Also, further investigation should be done regarding the Participants spontaneous use of phonological spelling strategies during the maintenance probes.

Furthermore, the orthographic spelling strategy used only included positive practice. Typically developing children between the ages of 5 and 7 years of age have demonstrated the ability to learn and understand phonology, form rules and morphology etymology concepts improving the student's spelling and literacy skills (Devonshire, Morries, & Fluck, 2013). Future studies could investigate the incorporation of these principles into MSAP and compare the effects of the program with typically developing individuals and children on the autism spectrum.

Intensity of Treatment

A future study could compare MSAP's effectiveness when teaching the target words once a week versus twice a week to complete the 10 instructional sessions. This would elucidate the optimal intervention intensity for these spelling tasks (Baker 2012).

CONCLUSION

The Participant demonstrated spelling acquisition over 10 instructional sessions and maintained the orthographic knowledge one month after the last instructional session. According to previous research, musical multimodal interventions may have a functional relationship to the development of language skills (Koelsch et al, 2005; Fedorenko et al., 2009; Heaton et al, 2007; Patel et al., 1998; Schön et al., 2010; Wan, 2011). However, further investigations need to be done to clearly delineate how that functional relationship can improve specific skills such as articulation, reading, and spelling. A comprehensive understanding of the relationship between music, language, and speech has yet to be achieved; however, this study stimulates ideas for future directions for multimodal speech and language interventions that can augment speech and language learning tools.

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