

THESIS

IMMEDIATE EFFECTS OF TRAINING WITH MUSICAL MNEMONICS
ON VERBAL MEMORY IN CHILDREN

Submitted by

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ABSTRACT

IMMEDIATE EFFECTS OF TRAINING WITH MUSICAL MNEMONICS ON VERBAL MEMORY IN CHILDREN

The purpose of this study was to compare the effects of musical mnemonics versus spoken word in training verbal memory in children. A randomized control trial of typically-developing 9-11 year old children was conducted using the Rey Auditory Verbal Learning Test (RAVLT), a test measuring a participant's ability to recall a list of 15 words over multiple exposures. Members of the group that listened to words sung to them recalled an average of 20% more words after listening to and recalling an interference list than members of the control group that listened to the same words spoken. This difference persisted, though slightly smaller (17%) when participants recalled words after a 15-minute waiting period. Group participants who listened to words sung demonstrated a higher incidence of words recalled in correct serial order. Potential contributions of musical mnemonics during the learning phase were also considered. While key findings were statistically significant, other examples of improved performance for participants who listened to words sung were below the level of significance. At times large standard deviations and varied performance across tasks may suggest these performance effects are susceptible to individual differences, or that heterogeneity of cognitive functioning levels was represented in the sample. These findings suggest that musical mnemonic training may be more effective than rehearsal with spoken words in verbal memory learning tasks in 9-11 year olds.

keywords: music therapy, mnemonics, verbal memory, RCT, AVLT

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CHAPTER 1: INTRODUCTION

A prevalent experience for many young children is learning the English alphabet using a commonly recognized melody, “Twinkle twinkle little star.” Songs are used by medical students and others in higher education to memorize complex material (Cirigliano, 2012). Despite the widespread use of this technique, there is little research on the use of musical mnemonics, or training of verbal memory using rhythmic and melodic presentation. While musical mnemonics are widely employed in teaching information such as the alphabet, little is known about the effects of musical mnemonics on learning in children and with special populations. Increased understanding of the effects of this learning strategy may lead to improved academic performance for typically developing children as well as those who struggle with traditional approaches to learning. Additionally, individuals with deficits in memory due to injury or illness may benefit from knowledge in this area.

Memory is a critical component of cognitive functioning and deficits to verbal memory are a feature of many neurological disorders and injuries (Dehn, 2010). A current theory of musical engagement based neuroplasticity suggests that deficits in verbal memory due to neurologic injury or illness might be improved through the use of musical mnemonics (Thaut, 2005; Thaut, Peterson & McIntosh, 2005). Improved performance on tests of verbal learning were found in adults with Multiple Sclerosis when verbal content was presented using rhythmic-melodic templates (Thaut, Peterson, McIntosh & Hoemberg, 2014; Thaut, Peterson, Sena & McIntosh, 2008). The purpose of this study is to compare recall and retention performance of verbal memory training with children using repeat exposure of either a rhythmically and melodically presented word list or the same word list presented spoken.

Background and Rationale

Deficits in verbal memory are features of many conditions including injuries, illnesses and neurodevelopmental disorders. Individuals with traumatic brain injury, brain tumor, epilepsy, stroke, developmental disability, autism, Attention Deficit Hyperactivity Disorder (ADHD) and Down syndrome may experience memory impairments (Dehn, 2010).

Furthermore, there is some indication that children with poor literacy may also have deficits in memory function. In a study of 104 kindergarten and first graders, Al Otaiba & Fuchs (2006) found scores of verbal memory to be consistently lower in the group not responsive to best-practice approaches to literacy in early childhood. In two British birth cohort studies, measures of literacy at age 21 were correlated with poor initial employment and career advancement (Bynner, 2004). Interventions that can improve verbal memory performance may impact early literacy for these special populations. Musical mnemonics may provide an approach to memory improvement in clinical populations as a simple strategy for memorizing important safety information such as a home phone number or address.

As meaning is often derived from the serial presentation of information, an important consideration in memory research is serial location and order. In trials of verbal memory, primacy refers to words initially presented in a learning list and primacy was found to be affected by memory dysfunction (Lezak, 1983). In normative trials with typically-developing 9-10 year-olds, serial position effects were noted for both primacy and recency (words presented at the end of the list; Forrester & Geffen, 1991). Given these known patterns of learning with both memory disordered and typical populations, it is also important to consider the effects of serial order in learning using musical mnemonics. Studies of individuals without hearing revealed decreased prefrontal cortical development as well as poorer performance on tests of sequencing than age

matched controls with normal hearing (Conway, Pisoni & Kronenberger, 2009). These findings suggest a privileged role for auditory information in the learning process. Music, as a system for delivering highly organizing auditory information, may have unique effects upon operations involving the phonological loop.

Researchers have investigated the effect of musical mnemonics training using rhythmic and melodic templates on verbal memory. An early study by Gfeller (1983) with children with learning disabilities found improved learning of verbal information in a sung condition. However, a recent study of three-to-five year old children with developmental disabilities using spoken and sung presentations of a seven digit number did not find any significant difference in conditions (Selph, 2015). In a study with adults with Multiple Sclerosis (MS) comparing recall performance of word lists that were presented either spoken or sung, participants in the music condition demonstrated improved memory for word order (Thaut, Peterson, Sena & McIntosh, 2008). Another study with individuals with MS utilizing a similar test procedure while also examining EEG activity found word order memory as predictive of higher overall word recall performance (Thaut, Peterson, McIntosh & Hoemberg, 2014). This study also found increased bilateral synchronization of the prefrontal cortices in participants who heard the word lists sung compared to those who heard the lists spoken. Termed by the authors as “learning-related synchronization,” this observation also corresponded with improved word order and overall word recall performance (Thaut, Peterson, McIntosh & Hoemberg, 2014, p. 3).

These findings appear to demonstrate a neurobiological difference in brain activity during verbal learning using spoken information when compared to information delivered using rhythmic and melodic templates. While these results suggest promise for the use of musical mnemonics with this adult population, their effects with children is largely unknown.

The music therapy approach of Neurologic Music Therapy utilizes a framework for treatment planning where non-musical exercises are translated into musical exercises targeting specific outcomes (Thaut, 2005). Standardized non-musical assessments are the most valid and reliable measures to demonstrate therapeutic outcomes from targeted musical engagement (Thaut & Hoemberg, 2014). The Rey Auditory Verbal Learning Test (RAVLT) is a widely used neuropsychological assessment instrument for verbal learning and memory (Schmidt, 1996). The assessment has been translated into a sung form and used with healthy adults (Thaut, Peterson & McIntosh, 2005) and with adults with MS (Thaut, Peterson, Sena & McIntosh, 2008; Thaut, Peterson, McIntosh & Hoemberg, 2014). Improvements in word order and recall with adults with MS was found when verbal memory was trained with music and this treatment effect size was used in a power analysis to estimate a proposed sample size to adequately answer the questions of the present study. The current study builds on previous research using a musical translation of the RAVLT with adults and seeks to establish a baseline understanding of the effects of musical mnemonics with typically developing children. Better understanding of interventions that improve memory performance may lead to benefits for populations affected by deficits in verbal memory.

Research questions

This study seeks to answer two central questions:

1. Are rhythmic and melodic templates more effective than verbal auditory presentations in trials of word list memorization with typically-developing children?
2. Does training with musical mnemonics demonstrate any advantageous serial order or position effects for typically-developing children?

