THESIS


THE EFFECT OF MUSICAL MNEMONICS ON LEARNING AND RECALL IN

PRESCHOOL-AGED CHILDREN WITH DEVELOPMENTAL DISABILITES



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ABSTRACT

THE EFFECT OF MUSICAL MNEMONICS ON LEARNING AND RECALL IN

PRESCHOOL-AGED CHILDREN WITH DEVELOPMENTAL DISABILITES

The purpose of this study was to assess whether musical mnemonics rehearsal is more effective than verbal rehearsal on immediate and delayed recall of novel information for preschool-aged children with developmental delays.  Forty 3- to 5-year old children in a special education program were selected from a prescreening process as participants.  Participants were randomly divided into two groups by a computerized randomizer.  Group 1 received all input in spoken format and Group 2 received all input in sung format.  All participants listened to a random, non-repetitive seven-digit number.  Sung numbers matched the opening phrase of "Old MacDonald." For each trial, the researcher played the pre-recorded number five times.  The number of correct consecutive digits was recorded both at the end of each hearing, after a one-minute distraction and following a five minute delay.  Since there was evidence of skew in the serial order recall results, serial scores were compared within group and across groups using non-parametric statistical analysis.  Results showed no significant difference between the music and non-music groups.  Overall serial order recall scores were low, suggesting that the digit span was beyond the developmental capabilities of many of the participants. There was a significant effect of time and age, however.  Paired comparisons showed significantly greater recall in Trial 4 versus Trial 1, and in Trial 5 versus delayed recall, suggesting both an increase in recall due to learning and a decrease in recall after the 5-minute delay and distraction activity.  Five-year olds also performed significantly better than 3-4 year olds on delayed absolute recall and immediate serial order recall.  Future research suggestions are discussed.

# ACKNOWLEDGEMENTS

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CHAPTER I: INTRODUCTION

**Purpose**

       Teachers and students frequently use mnemonics to teach a new concept or rehearse information.  Many may recall the mnemonic reminders "stop, drop and roll" or "I before E except after C," and parents and educators frequently use the ABC song to teach children the letters and order of the alphabet. The ability to memorize and recall new information is an essential part of the learning process (Baddeley 2012; Moore, Peterson, O'Shea, McIntosh, & Thaut, 2008). Widely used in the classroom, mnemonics are meant to support memory and recall of novel information (Scruggs, Mastropieri, Berkeley & Marshak, 2010).  Musical mnemonics use rhythm and melody to further enhance memorization and recall.  Although a commonly used method for memory training, the use of musical mnemonics has little research literature to support its efficacy.  If more research further supports its efficacy, musical mnemonics could be a useful memory tool for children with memory deficits.

       Children with developmental delays often have deficits in memory skills and these deficits can be predictive of future academic progress (Gathercole, Pickering, Knight, & Stegmann 2004; Hecht, Torgesen, Wagner, & Rashotte, 2001; Michalczyk, Krajewski, Preßler, & Hasselhorn, 2013).   Young children with developmental delays could benefit from memory tools such as mnemonics to improve memory functioning, which may, in turn, affect academic achievement. Although two studies have explored the effects of musical mnemonics in children with special needs with promising results (Claussen & Thaut, 1997; Gfeller, 1983), the use of musical mnemonics for this population is under-represented in the research literature. The

purpose of this study was to investigate the effects of musical mnemonics compared to spoken input on verbal memory in preschool children with developmental delays.

**Background**

Memory and recall are integral parts of academic learning. The ability to retain and retrieve information plays a role in language acquisition, reading, writing and mathematics; not to mention the daily living skills that involve memory, such as taking the correct bus, remembering where the keys were laid, recalling names of people and places, etc. While there are many theories about how we form and retrieve memories, for the purpose of this study, working memory and its relationship to learning will be discussed.