Impacts and Limitations

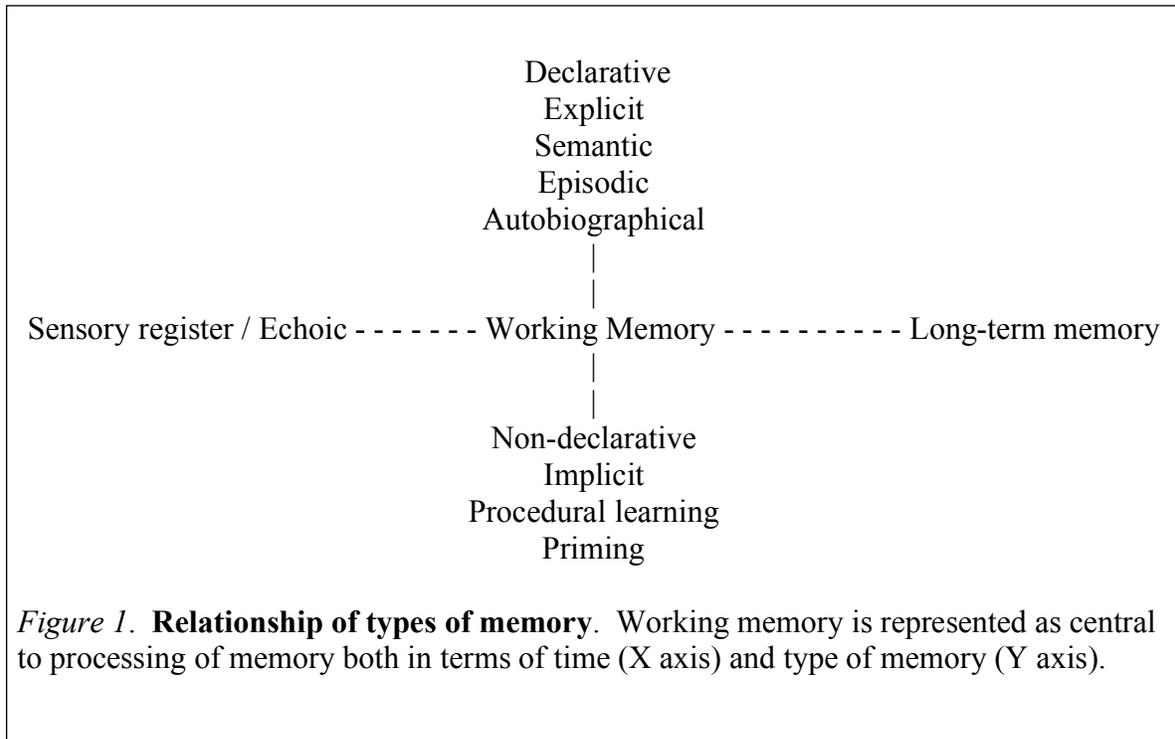
Immediate effects of musical mnemonics training using the RAVLT has yet to be established with children. A well-designed RCT with typically developing children would demonstrate any immediate effects of verbal memory training with rhythmic and melodic templates and would provide a baseline for further investigation with special populations. The present design assumes some limitations such as varying levels of cognitive functioning and maturation of the age range being recruited as well as reliance on parents to assess their child for inclusion and exclusion criteria. The study design assumes that musical translation of the RAVLT is sensitive to the main effect of musical mnemonics training on verbal memory in children.

CHAPTER 2: LITERATURE REVIEW

Defining Memory

Memory functioning is integrated into many cognitive processes and different forms of memory contribute to an individual's ability to learn and function independently (Dehn, 2010). In an effort to understand and define distinctions between memory processes and their neuroanatomical correlates, numerous terms have been used by memory researchers and theorists. Implicit, or procedural memory allows an individual to learn and repeat motor tasks, and informs other unconscious behaviors (Seger, 1998). Explicit, also called semantic or declarative memory, is the process whereby facts and verbal information is recalled (Squire, 2004). Declarative memories are further classified as episodic, memories related to personal experiences, or semantic, representations of facts (Tulving, 1972). In addition to these classifications of types of memory, time is another important factor to consider when defining memory processing.

Information arrives to us through our senses. Early work by Ulric Neisser identified a short term storage system for auditory information termed echoic memory (Bruce, 1989). The mechanism whereby these very short-term auditory sensory images are transformed into long-term memories is called working memory (Miller, Galanter, & Pribram, 1960). Figure 1 provides a key to some of the relationships of the different terms. The X axis represents the length of time information is retained and the Y axis represents the type of information.



Working Memory

Central to the translation of short term, echoic memories into long term declarative memories is the operation of working memory on the target content. Working memory enables an individual to retain sensory information for brief periods of time while also performing other cognitive operations on that information, such as retrieving information from long term memory. Baddeley and Hitch initially proposed a three-part working memory system to account for this (1974). In their model, two sensory storage systems, a phonological loop for auditory information and a visuospatial sketchpad for visual information, are engaged by a central executive function, modulating attention and accessing relevant long-term memories (Baddeley & Hitch, 1974). Following studies of amnesics with selective memory impairment, Baddeley (2001) later suggested a separate mechanism, called the episodic buffer, whereby long-term declarative memories are integrated into working memory.

Tests of performance of echoic memory found short-term storage limited from 2 to 4 seconds (Darwin, Turvey & Crowder, 1972). Seeking to further understand how sensory information is sustained for longer periods than a few seconds, Baddeley (1966) compared performance of lists of similar and dissimilar words and found that participants could more easily immediately recall lists of dissimilar sounding words. This led to his further defining the phonological loop as having not only the short term auditory sensory store that Neisser referred to as echoic memory, but also a subvocal system that operates in tandem refreshing selected sounds in the short term memory store (Baddeley, 2003). Interestingly, the performance limitations of phonemically similar words found in trials of short term memory were not found during repeated trials (Baddeley, 2003).

Early experiments done by George Miller (1956) led to observations that working memory processes allow us to group information together into meaningful chunks. As music is an entirely time ordered auditory language that utilizes a hierarchy of notes, phrases, motives and rhythms to organize and group information (Deutsch, 1982), it may provide additional structure in working memory tasks. Both aspects of the phonological loop, echoic memory and the subvocal rehearsal system, are central to both verbal memory and music processing. It appears there is significant overlap in theories governing auditory memory processing and music, but is there a neurological basis for music in memory training? Comparing the neural networks utilized by these processes may yield insight into how musical mnemonics may contribute to verbal learning through both shared and differentiated activations.

Neuroanatomy of Working Memory

Before the development of sophisticated imaging technology, researchers theorized the neuroanatomical correlates of working memory processes through the comparison of cognitive

tests, surgical reports or dissection of an individual's brain after death. In recent years, imaging tools have enabled identification of specific brain areas while performing memory tasks (Dehn, 2010). The phonological loop's phonological store and subvocal rehearsal system display left hemisphere dominance. Romero, Walsh, & Papagno (2006) reported the short term store of the phonological loop as located in the left inferior parietal lobule [supra marginal gyrus, Brodmann's area (BA) 40] with premotor regions (BA 44 and BA 6) being responsible for articulatory control process of subvocal rehearsal, while Baddeley (2003) reported BA 44 as being responsible for storage and BA 40 and BA 6 as responsible for subvocal rehearsal. While imaging can demonstrate brain areas used during a specific memory task, lesion studies identify those areas essential to performing specific memory tasks. Lesion studies suggest that areas of the inferior parietal cortex are required for the phonological sensory store and Broca's area, as well as supplementary motor association areas are responsible for subvocal rehearsal (Müller & Knight, 2006). While there are some inconsistencies between these reports, it appears that there are distinctly different neuroanatomical locations for the short term phonological store and the sub vocal rehearsal systems and that verbal working memory processes activate multiple left hemisphere neural circuits that control speech perception and production (Buchsbaum & D'Esposito, 2008).

The central executive component of working memory is utilized for monitoring, shifting attention, inhibiting interference and implementing strategies, all cognitive functions typically associated with prefrontal cortex processing (Dehn, 2010). Kane and Engle (2002) report that the dorsolateral prefrontal cortex is activated during working memory tests where participants are required to sustain target information while ignoring interfering stimuli. Dorsolateral prefrontal cortical areas have displayed greater activation with working memory tasks of

increasing complexity (Prabhakaran, Narayanan, Zhao & Gabrieli, 2000), reinforcing the role of the central executive in higher order cognitive functions required by working memory.

The episodic buffer provides working memory access to long term memories (Baddeley, 2000). In a verbal memory task where participants were presented a series of words visually, left and right hippocampal activations were found during encoding and retrieval phases (Karlsgodt, Shirinyan, van Erp, Cohen, & Cannon, 2005), and dorsolateral prefrontal cortex areas were found during the maintenance phase of processing (Karsgodt et al., 2005). This suggests a modulating role of the central executive on the key brain structure responsible for memory formation and links to long term memories for information being processed by working memory.

Brain areas responsible for other cognitive, motor and emotional experiences are also activated during working memory tasks, including the amygdala and thalamus (Cahill & McGaugh, 1998; Faw, 2003; McGaugh, 2004), suggesting that deep and integrated neural circuits are required for new long-term declarative memories to be made.

Neural Activations with Music

Music engages many of the same neural structures involved in working memory (Janata, Tillman & Bharucha, 2002) as well as deeply integrated cortical and subcortical circuits (Grahn & Rowe, 2009). Sound initially activates the short-term memory stores located in the auditory cortex and bilaterally in the temporal-prefrontal cortical areas (Alain, Woods & Knight, 1998; Koelsch, 2011). Pitch is processed in Heschl's gyrus, in both hemispheres (Patterson, Uppenkamp, Johnsrude & Griffiths, 2002) and rhythm activates subcortical structures such as the cerebellum and basal ganglia, as well as premotor cortex (Levitin, 2007). Lyrical content is typically processed in the same areas of the brain responsible for speech and language, including the hippocampus, Broca's area in the left temporal areas, as well as a right hemisphere homolog

to Broca's area (Alain, Woods & Knight, 1998). These findings demonstrate that music processing uses brain areas also used in working memory tasks.

Music's ability to attract attention and motivate engagement may benefit working memory training. Dopaminergic systems in limbic and paralimbic brain areas, areas responsible for reward and experiencing pleasure are activated with music (Koelsch, 2010). Additionally, the hippocampus, known to be responsible for creation of memory for new information, is also activated during music processing (Brown, Martinez & Parsons, 2004). Taken together, the activation of these shared and differential pathways provide rationale for training verbal memory using musical engagement. Through the shared neural architecture of working memory for verbal information, and the additional networks unique to music processing, musical engagement may provide a means for improving verbal memory (Thaut, 2010).

Memory Training with Mnemonics

Mnemonics are systems for representing information in ways that assist in memorization tasks (Wilson, 2009). Verbal mnemonics use words or phrases to represent target information, an example being Roy G. Biv representing the colors of the rainbow: Red, orange, yellow, green, blue, indigo and violet. Visual mnemonics take advantage of imagery or pictures, such as picturing a prominent facial feature of someone while thinking of their name (Wilson, 2009). Other mnemonic devices may use music or kinesthetic cues such as learning a sequence of movements for the song Itsy Bitsy Spider (Gardiner & Thaut, 2014). Mnemonics may be used in both the classroom with typically developing populations, as well as with clinical child populations experiencing memory impairment (Dehn, 2010).

Consideration of individual differences and preferences, in addition to being a cornerstone of evidence-based practice (Haynes, Devereaux & Guyatt, 2002), is important to the

successful utilization of mnemonics in real life situations (Wilson, 2009). Additionally, individual differences have been found in working memory processes (Unsworth & Engle, 2007). Processing of emotions has been implicated more broadly in memory functioning (Markowitsch, 2000) and one of the proposed mechanisms for music's success in therapy has been suggested to be its ability to produce an affective, aesthetic response (Thaut, 2005). Strategies that can leverage emotional salience for an individual may deepen engagement in the training, motivating implementation and influencing effectiveness of the strategy. Music has proven to be an attractive and compelling stimulus for many, so its use as a mnemonic rehearsal strategy may overcome barriers to practice that mnemonics such as method of loci have faced.

Training Memory using Music

Musical training has been shown to change brain structures and summaries of imaging studies conducted over the past twenty years corral evidence suggesting that regular study of music influences plastic changes in brain functioning (Habib & Besson, 2009; Moreno, Bialystok, Barac, Schellenberg, Cepeda & Chau, 2011; Wan & Schlaug, 2010). Correlational studies have found links between memory performance and musical training. Chan, Ho & Cheung (1998) found that adults who had musical training before the age of 12 had significantly better verbal memory performance than age-matched peers without early musical training. A later study conducted by Ho, Cheung & Chan (2003) found similar results with a child population. George & Coch (2011) compared event-related potential (ERP) data and performance on a standardized test of working memory of musicians and non-musicians and found both better performance measures as well as ERP data suggesting more efficient working memory performance in musicians. An experimental study of 4-6 year old children engaged in one year of Suzuki-based violin instruction performed better and improved more significantly

than their age matched peers in digit span memory tests (Fujioka, Ross, Kakigi, Pantey & Trainor, 2006). Taken together, this correlational and experimental data support theories that musical training has a transfer effect upon a participant's working memory ability. But targeted training of verbal memory using music can have more immediate effects on learning and verbal memory performance.

To better understand potential mechanisms of verbal learning training using music, Peterson & Thaut (2007) used electroencephalograph (EEG) measures to compare a sung version of the RAVLT with the conventional spoken version in a randomized trial with 18-26 year olds. The study authors found an increased oscillatory synchronization both within and between left and right prefrontal cortical areas in the group training with sung presentations of words. Study authors arrived at their dependent variable of learning related change in coherence (LRCC) (p. 218) by measuring synchronous firing of proximal pairs of scalp electrodes in one hemisphere with synchronous firing in the opposite hemisphere when a new word was recalled. The LRCC measure was examined during five trials representing learning and in recall following both a short and long delay interval. While this study only included 16 participants, it appears to demonstrate a key physiological difference in brain activity during verbal learning using musical templates and may point to mechanisms underlying training benefits found in previous studies of musical mnemonics.

Thaut, Peterson, McIntosh, & Hoemberg (2014) reported that adults with MS experienced increased bilateral synchronization in the prefrontal cortices when engaged in memory training using sung presentations of word lists. These recent reports suggest that in both typical adult as well as adults with MS, training using musical templates induces learning related synchronization when applied to verbal learning. Study authors suggested that it is the temporal

nature of music that results in these positive outcomes in verbal learning (Thaut, et al., 2014). Experimental data of training effects provide further evidence about the usefulness of musical mnemonics.

Gfeller (1983) conducted two experiments with 30 typically developing and 30 children with learning disabilities ages 9-11, using spoken and sung presentations of multiplication tables. In her first experiment one training session was provided for both groups and the group that listened to the spoken content recalled more information. In the second experiment, both groups received 4 different test conditions: 1) verbal rehearsal, 2) verbal rehearsal with modeling and cues, 3) music rehearsal and 4) music rehearsal with modeling and cues (Gfeller, 1983). Significant improvements were found in the group that trained with music rehearsal with modeling and cues and led the study author to conclude that "...the manner in which the strategy is presented and encouraged appears to be a crucial factor in that strategy's effectiveness" (p.188).

Further study of training with musical templates was conducted by Wolfe and Hom (1993). In their study with five year olds, telephone numbers were presented either spoken or sung using a familiar melody. Study participants in the sung condition required significantly fewer trials to learn the target telephone number. Wallace (1994) conducted experiments comparing spoken text versus sung text and found greater recall when text was presented using the rhythm and melody. Interestingly, when a line of text was sung only once, or if different melodies were used with each repetition of text, then spoken text enabled/led to improved recall. To understand the effects of musical templates on children with learning disabilities, Claussen and Thaut (1997) presented multiplication tables in spoken or sung forms. As in earlier trials, participants receiving the sung condition out performed their peers who heard the spoken

presentation of multiplication tables. Taken together, these experiments suggest that training of verbal memory with musical templates may be more effective than verbal memory training with spoken presentation. Furthermore, it appears that some of these benefits to verbal memory require multiple rehearsals, or training, to be observed (Wallace, 1994). A study by Moore, Peterson, O'Shea, McIntosh & Thaut (2008) examined recognition memory in adults with MS using a musical translation of the RAVLT, but found no significant differences in recognition scores between the group listening to word lists spoken and those listening to word lists sung. Recall performance on the learning trials was not described in this study.

While musical mnemonics has been explored with adults in recent years, musical mnemonics with children has not received as much attention. Most recently, Selph (2015), tested the effect of musical mnemonics with 3-5 year old children with developmental delay. Forty children were randomly divided into two groups, a control group listened to a spoken presentation of a seven-digit sequence while a test group listened to a sung presentation of the sequence. The familiar song "Old MacDonald" provided the rhythmic and melodic template for the number sequence. Selph's study was modeled after the RAVLT, with participants experiencing five learning trials, a one minute distraction condition (listening to a brief song) followed by a recall trial, a five minute delay and final recall trial. No recognition test was performed as part of this study. No significant difference was found between conditions and the study author suggested that the expectations of the test—learning a novel seven-digit sequence—may have been beyond the capacity of the study participants (Selph, 2015). While this study, like the study conducted by Wolfe and Hom (1993), utilized familiar music, it remains unclear if familiarity of the musical material is important in its function as a memory training tool.