Working memory, sometimes referred to as declarative memory, involves short-term storage, rehearsal and manipulation of information (Moore et al., 2008). According to Baddeley (2012) and Cowan (1999), working memory goes beyond short-term memory alone, involving both storing and manipulating input. With a limited capacity of about six or seven items or three to five chunks, working memory is the first step in the learning process (Baddeley, 2012; Cowan, 1999; Moore et al., 2008). Through repetition and rehearsal, input can move into long-term memory. An item of information is not considered learned until it is consolidated into long-term memory, where it can be retrieved over time (Moore et al., 2008). Recent advances in neurological imaging have revealed brain areas involved in memory and retrieval, including areas in the frontal, temporal and occipital lobes, the hippocampus, parahippocampus and amygdala (Baddeley, 2012; Binder, Desai, Graves, & Conant, 2009; Thaut, 2008). Working memory ability varies among individuals and deficits in working memory ability have been linked to poor academic performance (Gathercole et al., 2004; Hecht et al., 2001; Michalczyk et

al., 2013). Though not fully understood, working memory appears to be an important part of the learning process and may affect a person's academic achievement.

Children with developmental delays, including language delays and intellectual disabilities, appear to have working memory deficits that go beyond their overall developmental challenges, and tend to show more significant delays within phonological (verbal) memory tasks (Schuchardt, Gebhardt, & Mäehler, 2010; Spanoudis & Natsopoulos, 2011). In children as early as five years of age, delays in working memory appear to negatively affect both language skills and early math competencies (Michalczyk et al., 2013). According to Preßler, Krajewski and Hasselhorn (2013), delays in working memory have been linked to poorer phonological awareness. Furthermore, children with low verbal memory skills have been shown to perform poorly on both phonological and mathematical assessments (Preßler et al., 2013). Research suggests that phonological memory has an important relationship to learning, and that relationship extends beyond directly verbal learning. If working memory is predictive of academic performance, it follows that researchers need to investigate methods of improving verbal memory functioning.

While working memory seems to be a fairly stable trait, studies using intense memory practice in adults have shown the potential to improve working memory performance (Jaeggi, Buschkuehl, Jonides, Perrig, 2008; Olesen, Westerberg, Klingberg, 2004). Other forms of practice, such as musical training, may also contribute to working memory skills. For example, children and adults with musical training have been shown to have better working memory skills than non-musicians, especially when assessing verbal memory (Chan, Ho, & Cheung, 1998; Hogan & Huesman 2008; Jakobson, Lewycky, Kilgour, & Stoesz, 2008; Roden, Kreutz, & Bongard, 2012). As both memory practice and musical experiences appear to have a positive

effect on working memory ability, it is possible that exposure to musical experience in consort with memory rehearsal may improve or enhance working memory functioning.  One method of combining memory rehearsal and music is the use of musical mnemonics.

A mnemonic is a tool used to assist in memory and retrieval.  Lombardi and Butera (1998) describe a mnemonic as "a word, sentence, or picture device or technique for improving or strengthening memory" (p. 285).  Simple songs, acronyms, or symbols all may function as mnemonics.  Whether a picture, chant or an abbreviation, mnemonics work best when structured (Moore et al., 2008).  One can create structure in mnemonics through chunking- the process of grouping input into relevant "chunks." Baddeley (2012) and Cowan (1999) hypothesize that chunking is an effective memory tool, and may be why it is often easier to memorize a sentence than a string of non-related words.  Music, by its very nature, is structured and "chunked." Through rhythm and melody, music contains repetition and patterns, making it easy to remember and access.  Furthermore, much of western music is made up of measures and phrases.  These demarcations are built-in chunks within the larger musical structure.  Musical mnemonics take the information that one needs to commit to memory, and translates it into a structured song or chant.  An effective musical mnemonic should incorporate melodies and/or rhythms that support chunking (Moore et al., 2008).  The inherent aspects of music—the structure of melody and rhythm and the larger chunks of musical phrases—may make musical mnemonics an effective way to enhance memory.

Researchers investigating musical mnemonics have found promising results, but these results are limited in quantity and consistency.  A handful of studies on healthy adults compared sung versus spoken verbal input of novel information, and found that participants in the musical conditions had improved immediate recall (McElhinney & Annett, 1996; Wallace, 1994) and

long-term recall (Rainey & Larsen, 2002). Conversely, Racette and Peretz (2007) found that combining melodies and lyrics during encoding and recall impaired memory performance. Studies on adults with Alzheimer's disease and multiple sclerosis have shown positive neurological and behavioral effects of musical mnemonics in word order and lyric recall (Simmons-Stern, Budson, & Ally, 2010; Thaut, Peterson, & McIntosh, 2005; Thaut, Peterson, Sena, & Mcintosh, 2008). A similar study by Moore et al. (2008), however, found no significant difference between the spoken and sung groups in a word recognition task. A small body of literature alludes to the potential of musical mnemonics as a memory tool for children and children with developmental disabilities (Claussen & Thaut, 1997; Gfeller 1985; Wolfe & Hom, 1993). All together, researchers studying the use of musical mnemonics have found a positive trend toward efficacy, but the overall lack of studies and mixed findings suggest a need for further study.

**Rationale**

While an emerging body of literature shows the potential efficacy of musical mnemonics, only a few studies look at musical mnemonics with children, only two of which include children with disabilities. Furthermore, all existing studies looked at children no younger than five years of age. Children with developmental disabilities often present with working memory deficits in addition to academic challenges and these delays in working memory skills may have ramifications that extend throughout a child's academic career (Schuchardt et al., 2010; Spanoudis & Natsopoulos, 2011). Since researchers demonstrate that working memory ability is connected to phonological and mathematical ability, improving working memory ability for children with delays may enhance their overall academic functioning. In this way, these children may benefit from musical mnemonics as a tool to enhance working memory. Considering that

phonological processing, verbal ability and number competencies are developing rapidly during the preschool years, and that verbal memory skills appear to have a significant connection to these academic areas, it seems that research for this population is warranted (Michalczyk et al., 2013; Preßler et al., 2013). If, as researchers suggest, musical mnemonics are an effective tool for enhancing verbal memory ability, then studies aimed at investigating this music therapy tool for children with developmental disabilities could reveal an effective method for improving their memory and recall.

**Study Significance and Potential Impact**

Young children, and particularly young children with developmental delays, are under-represented in the research literature. Research exists showing the negative effects of poor working memory skills and developmental delays on academic achievement, but few studies look at solutions to these challenges. The existing studies on musical mnemonics and childhood populations are not conclusive, and no *discoverable* studies related to musical mnemonics and preschool-aged children with developmental delays exist, suggesting a significant gap in the research. While findings from this study only begin to fill the research gap, they may serve to inform future research. Therapists and educators who work with this population may also benefit from new insight into a potentially effective learning strategy.

**Research Questions and Hypothesis**

The study aimed to address the following research questions:

1.  Will musical mnemonics be more effective than spoken input for immediate recall of a novel number sequence?

2.  Will musical mnemonics be an effective tool for delayed memory recall?

3. Will there be a statistically significant difference in participants' ability to recall a

   number sequence between the music group and the spoken input group?

The researcher proposed the null hypothesis.  The music group and the spoken group will have

similar success at recalling a number order sequence, resulting in no statistical difference

between the two groups.

CHAPTER II: LITERATURE REVIEW

**Working Memory**

*Neurological Activation in Working Memory*

Neurological inquiry into memory systems has shown multiple brain areas that are implicated in memory functioning**.** Current research into brain and memory functioning shows activation occurring across hemispheres and in the cerebral cortex, inner brain areas, and the cerebellum (Binder et al., 2009; Karakas et al., 2013; Tranel & Damasio, 2002). Memory processing affects areas of the brain that overlap with cognitive, language, and sensory functions, suggesting a link between memory ability and skills in various domains.

In a recent study by Karakas et al. (2013), researchers looked at fMRI results from 61 adults as they undertook a working memory task. Brain areas activated during the task included: the frontal cortex, dorsolateral prefrontal cortex, cingulate gyrus, the angular gyrus and the supramarginal gyrus of the parietal cortex. These areas include brain regions also implicated in attention, linguistic function and motor speech (Karakas et al., 2013). Since the memory task involved reading text without listening to verbal input, auditory cortex areas were not activated in this sample. A meta-analysis of 120 fMRI studies by Binder et al. (2009) showed similar areas of neuronal activation during semantic processing. Semantic processing, or how one learns and accesses cognitive information including names, colors, shapes, numbers, is an important part of working memory. Additionally, Binder et al. (2009) found activations in temporal regions of the brain, including "the lateral temporal lobe" and "a ventromedial region of the temporal lobe centered on the mid-fusiform gyrus and adjacent parahippocampus" (p. 2771).

Importantly, brain areas implicated in working memory and semantic processing tasks appear to overlap with other cognitive and language functions.