Clearly there is much to be learned about the role of musical mnemonics training with both adults and children. Building on previous studies of musical mnemonics, the present study aims to identify effects of musical presentation of list words in a repeat exposure verbal memory task. Past studies have used either assumed familiar songs or novel melodies to deliver the verbal content. This study will use a novel melody to avoid any prior verbal associations with the musical content. By utilizing a musical translation of the RAVLT, an established method for quantifying verbal memory performance across a range of ages, the effects of musical mnemonics with typically developing children may provide a baseline for comparison with clinical populations and others with memory dysfunction.

CHAPTER 3: METHOD

A randomized and controlled group comparison study of the immediate effects of rhythmic and melodic templates on verbal recall, recognition and serial position and order effects using the RAVLT was proposed to the Institutional Review Board of Colorado State University and permission to recruit participants was granted. The RAVLT served as the instrument to compare memory performance with sung or spoken conditions. The music for the present study was a novel melody and different melodies were used for presentation of list A and list B words.

A power analysis to estimate sample size was conducted using data from Forrester & Geffen's (1991) large scale study of typically developing Australian children and Thaut, Peterson, McIntosh & Hoemberg's (2014) mean change between treatment and control groups of adults with MS. While a treatment effect found in a clinically affected adult population is not an ideal comparison for a typically developing child population, it was the best example provided by the literature to suggest a sample size. Interestingly, the mean retention score (the total recall of words from the original training list) for the 11 year olds was 9.5 (Forrester & Geffen, 1991), while the mean retention score for the adults with MS in the control group (participants who were presented with words spoken) was 9.7 (Thaut et al., 2014). This similarity in mean performance at the retention trial at least suggests some parity in terms of raw performance on the RAVLT. Adults with MS who were presented with sung words performed better at retention, scoring a mean of 11.6 words (Thaut et al., 2014). A similar percentage change in retention score (12.3% or 1.8 words) in the proposed sample would require a total n of 26, or 13 participants per group with an alpha of 0.05 to yield power of 80%. As this study posed less than minimal risk, a total of 40 participants was permitted by the Institutional Review Board (IRB) of Colorado State University (CSU). Solicitations were distributed through the Institute for

Translational Health Sciences research database and monthly via email and flyer through social media networks.

Research Design

Study participants were randomized into two groups: 1) those who listened to a 15-word list spoken and 2) those who listened to the list sung [see Appendix A for primary (List A) and interference (List B) words and music notation]. Within each group, dependent variables included recall, recognition and serial word order performance over the 10 observations [Learning trials for list A, 1-5; learning trial for list B; list A trial 6 (after distractor list B); list A trial 7 (after time delay) and the recognition test (identification of list A and B words)].

In order to understand the differences between groups, the between-subject factor of group and within-subject factor of time was compared. The independent variable was presentation type comprised of two conditions: a musical setting of the RAVLT where word lists for trials A1-5 and B were presented sung and the standard presentation of the RAVLT with word lists presented spoken. Participants listened to a recorded presentation of the narrator that provided brief instructions and presentation of the words (see Appendix B, Narrator's instructions to participants).

Participants

A convenience sample of typically developing children ages 9 - 11 was recruited and randomly assigned to either the sung condition or the spoken condition. Inclusion criteria required participants to be between 9-11 years old and have normal hearing. All parents responded to the call for participants via email or phone and were directed to consider inclusion and exclusion criteria to determine if their child was "typically developing" and without any known developmental or sensory processing disorders.

A block randomization list indicating the order of assignment of participants was created by the Principal Investigator and submitted to the IRB. Subjects were assigned either the control or test condition according to this randomization schedule. Chronology was demonstrated through the codes as each included the date (and a letter if there were multiple participants on a single day) and whether they received the test (Y) or control (X) condition. Confirmation of agreement with the block randomization is possible by examining the randomization schedule and the participant code list. While a total of 33 participants were recruited and participated in the study, one was disqualified from inclusion. The disqualified participant was found to have ADHD but arrived at the test center with his mother and sister (who was to participate in the study). Despite the fact that this participant was eager to participate and performed quite well, these data were not included in the analysis.

Measures

Andre Rey, a French memory researcher, developed a 15-word test of verbal memory that proved to be a valuable contribution to the future study of memory (1958). The Rey Auditory Verbal Learning Test (RAVLT) was adapted for English use by Taylor (1959) and included special procedures for children (Schmidt, 1996). Procedures for this study were based on prior research utilizing the RAVLT: Taylor (1959), Lezak (1983) and Thaut et al, (2014). The RAVLT is a test of verbal learning using a list of 15 unrelated words. Because the RAVLT utilizes a repeated presentation of word list, a participant's learning across multiple trials can be examined, as well as observing interference effects from introduction of a distraction list (List B), retention of the original list after the distraction list, as well as recall after a waiting period.

In keeping with typical administration of the RAVLT, the words were presented one per second and the participant was asked to recall as many words as possible after each presentation.

An initial series of five presentations (T1-5) was followed by presentation of a second list of words that served as a distractor list (T6 – List B). After attempting to recall the distraction list words, the participants were again prompted to recall the words from the original list (T7, or retention trial). Participants were then provided a 15-minute time break. After the 15-minute wash-out period, participants put on headphones and again were prompted by the narrator to recall the original list words (T8, or delayed recall trial). After this final retention phase, participants were presented with the Recognition test (see Appendix E). The Recognition test was a written form used in prior studies of the RAVLT (Schmidt, 1996), a single page containing 50 words: Words from both lists A and B as well as 20 other words that were not presented on either list. Participants were given brief instructions from the rater to place an “A” next to words they recognized as being on List A – the list they heard multiple times—and a “B” next to the words they recognized as being on List B—the list they heard only once. Participants were instructed to ignore words they did not hear on either list. This was a departure from an aural administration of the recognition portion of the RAVLT, as it required the participant to reference the target content (List A and List B words) as written rather than auditory information.

The text for the test condition was derived from the original Taylor (1959), and included some of the positive, reassuring characteristics noted in Taylor’s version (Schmidt, 1996). As understanding serial order effects was a question for this study, the instruction “*You do not need to say them in the order I read them.*” was not included.

Retention and recall

The RAVLT provides an opportunity to examine several aspects of a participant’s memory performance. Comparison of individual trials provide information about the influence of music training at stages of acquisition of auditory verbal information, while comparison of

summary and composite scores provides insight into the learning process. Dependent variables for this study include recall scores at retention (Trial 7, following presentation and recall of distractor list), delayed recall (Trial 8, following a 15 minute wash out interval) and recognition. Interference on learning was recorded by counting repetitions (all instances of a word being repeated during recall), intrusions (words that are recalled by a participant but that do not appear on the target list), contaminations (words incorrectly recalled as belonging to the opposing list). The co-PI and inter-rater used the recall scoring form (see Appendix C) to transcribe and score the recording of each participant's performance.

Acquisition and learning

Total learning (summary of trials 1-5) is a commonly reported measure of RAVLT performance (Forrester & Geffen, 1991; Schmidt, 1996) and provides a summary of participant initial learning before presentation of interference from a distractor list or time delay.

Researchers have developed composite scores in an attempt to isolate the performance of repeated practice, eg. learning, by removing the influence of the initial response to the words.

In order to better isolate the learning process from the initial recall after the first learning trial, Ivnik (1992) suggested a corrected total learning score that eliminates the participants recall performance for Trial 1 (see Figure 2). By eliminating the effect of performance of Trial 1 across the five trials of List A words, a better representation of the effects of repeated practice is purportedly represented.

$$\text{Corrected Total Learning} = (\text{sum of T1-5}) - (5 \times \text{Sum of T1})$$

Figure 2. Expression for Computing Corrected Total Learning.

The corrected total learning score is the sum of all words correctly recalled over the 1st 5 learning trials minus 5 times the words recalled in the 1st learning trial.

Learning rate is another measure commonly used to represent the learning process and is computed by subtracting the number of words recalled in Trial 1 from the number of words recalled in Trial 5 (Vakil et al., 2010). Composite scores were computed to compare effect of independent variable on measures of learning. Differences in total learning, corrected total learning and learning rate scores of both groups were considered in the data analysis to assess the effects of musical verbal learning training during the learning phase.

Finally, interference in verbal learning as measured by intrusions (words not found on the target list) and repetitions (words repeated during a recall trial) were counted for the first 5 trials, at retention recall (T7) and the delayed recall trial (T8). Contaminations (assignment of a List A or List B word to the opposing list) were counted at trials 6, 7 and 8. Intrusions and contaminations were counted in the recognition test.