Tranel and Damasio (2002) point to several areas in the temporal lobe that, based on lesion studies, correlate to memory functioning. One temporal lobe area in particular, the hippocampus, appears to be linked to declarative memory. Declarative memory refers to information that is consciously retrieved, such as names, faces, etc. Much of the learning process is based on declarative memories, as in memorizing the table of elements, spelling or a mathematical equation. Tranel and Damasio (2002) also noted several other cortex areas associated with memory: the amygdala, frontal lobes, and prefrontal lobes. Primary association cortices in the brain that activate during sensory perception of a sight, sound or touch also appear to activate when recalling those sensations (Tranel & Damasio, 2002). For example, one may engage primary association areas of the auditory cortex when remembering a favorite song. Subcortical brain areas including the thalamus and basal ganglia also appear to be implicated in memories along with the cerebellum (Tranel & Damasio, 2002). Neurological research suggests that memory processing and recall engages multiple brain areas, and that certain brain areas may activate more or less depending on what type of memory is being learned or recalled.

### Theories of Working Memory

Although neuro-imaging studies have increased our understanding of memory, many questions about how memory works remain. From the psychological perspective, several theories of memory exist. For the purposes of this literature review, two theories will be discussed: Baddeley's model of working memory and Cowan's embedded process theory. While each theory has distinctions (most obviously in disparate terminology), the overall concepts put forth by both reflect a view of working memory as a system in which memories are readily

accessible and in which cognitive processing involves both the short-term storage and manipulation of new information (Baddeley, 2012; Cowan, 1999).  Significantly, both Baddeley (2012) and Cowan (1999) support chunking, or grouping input, as a way to enhance encoding and retrieval.

Baddeley (2012) proposed a four-part working memory system: the phonological loop, visual-spatial sketchpad, the central executive, and the episodic buffer.  The phonological loop system stores and manipulates auditory and communicative input (including non-verbal forms of communication, such as sign-language). Processing tones, words, numbers, and their order or sequence, the phonological loop is an important part of early learning and development.

According to Baddeley (2012), adults can typically recall up to six or seven digits.  This seemingly low limit is due more to forgetting the order or sequence of digits than in forgetting the digits themselves.  The process of serial order recall appears to be both a challenging and a highly useful cognitive ability (Baddeley, 2012).  Speaking and understanding language requires the ability to retain and recall serial information, through hearing and remembering the sequence of words, in order to accurately process their meaning.  Understanding the order of numbers, as well, carries meaning in the form of phone numbers, zip codes, equations, etc.  Also, words and numbers that are grouped in a meaningful- known as chunking- way may allow the learner to expand recall capacity beyond seven digits.  It is possible that children with deficits in serial order recall and/or chunking may also have deficits in language and early mathematical comprehension.

Phonological loop processing is not limited to auditory input alone. Even when words or objects are presented visually, adults activate the phonological loop through internal vocal rehearsal (Baddeley, 2012).  When seeing the image of a pencil, for example, one will covertly

"speak" the word "pencil" to oneself. Rehearsal is an important means of moving information from short to long-term memory where it can be readily accessed. If internal rehearsal is eliminated through "ariculatory suppression," recall appears to suffer (Baddeley, 2012, p. 8). When presented with visual representations of words for recall, participants in a 1975 study showed a decrease in accurate recall when they had to speak an irrelevant word out loud, thereby suppressing internal vocal rehearsal (Baddeley, Thomson & Buchanan, 1975). Words that are phonemically similar (house, horse) can also impair recall. Both findings suggest that internal rehearsal or "speech coding" aids in memory recall (Baddeley et al., 1975, p. 576). If internal rehearsal is important for verbal recall, a person who does not engage in covert vocal practice may be less able to recall auditory input.

There is "considerable developmental evidence" that children do not engage in covert vocal rehearsal until around age seven (Tam, Jarrold, Baddeley & Sabatos-DeVito, 2010, p. 308). Tam et al. (2010), however, found that children as young as 6 years of age showed some signs of phonological rehearsal by recalling visually presented items without overt (out loud) verbal rehearsal. A follow up experiment by Tam et al. (2010) showed similar results; with both 6-and 8-year olds using phonological rehearsal to recall visually presented input. In both studies, the differences in internal rehearsal were not significant, although the older children did show slightly better recall. These findings suggest that children younger than 7 years old may have internal rehearsal, although their rehearsal strategies may not be as well formed as children over age seven (Tam et al., 2010). These results also support Baddeley's view of rehearsal as an integral part of working memory retention and recall.