Serial order

Serial word order was examined through the measure of pairwise word order recall (Thaut et al., 2014). A measure of order of recall, each pair of words recalled in the order they were presented received a score of one. A total of 14 represented all 15 words recalled in order. Repeated pairs were not counted a second time, however if a single word repetition resulted in a correct word pair order that had not been counted (for ex. “school, drum...school, parent”) recall order for that word pair was counted.

Serial position effects

Location of recalled words on the list was calculated by tallying the totals for each of 5 positions of list words: position A=words 1-3, position B = words 4-6, etc. For a more detailed description of position scoring, please see the Recall Scoring Rubric (Appendix D). Generally, a prevalence of memory for words from the beginning of lists is considered primacy while

remembering words from the end of a list is commonly referred to as recency. Words from the middle of a list are referred to as such. Differences in serial position were compared between groups to identify potential effects of musical verbal training on primacy or recency in recall.

Recognition

Recognition scoring included tally of correctly identified List A and List B words, as well as incidence of list assignment to non list words (intrusions) and list assignment to the opposing list (contaminations).

Procedure

The child and parent were met at a private test center in the Northwestern United States. A script for meeting families and child participants was used, including a brief greeting, an orientation to the testing area (water provided, access to restroom facilities) and initial introduction to the test procedure. Instructions to the participant included information about expectations for the test, including that they would be wearing headphones, listening to instructions from a narrator, and being presented with a list of words they would have to say back. After these initial instructions, the assent form was read to the participant and both assent and parental consent forms were signed.

The participant then put on Sennheiser headphones Model HD-202 to hear a short recording to ensure satisfactory volume level, followed by an audio recording of either the control or experimental condition according to the block randomization schedule, played through an iPod Model ME178LL/A, iOS 6.1.2. As the first published instructions for the procedure were developed for children (Taylor, 1959; Schmidt, 1996), and this test was conducted with children, the narrator for this test was an 11-year-old female. The intention behind this choice for a child's presentation of the instructions for the test procedure was to facilitate peer

engagement in the testing process and reduce some of the unpredictability noted in studies with children. Full transcript of narration is available in Appendix B (Narrator's instructions to participants). Words used for the memory trials and the recognition test were materials used in prior trials of the RAVLT (Schmidt, 1996).

The control condition consisted of listening to a list of 15 unrelated words presented spoken at one per second. Immediately following hearing the list of words, the child was prompted to say back as many words as they could recall. A Sony PCM-D50 Linear PCM recorder and stereo Tascam TM-ST1 condenser microphone was used to record the participant's responses for later transcription. For the first list of words (List A), there were five learning trials (T1-5). Following learning trial T5, a second list of 15 words (List B) was presented (Trial 6), and the participant was prompted to say back as many words as they could recall of the List B words. The participant was then asked to recall words from List A (Trial 7), but without hearing them as before. After this seventh trial, a 15-minute break was provided to enable a delayed recall and recognition assessment. During the 15-minute waiting interval, the participant and parent were offered water, use of the restroom facilities and allowed to wait in the testing area or in the waiting room of the facility, a simple space with 3 chairs, a table and an assortment of reading materials.

Following the break, the participant and parent returned to the test area and the participant again put on headphones and was prompted by the narrator to recall the List A words again (Trial 8). The participant was then provided with a list of 50 words including words from List A, List B and semantically and phonemically related "foil" words (Schmidt, 1996). The participant was asked to place an A next to the words they recognized as being from List A (the list of words they heard several times) and to place a B next to words they recognized as being

from List B (the words they heard only once). They were instructed to ignore the words they did not recognize from either List A or B.

The test condition followed the same procedures as the control condition with the exception that word lists were presented in sung form using an original rhythmic and melodic framework. The order and timing of words were presented just as in the control condition, but with a melodic contour and an accentuation of rhythm with two syllable words being sung as $\frac{1}{2}$ second $\frac{1}{8}^{\text{th}}$ notes (see Appendix A). This musical translation of the original RAVLT procedures provided a model for examining the immediate effects of musical training on verbal memory performance outcomes using a standardized assessment tool.

To reduce risks to internal validity, participants were randomly assigned to either the treatment or control group based on a pre-determined randomization schedule and testing procedures were developed to ensure control and test groups received identical presentation of the test with the only exception being words presented spoken or sung. The presentation of the words through a recording of a narrator was designed to limit any interaction biases between the examiner and the participant. Additionally, observations of emotional reactions were captured by the co-PI, noting specific complaints of participants and tallying emotional and environmental reactions using provided score sheet [single complaint (statements of being bored, tired, test difficulty = 1 point), each instance of complaint = 1 point]. Additionally, the co-PI noted reactions or environmental issues during the test that may have limited a participant's engagement in the test procedure. Through these measures, a qualitative analysis of participants' reactions to the test procedures provided additional information about individual performance.

After the participant completed the recognition test, the examiner provided the parent and participant with exit surveys in order to share their experience as study participants. Upon

completion of the exit surveys, both participant and parent were thanked for their participation and the participant was provided with \$15 compensation.

Data Analysis

An audio recording of each learning trial was made and coded for later review by the co-PI and an inter-rater to verify correct scoring of participant performance. Initial acquisition and learning (learning trials 1-5), retention (recall of primary list after presentation and recall of distractor list), and delayed recall (recall of primary list after 15 minute wash-out interval) were transcribed independently by the co-PI and the inter-rater. Total words recalled, repetitions, intrusions, and contaminations were tabulated for each trial, as well as serial position, and pairwise order effects. The co-PI and inter-rater independently scored each participants recognition test (identifying List A and B words from a larger list of similar sounding words). Results from hand scoring were entered into a spreadsheet for further statistical modeling and comparison of inter-rater agreement. Data was not found to be normally distributed so Independent Samples Mann-Whitney-U tests were used for analysis of all hypotheses and exact *p*-values were reported.

Results

Interference effects were considered by counting incidence of repetitions, intrusions and contaminations across trials. Repetitions across both groups were minimal [Trials 1-5 M(SD) - Spoken: 1.9 (2.8), Sung 2.8 (3.1)] and this difference was not found to be statistically significant (Mann-Whitney-U: $U = 92.0$; $p = 0.184$). Intrusions across both groups were also minimal [Trials 1-5 M(SD) – Spoken: 0.4 (0.6), Sung: 1.6 (2.0) and this difference was also not found to be statistically significant (Mann-Whitney-U: $U = 83.0$; $p = 0.094$)]. Contaminations were limited across both conditions [M(SD) - T6 Spoken: 0.1 (0.3), T6 Sung: 0.1 (0.3); T7 Spoken:

0.2 (0.5), T7 Sung: 0.0 (0.0)] and these differences were also not found to be statistically significant (Mann-Whitney-U: T6: $U = 128.0, p = 1.000$; T7: $U = 112.0, p = 0.564$). As analysis using Mann-Whitney-U tests found distributions of repetitions, intrusions and contaminations to be equally distributed in both conditions, no adjustments to raw scores were made to account for interference for any participant. As score data referenced integer (single word) counts, summary statistics were reported with one decimal point precision.

Inter-rater reliability

Table 1

Intra-Class Coefficients (ICC) for co-PI and Inter-rater Data Sets by Dependent Variable

Trial	Co-PI	Inter-rater	ICC
	M(SD)	M(SD)	
T7	9.9(3.6)	9.9(3.6)	1.000
T8	10.1(3.2)	10.1(3.2)	.998
T1-5	44.1(11.7)	43.9(11.7)	.933
CTL	18.8(7.8)	18.7(7.4)	.830
LR	5.9(2.4)	5.8(2.5)	.982
T7PO	2.7(3.5)	2.6(3.6)	.989
T1-5PO	11.1(8.6)	10.8(8.4)	.991
T8PO	3.2(3.5)	3.0(3.2)	.975
T1-8PO	17(14.8)	16.9(17.2)	.976
Rec A	13.4(2.1)	13.5(2.0)	.979
Rec B	6.8(2.9)	6.5(2.7)	.793
SP1-5a	10.1(3.2)	10.1(3.2)	.998
SP1-5b	9.9(3.3)	9.9(3.3)	1.000
SP1-5c	6.2(3.1)	6.1(3.1)	.997
SP1-5d	8.3(3.1)	8.2(3.3)	.989
SP1-5e	9.4(2.9)	9.4(3.0)	.991

Note. T7 = Trial 7, T8 = Trial 8; T1-5 = Total, Trials 1-5; CTL = Corrected Total Learning; LR = Learning rate; PO = Pairwise order; Rec = Recognition scores for Lists A and B; SP = Serial position (a-e) totals for trials 1-5.