Cowan perceives working memory as part of long-term memory, and divides it into three embedded levels: "a) long-term memory b) the subset of long-term memory that is currently

activated, and c) the subset of activated memory that is in focus of attention and awareness"
(Cowan, 1999, p. 62). In contrast to Baddeley's six or seven digits, Cowan (1999) purports that
one can only recall a very limited number of items: three to five. Importantly, using encoding
strategies such as chunking may increase these limits. Although a recall capacity of only three
items may seem small, Cowan notes that these items may each contain chunks of longer
information. For example, a seven-digit phone number (6448174) would likely be considered
two or three chunks of input in Cowan's model (644-81-74).

Both Baddeley and Cowan refer to chunking as a means of retaining larger sets of input,
and Cowan's concept is similar to Baddeley's view that one can recall more than six or seven
items of input when the items are related (Baddeley, 2012; Baddeley et al., 1975; Cowan, 1999).
The ability to combine and recall similar items, as in chunking, enables one to recall more words
when they occur within a sentence than when they are unrelated (Baddeley, 2012). Chunking
may also explain why one can recall the lyrics of a familiar song containing far more than seven
items of information.

Cowan's developmental view of memory—that it increases through childhood
development—coincides with Baddeley (Cowan, Saults, Nugent, & Elliott, 1999). As one
might expect, children can recall longer word or number lists as they age. Reviewing evidence
from several experiments concerning developmental recall ability, Cowan et al. (1999) found
that children's recall of attended words was affected by list length, with increased accuracy for
shorter lists and correlations between performance and age. When looking at unattended lists,
however, the results were the same regardless of list length, with adults and older children
performing better than the young children. These results suggest that, not surprisingly, attention
improves recall. More importantly, performance on the unattended lists showed that children

have a more limited storage capacity than adults, outside of attention effects, which also appears to increase throughout development (Cowan et al., 1999).

Further review by Cowan et al. (1999) showed a correlation between age and processing speed- measured as "inter-word" pauses- during recall, with younger children showing slower processing times (p. 357).  Interestingly, these pauses between list items remained relatively stable, regardless of list length.  Decreases in pause length throughout development suggest improved recall ability through enhanced processing. Gilchrist, Cowan and Naveh-Benjamin (2009) also noted that the ability to chunk input into meaningful groups might improve through the course of development.  In an experiment comparing first graders, sixth graders, and adults, Gilchrist et al. (2009) found that word span increased for older children and adults, and that the number of recalled chunks (measured as linguistic clauses) also increased with age.  When participants were presented with nonsense sentences, they performed significantly worse than when presented with meaningful sentences.  These findings support the role of chunking. Overall results show that both memory capacity and the ability to chunk information grow through development (Cowan, 1999; Gilchrist et al., 2009).

By synthesizing the findings of both Baddeley and Cowan, it appears that memory and recall benefit from both attention (Cowan, 1999) and rehearsal (Baddeley, 2012), and that storage capacity can increase through structure and, specifically, chunking.  An essential component of both theories- chunking- will be addressed in this study through the innate chunking of musical melody, rhythm and phrases.  As a common element in both theories, chunking is an important technique for improved memory capacity and recall.  For both Cowan (1999) and Baddeley (2012), memory also appears to be developmental as one's ability to attend, process, rehearse, and store input increases with age.

*Working Memory and Developmental Disabilities*

Although memory ability appears to improve as children grow, memory is a unique trait for each individual.  Not surprisingly, children with intellectual disabilities and learning or language delays often have memory deficits as well (Schuchardt et al., 2010; Spanoudis & Natsopoulos, 2011; van der Schuit, Segers, van Balkom, & Verhoeven, 2011).  Interestingly, these memory deficits may extend beyond a child's general developmental delays.

Children with intellectual disabilities (ID) such as Down syndrome have developmental delays in multiple areas of functioning.  Recent research by van der Schuit et al. (2011) comparing young children with ID and typically developing children (average age 4 years and 4 months) showed that children with ID scored significantly lower than their age-matched peers on a number of tasks, including phonological working memory, nonverbal intelligence, syntax and vocabulary.  When controlling for differences in nonverbal intelligence, children with ID still showed deficits in phonological working memory and syntax (van der Schuit, 2011).  Furthermore, on a follow up test (one year later), results showed that for children with ID, phonological working memory ability was predictive of vocabulary acquisition between ages four and five (van der Schuit, 2011).  These results suggest that delays in phonological working memory and syntax go beyond the overall developmental delays associated with a child's mental functioning level and may forecast future academic attainment (van der Schuit, 2011).

A similar study by Schuchardt et al. (2010) looking at older children (average age =15 years) with borderline ID (BID) and mild ID (MID) found that, when compared to *chronologically* age-matched peers, both children with BID and MID performed lower on phonological, visual-spatial and central executive working memory tasks.  Children of average intelligence performed better than those with BID, and those with BID performed better than

those with MID (Schuchardt et al., 2010).  Therefore, findings suggest a correlation between IQ and working memory.  Schuchardt et al. (2010) also found, when compared to *mentally* age-matched peers (MID age 15, BID age 10, and control age 7), children with MID and BID scored similarly on visual-spatial and central executive memory tasks, suggesting a developmental lag in these areas of working memory in synch with overall developmental delays.  Conversely, for the phonological loop tasks, children with ID performed significantly more poorly than both their *chronological* and *mental* aged-matched peers.  These findings match those of van der Schuit (2011) in pointing out a more severe delay in phonological working memory that may not be explained by an overall developmental delay alone.  Significant delays in verbal working memory may explain why children with intellectual disabilities often have limited language skills (van der Schuit, 2011).

Children with average intelligence but who have specific learning challenges, such as those with a language delay or specific language impairment, also appear to have deficits in verbal working memory (Chilosi et al., 2009; Spanoudis & Natsopoulos, 2011).  A 2009 study by Chilosi et al. (2009) looked at 46 Italian children (third through eighth graders) who all had low reading test scores.  Of the 46 children, 26 had a language delay (LD) in addition to low reading skills.  All children underwent a series of assessments, measuring reading and writing ability, verbal abilities (including phonological working memory) and nonverbal ability (including visuo-spatial working memory).  As expected, both groups of children performed poorly on the reading and writing assessments. Interestingly, for the verbal assessments, children with no language delay performed within expected ranges (with no discernable delay).  Children with a language delay, on the other hand, performed slightly below expected limits on phonological working memory.  Children with languaege delay had an overall mild to moderate

deficit in verbal ability, whereas children with no language delay performed within normal limits (Chilosi et al., 2009).  These results follow other studies showing a correlation between language ability, academic performance and working memory.

Similar to language delays, specific language impairment (SLI) refers to a wide range of language disorders experienced by children (Spanoudis & Natsopoulos, 2011). For their study, Spanoudis & Natsopoulos (2011) compared 50 Greek children with language deficits to 50 typically developing Greek children.  The children (aged eight to twelve years) were selected based on a composite of scores from five test measures and were matched for age and nonverbal intelligence. Each child underwent five language ability tasks and four memory tasks.

Results from Spanoudis & Natsopoulos' 2011 study showed that children with language impairments scored significantly lower than the control group on all memory measures, including both phonological memory tasks and long-term memory tasks.  Children with SLI also performed more poorly on recall tasks than their peer group, suggesting that children with SLI had difficulties both in encoding and rehearsing new material.  Overall results suggest that children with SLI have delays in both processing/encoding and storing novel information (Spanoudis & Natsopoulos, 2011).  As the ability to encode and store information is an integral part of the learning process, the ramifications of deficits in these areas could affect academic performance in a variety of areas, including reading skills, writing skills, and ability to acquire new vocabulary.

***Working Memory and Educational Achievement***

A number of recent studies have shown a link between deficits in working memory skills and delays in language, reading, writing, and mathematical achievement (Gathercole et al., 2004; Hecht et al., 2001; Michalczyk, et al., 2013; Preßler et al., 2013).  Although less apparent than

the connection between verbal skills and phonological working memory, the connection between auditory memory ability and math appears to draw on the verbal nature of early math competencies: naming numbers and quantities, internally rehearsing multiplication tables, etc. For both language and math based learning, memory ability, and particularly phonological working memory, appears to both affect and predict future educational attainment.