Effectiveness of the randomization

Inter-rater reliability was established through use of the Intra-Class Coefficient (ICC) statistical procedure. The ICC is a measure of agreement between two sets of data with the score

of 1.000 representing absolute agreement. ICC tests were completed for dependent variables T7, T8, T1-5PO, T7PO, T8PO, Serial position and Recognition score dependent variables. ICC comparisons of the co-PI's and Inter-rater's scores are represented in Table 1.

The distribution of age was found to be the same across spoken and sung groups (Mann-Whitney-U: $U = 85.5$; $p = 0.110$) and gender was split evenly as well (spoken word group: 5 female, 11 male; sung word group: 5 female, 11 male). Further comparison of demographics found no significant difference of mean in the sung condition between girls (T7: 11.6, T8: 11.6) and boys (T7: 11.3, T8: 11.3) (Mann-Whitney-U: T7: $U = 24.5$, $p = 0.743$; T8: $U = 24.5$, $p = 0.743$). While some difference in the mean was found between girls (T7: 10.4; T8: 9.8) and boys (T7: 7.5; T8: 8.4) in the spoken condition, these differences were also not found to be statistically significant (Mann-Whitney-U: T7: $U = 17.0$, $p = 0.267$; T8: $U = 20.5$, $p = 0.441$). This suggests that the key demographic considerations of age and gender were equally distributed between groups.

Recall measures

Table 2

Mean Recall and Composite Scores By Group for All Trials

Trial	Spoken		Sung		Total	
	<i>n</i>	M (<i>SD</i>)	<i>n</i>	M (<i>SD</i>)	<i>n</i>	M (<i>SD</i>)
T1	16	4.8 (2.5)	16	5.3 (2.0)	32	5.1 (2.2)
T2	16	7.6 (2.2)	16	7.9 (1.4)	32	7.8 (1.8)
T3	16	8.8 (3.2)	16	9.9 (2.3)	32	9.3 (2.8)
T4	16	9.9 (3.4)	16	11.4 (2.1)	32	10.6 (2.9)
T5	16	9.8 (3.7)	16	12.2 (1.8)	32	11 (3.1)
T1-5 total	16	41.4 (14.7)	16	46.8 (7.3)	32	44.1 (11.7)
T6 (List B)	16	3.6 (1.5)	16	4.1 (1.4)	32	3.9 (1.5)
T7*	16	8.4 (4.1)	16	11.4 (2.4)	32	9.9 (3.6)
T8*	16	8.8 (3.5)	16	11.4 (2.4)	32	10.1 (3.2)
CTL	16	17.4 (7.8)	16	20.2 (7.7)	32	18.8 (7.8)
LR*	16	4.9 (2.1)	16	6.9 (2.4)	32	5.9 (2.4)

Note. *significant at $p < .05$; Composite scores: CTL = Corrected Total Learning, LR = Learning rate.

Mean recall scores for each trial, by group are provided in Table 2. At retention (T7), the mean of the sung word condition was 11.4 words (SD = 2.4) and the mean of the spoken condition was 8.4 (SD = 4.1) words. Analysis using the Mann-Whitney-U test found this difference at the retention stage as statistically significant ($U = 70.5, p = 0.029$). Analysis using Cohen's d found this effect size was found to be large ($d = 0.893$).

At the delayed recall trial (T8), participants who listened to words sung outperformed those who heard words spoken by an average of 2.6 words. Analysis using Mann-Whitney-U found this to be a statistically significant difference in performance ($U = 73.5, p = 0.039$). A Cohen's d analysis of the difference between the treatment and control group at delayed recall also found a large effect ($d = 0.866$).

Acquisition and learning measures

Learning was modeled through comparison of three scores: Total learning, corrected total learning and learning rate. *Total learning* – the sum of all correctly recalled words across Trials 1-5 provides a measure of overall performance over the course of multiple repetitions of the same list of words (Vakil et al., 2010). In terms of total learning, participants who listened to words sung recalled on average 5.4 more words than those who experienced the spoken condition. This difference was not found to be statistically significant (Mann-Whitney-U: $U = 105; p = 0.402$).

Composite scores represent quantitative approaches to parsing participant learning performance. In both composite scores of learning calculated in this study, total corrected learning and learning rate, differences were found between groups, however learning rate was the only composite score found to have a statistically significant difference between groups. On average, the participants who heard the word lists sung had a corrected learning rate of 2.8 more

words than those who heard the words spoken, but this positive difference was not found to be statistically significant (Mann-Whitney-U: $U = 99.5$; $p = 0.287$). When learning rate was considered, again a positive difference was found in favor of the music training condition, with participants who heard word lists sung recalling 2.0 words more on average in Trial 5 than in Trial 1 compared to participants who heard words spoken. This difference was found to be statistically significant (Mann-Whitney-U: $U = 69.0$; $p = 0.026$) and to have a large effect size (Cohen's $d = 0.887$).

Serial order effects

In the present study of typically developing children, participants who listened to words sung recalled more words in the order they were presented across all trials. Table 3 provides an overview of pairwise order performance for both groups: Total word pairs recalled in order for Trials 7 and 8, as well as totals for Trials 1-5 and total of all trials for List A (Trials 1-8).

Table 3

Pairwise Order Totals and Summary Scores

Trial	Spoken		Sung		Total	
	<i>n</i>	M (<i>SD</i>)	<i>n</i>	M (<i>SD</i>)	<i>n</i>	M (<i>SD</i>)
T1-5PO*	16	7.8 (3.6)	16	14.4 (10.8)	32	11.1 (8.6)
T7-PO*	16	1.3 (1.6)	16	4.0 (4.3)	32	2.7 (3.5)
T8-PO*	16	1.7 (1.3)	16	4.7 (4.3)	32	3.2 (3.5)
T1-8 PO*	16	10.9 (5.3)	16	23.1 (18.6)	32	17 (14.8)

Note. *significant at $p < .05$; PO = total word pairs recalled in correct serial order.

In all measures of pairwise order for List A words, the group who listened to words sung had a statistically significant increase in scores when compared to those who listened to words spoken. Average pairwise word recall total for the spoken word group at Trial 7 was 1.3 words while the sung word group at Trial 7 recalled 4 words on average. This difference was found to be statistically significant (Mann-Whitney-U: $U = 71.0$; $p = 0.032$; Cohen's $d = 0.827$). Mean

Pairwise word order difference between groups for Trial 8 was 3 words ($U = 58.5$; $p = 0.007$; Cohen's $d = 0.947$). Mean difference between groups in total of trials 1-5 was 6.6 words ($U = 74.5$; $p = 0.043$; Cohen's $d = 0.828$) and combining pairwise order performance across all learning trials of List A words (Trials 1-8), mean difference between groups was 12.2 words ($U = 59.0$; $p = 0.008$; Cohen's $d = 0.887$).

Serial position effects

Recency and primacy effects were considered by comparing summary totals of serial position scores between groups. In serial position A (words 1-3), the average total words recalled across trials 1-5 was 10.1 for both groups. In the following positions, there were more words recalled by participants who listened to words sung. Participants in the sung word group recalled a mean increased difference of 1.1 (at position B), 1.8 (at position C), 1.2 (at position D) and 1.8 (at position E) words across learning trials 1-5 than participants who heard words spoken. These data suggest a tendency for participants who heard words spoken to better recall words from the beginning of the list, followed by words from the end of the list and finally, words from the middle of the list. These primacy, then recency effects were very similar for participants who heard words sung, but with better performance in that group of words recalled in recency positions, followed by the middle position.

While these positive differences in the sung word condition were present, they did not reach statistical significance when compared to the same serial position scores of the spoken word group. As with recall data, serial position data was not normally distributed. Mann-Whitney-U tests found no significant differences between groups at any serial position [Serial Position A totals for trials 1-5(SP1-5A): $U = 116.0$, $p = 0.669$; SP1-5B: $U = 111.0$, $p = 0.539$; SP1-5C: $U = 82.5$, $p = 0.086$; SP1-5D: $U = 107.5$, $p = 0.445$; SP1-5E: $U = 83.5$, $p = 0.094$]. As

no significant differences were found between groups in any of the positions, this statistical model does not require application of the Bonferroni correction.