As Hecht et al. (2001) illustrated in their four-year study following the phonological ability and mathematical performance of 201 elementary students, phonological awareness and phonological working memory affect mathematical achievement. While phonological processing was predictive of math skills over all four grades, correlations between phonological working memory and mathematical ability seemed to be strongest at a younger age (from second to third grade) (Hecht et al., 2001). These connections were most likely due to the fact that early math skills draw on verbal skills (naming numbers, saying computations such as "one plus one equals two"), whereas higher math skills involve manipulation and writing that may rely more on the visual-spatial aspect of working memory. In varying degrees, working memory as a whole seems to be essential to mathematical learning. Many arithmetic problems are quickly solved with rehearsed answers from long-term memory (Hecht et al., 2001). Also, learning new math skills requires enough working memory to maintain the initial part of the problem long enough to compute a response, making deficits in working memory a possible impediment to mathematical achievement.

A similar study conducted in the United Kingdom by Gathercole et al. (2004) compared curriculum attainment to performance on phonological working memory tasks in 73 children. Their study results showed that, in addition to mathematical learning, phonological memory ability affects performance on language-based skills. Comparing phonological working memory

ability and English and math attainment for 73 children (40 7-8 year olds and 43 14-15 year olds), Gathercole et al. (2004) found highly significant correlations between digit recall and listening recall and both English and mathematics attainment in the younger children.  For the older group, performance scores showed high correlations between science and math achievement and phonological memory ability. Interestingly, the correlation between working memory skills and English achievement was significant, but less so than the connection to math and science attainment.  In contrast to the findings of Hecht et al. (2001), the connection between math achievement and phonological working memory in this study did not decrease with age, but remained significant, even as the effects of working memory on language skills decreased (Gathercole et al., 2004).  Both studies, however, show a correlation between phonological working memory and educational achievement.  These studies, however, do not consider visual-spatial memory deficits, which may also affect academic attainment.

When grouping children based on type of working memory deficit- visual-spatial versus phonological- phonological working memory challenges were more detrimental to overall academic performance than visual-spatial memory deficits (Preßler et al., 2013). Over a yearlong study, Preßler et al. (2013) followed 92 children (average age 5 years) with low visual or phonological working memory as measured by scores on a series of performance tasks.  Children with average working memory scores in both areas were used as a control group.  At the end of one year, follow-up tests showed that children with low phonological memory scored significantly lower than their peers on language and number competency tasks.  Children who had low visual-spatial working memory ability also had low scores on number competency tasks, but were less impaired on phonological tasks (Preßler et al., 2013).  These results match previous research showing a correlation between poor working memory and poor academic achievement.

Most interestingly, it further suggests that poor phonological awareness may affect both early language and math skills (Preßler et al., 2013).

A large-scale study of 1,343 5 to 6-year old German children conducted by Michalczyk et al. (2013) showed slightly varied results. Overall, phonological awareness ability had a significant impact on simple quantity number competencies (QNCs) that involved competencies related to basic number skills (i.e., naming numbers and sequentially counting). More advanced QNCs such as understanding quantities, and manipulating and comparing numbers, were not significantly affected by phonological awareness. Phonological loop and central executive memory tasks did not, however, show a strong correlation to number competencies (Michalczyk et al. 2013). These low correlations are not aligned with previous studies showing stronger connections between verbal working memory skills and basic number skills. Michalczyk et al. (2013) did, however, note the link between phonological awareness and verbal memory skills, suggesting that a weakness in phonological awareness may affect weakness in both QNCs and working memory. Findings suggest that phonological awareness is a bridge connecting verbal working memory and number skill development.

As current research suggests, working memory ability has a significant impact on academic achievement. Deficits in phonological memory, though correlated to language learning, also appear to relate to delays in mathematical competencies. Since memory ability seems to impact school performance, one must consider if improvements in memory skills are possible.

### *Working Memory: Room for Improvement?*

Beyond the developmental growth of working memory, working memory ability appears to be a fairly stable trait. Considering working memory's effect on educational performance, a

deficit in this trait could become a significant academic hurdle for a student. Fortunately, recent studies show that memory skills can be improved through intense practice and rehearsal techniques (Jaeggi et al., 2008; Olesen et al., 2004).