Recognition

Difference in raw recognition scores for both groups was minimal and influence of intrusions and contaminations was not statistically different across groups. Mean List A words correctly identified by participants of the spoken word group was 13 words (SD = 2.6) while the sung word group participants identified 13.8 words (SD = 1.4) (Mann-Whitney-U: $U = 108.5$; $p = 0.468$). Mean List B words correctly identified by participants in the spoken word group was 7.1 (SD = 3.2) while test group participants correctly identified 6.6 (SD = 2.6) ($U = 121$; $p = 0.809$). While participants who listened to words sung performed marginally better in identifying List A words and spoken condition participants marginally better in identifying List B words, Mann-Whitney-U tests revealed both differences to be below the threshold for statistical significance. Additionally, there was no statistically significant difference between groups for recognition intrusions (Rec-A-intrusions: $U = 99.5$, $p = 0.287$; Rec-B-intrusions: $U = 95.5$, $p = 0.224$) or contaminations (List A words assigned to List B: $U = 89.5$, $p = 0.149$; List B words assigned to List A: $U = 102.0$, $p = 0.341$).

Table 4

Recognition Scores for Words Correctly Identified, Intrusions, and Repetitions

Trial	Spoken		Sung		Total	
	<i>n</i>	M (<i>SD</i>)	<i>n</i>	M (<i>SD</i>)	<i>n</i>	M (<i>SD</i>)
List A	16	13 (2.6)	16	13.8 (1.4)	32	13.4 (2.1)
A:B	16	0.9 (1.1)	16	0.4 (0.6)	32	0.7 (0.9)
A-intrusion	16	1.2 (1.4)	16	0.6 (0.6)	32	0.9 (1.1)
List B	16	7.1 (3.2)	16	6.6 (2.6)	32	6.8 (2.9)
B:A	16	0.6 (1.0)	16	0.3 (0.6)	32	0.4 (0.8)
B-intrusion	16	2.1 (4.3)	16	2.3 (2.5)	32	2.2 (3.4)

Note. A:B = List A assigned to List B; B:A = List B assigned to List A.

CHAPTER 4: DISCUSSION

The purpose of this study was to compare the effects of musical mnemonics versus spoken word in training verbal memory in children. A randomized control trial of typically-developing 9-11 year old children was conducted using the Rey Auditory Verbal Learning Test (RAVLT). Participants who listened to words sung remembered 20% more words at the retention trial (T7) and 17% more words at the delayed recall trial (T8) than participants who listened to words spoken. Similar proportion increases were observed in serial order scores as participants who listened to words sung recalled more words in the order they were presented (19% at T7 and 22% at T8) than participants who listened to words spoken.

Results of this study provide positive initial data demonstrating benefits of musical mnemonics training of verbal memory in typically developing 9-11 year olds. While these results are promising, there are several factors that should be considered when interpreting these data. Threats to internal validity were limited through random selection via block randomization schedule, maintaining consistent test procedures and limiting participants to a narrow developmental band (ages 9-11). However, by allowing parents to interpret the inclusion criteria of “typically developing” and “with no known neurodevelopmental or sensory processing disorder,” without a measure to confirm participant’s baseline cognitive performance, greater heterogeneity may have been introduced into the sample. Greater heterogeneity in the participant pool may have been responsible for the large standard deviations seen in some of the dependent variable scores for both groups. Inclusion of a separate measure of memory performance for all participants may have provided a better control of the sample. This study would also have benefited from an alternate treatment group. A similar but contrasting mnemonic technique may clarify the relevance of musical mnemonics on verbal memory.

Comparison with normative data of 9-10-year-olds from the Forrester & Geffen (1991) study [T1-5 total: 46.7(5.4); T7: 9.3(2.5); T8: 9.9(2.3)] finds the corresponding values from the present study slightly smaller. One possible reason for this difference may be the absence of visual modeling cues that a presentation of the words by a live test administrator would afford. The present study utilized a recording instead of the live presentation of words in Forrester & Geffen (1991).

The significance of musical mnemonics training over traditional spoken verbal learning is most clearly demonstrated in the learning process after interference of the competing list (Trial 7) and following a 15-minute wash out period (Trial 8). These are encouraging findings for consideration of musical mnemonics in verbal learning tasks as these two points in the learning process—after interference from a distraction and after a time delay—are frequently considered measures in AVLT reporting. While no statistical difference was found between groups in performance of List B words, these findings in favor of musical mnemonics at T7 and T8 may indicate a resistance to retroactive inhibition—a tendency for recently learned information to inhibit the recall of what had been previously learned. Musical mnemonics may then be especially useful for populations with memory deficits susceptible to retroactive inhibition.

In terms of effect during the learning phase, it appeared that the improved performance of the sung word group occurred in the later trials. Participants who listened to words sung demonstrated an only marginal mean positive difference in Trials 1 and 2, while the differences increased with Trial 3 (1.19 words), Trial 4 (1.5 words) and especially Trial 5 (2.44 words). Markedly improved performance for test group participants in these later stages of the training phase may have contributed to the significant differences seen in Trials 7 and 8. This improved performance in the sung condition group was also present in the composite learning rate score

and suggests that music's benefit to verbal memory training is more pronounced after repeated practice.

Similar effects were seen with serial position scores as more words from the middle to recency positions were recalled by sung group participants than by spoken group participants. Again, while these differences were not statistically significant in comparisons between groups for each position, the trend of improved performance of recently presented material is observable through comparison of means.

Previous studies of a similar test paradigm (Thaut et al., 2008, 2014) found improved pairwise word order in subjects who listened to word lists sung, in contrast to subjects who listened to the spoken condition. Results from the present study extend this observation with typically-developing children ages 9-11. Considering the apparent superiority of musical mnemonic effects on serial order of verbal memory, clinicians should make efforts to consider this application in treatment plans for clients and patients with specific verbal memory needs.

While the results of this study are promising in the area of acquisition, recall and retention, they did not support any significant difference of repeat listening of sung verbal information on recognition. While training verbal memory through presentation of sung words was as effective as spoken word presentation in recognition, it's real value may be in recall and retention tasks where cues for retrieval are unavailable and where remembering the correct order of the information is most important.

Implications for Clinical Practice

The effects of musical presentation on verbal memory appear to be strong, as reflected in the large effect sizes at T7 Retention (Cohen's $d = 0.894$) and T8 Delayed recall (Cohen's $d = 0.893$). Given that this effect was identified with typically developing children, it's application

for learning verbal material should be considered, especially for verbal memory tasks that require recall versus recognition. Helping a young child remember a phone number or address may be a concern for a parent, while older children and adults may struggle to recall passwords and academic concepts. These safety, autonomy and educational applications are but a few of the examples of how musical mnemonics can improve an individual's functioning.

Additionally, these effects of improved recall and order for verbal information delivered rhythmically and melodically should be further investigated to better understand how they may be applied with special populations. The participant that was disqualified from inclusion in the study outperformed the mean for the music group at both T7 retention trial and T8 delayed recall trial by 2.6 words. Additionally, his serial position scores demonstrated that he recalled more words over trials 1-5 from the prime positions (positions a and b), in contrast to the effects seen with the study population. Considering that primacy deficits are common in individuals with memory dysfunction (Lezak, 1983), this individual's robust performance in this area seems surprising. While this is only one individual's performance, it was exceptional. More study of musical mnemonics with this and other special populations is needed to determine their potential benefits for verbal learning.

The choice of musical materials used in this study—only rhythmic and melodic—should be considered by clinicians. While it may be easier for non-musicians to integrate this simplified approach as an additional learning strategy, it does not represent typical music therapy practice where harmony and musical form would likely be present in the mnemonic training. Clinicians implementing musical mnemonic interventions should consider their client's response to presented materials and adjust accordingly as additional materials such as harmony may assist some in attending to the learning process or too stimulating for others.

Conclusions

The results of this study suggest that training of verbal memory using musical mnemonics has a pronounced effect on both overall recall and serial word order recall and is superior to training verbal memory with spoken word . The biggest differences between groups were seen in the area of pairwise order and may suggest a link between correct order and overall performance, as seen in a previous study (Thaut et al., 2014). These limited findings suggest further research is needed to understand the nature of musical mnemonics training during the learning phase as well as connections between word order and overall word recall performance. Musical mnemonics should be implemented with typically developing populations and further research in education and with clinical populations is needed.

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APPENDIX A

Primary and Interference Lists Music Notation

Primary (List A) melody

♩=60



1
drum cur-tain bell cof-fee school par-ent moon gar-den hat far-mer nose tur-key col-or house ri-ver

Interference (List B) Melody

♩=60



1
desk ran-ger bird shoe stove moun-tain glass-es tow-el cloud boat lamb gun pen-cil church fish

Figure 3. Primary and Interference Lists Music Notation. Words, melodic and rhythmic notation used in Primary and Interference lists.

APPENDIX B

Narrator's instructions to participants

The following transcript provides a description of the recordings heard by study participants as well as notes about the procedure to give additional context for the reader. The test (sung) condition included the word “sing” and words were presented sung. The control (spoken) condition included the word “read” and words were presented spoken. Words in bold italics represent the recorded narration heard by study participants.

I am going to read/sing a list of words to you. After I have finished, I want you to say them back to me. Try to listen carefully and to remember as many as you can. Listen carefully.

Here I go.

(first presentation of the words)

Now you go ahead, tell me all the words you can remember.

A 30 second response period was provided in the recording to allow the participant to state all recalled words, then the voice of the narrator returned, stating:

This is fine; it is hard to remember many of them the first time. I will read/sing them again and afterward, you say again all the ones you know. (second presentation of the words)

Now you go ahead, tell me all the words you can remember.

A 30 second response period was provided to allow the participant to state all recalled words, then a slightly different response was delivered by the narrator:

This is fine, I will read/sing them again and afterward, you say again all the ones you know.

(third presentation of the words)

Now you go ahead, tell me all the words you can remember.

Again, a 30 second response period was provided to allow the participant to state all recalled words.

This is fine, I will read/sing them again and afterward, you say again all the ones you know.

(fourth presentation of the words)

Now you go ahead, tell me all the words you can remember.

Another 30 second response period was provided to allow the participant to state all recalled words.

This is fine, I will read/sing them again and afterward, you say again all the ones you know.

(fifth presentation of the words)

Now you go ahead, tell me all the words you can remember.

A 30 second response period was provided to allow the participant to state all recalled words, then the narrator introduced the List B words:

Now I am going to read/sing a different list of words to you. This one I am going to read/sing only once; we are not going to learn it as much as we did the other one. Let us just see what words you remember if I read it just once. Try to get as many as you can. Here we go.

After the narrator presented the List B words, they stated:

Now you go ahead, tell me all the words from this new list that you can remember.

After the 30 second response period, the narrator prompted recall for the List A words without presenting them again:

That is fine; now remember the other ones just once more, the words from the first list that you heard so many times before. But I will not read them again—you say them as you remember them now. OK, go ahead.

This was followed by a 30 second response period, the narrator thanking them for their participation so far and giving instructions for the waiting period and completion of the test:

Great, thank you for your participation in the study so far. You'll now have a short 15 minute break and when you return, the final part. But that part is really short.

The participant was then allowed to take a break in the immediate test area for 15 minutes. During this time, the participant was free to use the restroom, drink water and wait with their parent. After the 15 minute break, the participant returned for completion of the test. Upon return from the break, the narrator began:

Thank you for returning to complete the study. Now, remember the words from the first list that you heard so many times before. I will not read/sing them again—you say them as you remember them now. OK, go ahead.

After the 30 second response period, the narrator then introduced the recognition portion of the test.

This is fine. For this last part, you will receive a paper and pen from the examiner with a list of words. Thank you for your participation in this study.

The participant was then provided with the recognition test and instructions from rater to mark an “A” next to words they thought belonged to List A, a “B” next to words they thought belonged to list B and to ignore words they did not recognize from either list. After the participant completed the recognition test, the examiner provided the parent and participant with exit surveys and allowed them a short period of time to complete. After exit surveys were completed, the rater thanked both participant and parent and provided the participant with \$15 compensation.

APPENDIX D

Recall Scoring Rubric

Use Recall Scoring Form (Appendix C) to write words for each participant's test trial, note number of repetitions, intrusions and contaminations as well as serial position totals and serial order effects (pairwise word order and type and number of word chunks per trial).

Listen to the recording and note time of playback when participant begins recall of trial (this allows easy finding of beginning of recall for each trial within the sound file).

Write words in the column in the order they are spoken. If a participant speaks too quickly, write the 1st and 2nd letters of each word, then listen again from the beginning of the recall for that trial in order to correctly transcribe each recall trial.

Correct/Incorrect response scoring (for totals of individual trials):

Correct:

1. If the word matches the word on the target list (List A word recalled during any of Trials 1-5, 7 or 8).
2. If a word is plural (ex: Parents) and is on the target list.
3. If the participant initially states a word that was not on the list, but immediately corrects themselves, this retraction is not counted as a contamination [for ex. 160717bX in T7(List A Retention trial): "Desk, no..."], or an intrusion (for ex. "teacher, no parent").

Incorrect:

1. If the recalled word does not match any word on the target list.
2. If the root of the word is present but not the full word (ex. "farm" instead of Farmer), that word does not count as a correct recall.

Serial position scoring:

Serial position scoring is completed by totaling correct number of recalled words in each serial position for that trial:

Serial positions:

A			B			C			D			E		
/	\		/	\		/	\		/	\		/	\	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
drum	curtain	bell	coffee	school	parent	moon	garden	hat	farmer	nose	turkey	color	house	river

Mark the correct number of words recalled from each position in the serial position scoring area at the bottom of each trial on the Recall Scoring Form.

Repetitions:

All words that are repeated are counted as repetitions and the repeated word does not get counted a second time toward the total for that trial.

Contaminations:

For trials 6 or 8, any assignment of an opposing list word will be counted as a contamination.

For Trial 6, a List A word recalled (assigned) as a List B word would be considered a contamination. For Trials 7 and 8, List B words recalled (assigned) as List A would be counted as a contamination.

Serial order effects:

Pairwise order: For each two consecutive words that are recalled in the order they were presented, a point is given. A total of 14 would represent all 15 words recalled in order.

Word chunks represent groups of 3 or more words recalled in order. A tally of number and length of word chunks for each trial will be recorded.

APPENDIX E

Recognition Test

This list contains the words from the first list you heard several times, the second list you heard only once and other words you didn't hear on either list. Next to the words you recognize from the first list, mark an "A." Next to the words you recognize from the second list, mark a "B."

- | | | |
|----------------|----------------|----------------|
| _____ Bell | _____ River | _____ Stranger |
| _____ Window | _____ Towel | _____ Garden |
| _____ Hat | _____ Curtain | _____ Glasses |
| _____ Barn | _____ Flower | _____ Stocking |
| _____ Ranger | _____ Color | _____ Shoe |
| _____ Nose | _____ Desk | _____ Teacher |
| _____ Weather | _____ Gun | _____ Stove |
| _____ School | _____ Crayon | _____ Nest |
| _____ Hand | _____ Church | _____ Children |
| _____ Pencil | _____ Turkey | _____ Drum |
| _____ Home | _____ Fountain | _____ Toffee |
| _____ Fish | _____ Boat | _____ Lamb |
| _____ Moon | _____ Hut | |
| _____ Thumb | _____ Parent | |
| _____ Balloon | _____ Ocean | |
| _____ Bird | _____ Farmer | |
| _____ Mountain | _____ Hose | |
| _____ Coffee | _____ Cloud | _____ |
| _____ Mouse | _____ House | |

APPENDIX F

Recognition Scoring Rubric

Recognition form scoring instructions

- 1) Place a check mark on participant's Recognition form.
- 2) Observe "A" for list A responses and "B" for list B responses.
- 3) Make small check marks for all correct identifications of List A and List B words.
- 4) Strikethrough incorrectly assigned words.
- 5) For incorrectly marked words:

place a small "i" next to the word if it is an intrusion (not on either list)
place a small "c" next to the word if it is a contamination (assigned to incorrect List)
- 6) Tally total of correctly recognized List A and List B words and enter on bottom right of form
- 7) Tally total of List A intrusions and enter on bottom right of form
- 8) Tally total of List B intrusions and enter on bottom right of form
- 9) Tally total of List A contaminations (List B words incorrectly assigned as List A words)
- 10) Tally total of List B contaminations (List A words incorrectly assigned as List B words)

Transfer tally totals to side 2 summary area of participant Recall form

"i" + A = List A intrusion

"i" + B = List B intrusion

"c" + A = (Contamination) List B words assigned to List A (value for #9 above)

"c" + B = (Contamination) List A words assigned to List B (value for #10 above)