When adults engage in intensive rehearsal of a challenging working memory task, their performance can improve (Jaeggi et al., 2008). Over time, focused working memory practice also has been shown to enhance fluid intelligence (Jaeggi et al., 2008). Significantly, fluid intelligence is considered an integral part of cognitive functioning and learning (Jaeggi et al., 2008). Also, there is "considerable agreement" that fluid intelligence is closely linked to heredity and that it is hard to change beyond practicing for fluid intelligence tests themselves— an exercise that has shown little to no transfer (Jaeggi et al., 2008, p. 6829). If working memory exercises can improve working memory and fluid intelligence performance in adults, similar improvements may be possible in child populations. Especially considering the developmental nature of memory, one may surmise that memory practice at a young age may have even more substantial effects on memory ability and, therefore, academic achievement.

On a neurological level, intensive memory practice appears to enhance memory functioning (Olesen et al., 2004). Although using a limited participant pool (N=11), researchers found that intensive working memory training showed improvements in parietal and prefrontal brain areas (Olesen et al., 2004). As EEG scans administered before and after training showed increases in neuronal activity, participant response times also went down between the pre and post-tests, suggesting performance improvements in addition to neurological enhancement (Olesen et al., 2004). While the Olesen et al. (2004) study had a very small sample and required an intensive amount of memory practice (90 trials per day for approximately five weeks), the findings suggest that working memory is plastic, and can be improved.

*Working Memory and Mnemonics*

One method for enhancing memory is known as mnemonics.  According to Lombardi and Butera (1998), "a mnemonic is usually defined as a word, sentence, or picture device or technique for improving or strengthening memory" (p. 285).  Non-musical mnemonics, such as "please excuse my dear Aunt Sally" for the order of operations, have been shown to be effective memory aids for children with special needs in secondary classrooms (Lombardi & Butera, 1998).  Lombardi and Butera (1998) pointed out that, while some mnemonics are used to merely recall factual information, studies have shown that mnemonics can lead to higher-order thinking, including problem-solving skills.

Neurologically, an area of brain known as the default mode network also appears to be affected by mnemonic processing.  Although not fully understood, the default mode network (DMN) is a group of several cortical regions implicated in memory and internal thought processes (Shapira-Lichter, Oren, Jacob, Gruberger & Hendler, 2013). The DMN includes areas in the temporal lobe, prefrontal cortex, parietal cortex and cingulate cortex (Shapira-Lichter et al., 2013).  When comparing mnemonic versus non-mnemonic memory cues, functional MRI scans showed that during the mnemonic conditions, the DMN showed greater activation and connectivity (Shapira-Lichter et al., 2013).  As fMRI data from the Shapira-Lichter et al. (2013) study suggested, mnemonic memory retrieval activates more brain areas than non-mnemonic retrieval.  Furthermore, fMRI results showed a greater degree of synchrony within the DMN during mnemonic retrieval, when compared to non-mnemonic memory retrieval (Shapira-Lichter et al., 2013).  Non-musical mnemonic techniques appear to improve memory performance, neurological activation and synchronization.  It is possible that mnemonics provide added structure and cues that can enhance memory through improved rehearsal techniques and

improved neuronal synchrony. Another structured cue, music, may also serve to support and improve memory function.

**Music and Memory**

*Neurological Foundations of Music and Memory*

In looking at music's effect on working memory, one must first consider the neurological effects of music. Music affects many areas of the brain, crossing hemispheres and innervating both the cortex and the cerebellum (Thaut, 2008). Music listening and performance have been shown to increase neuronal activation and synchrony (Thaut, 2008). Advances in neurological imaging have revealed common brain areas for music experience, auditory perception, and memory functioning. Music's ability to affect and change multiple brain areas suggests that music may be an effective way to enhance non-musical functioning.

At a most basic level, music experiences appear to change the brain (Habib & Besson, 2009). Based on an overview of neuro-imaging evidence, it appears that musical training directly affects the brain. Professional musicians, and those who began study before age 7 showed changes in the motor and auditory cortices, in the Corpus Callosum, and in Broca's Area (Habib & Besson, 2009). While greater practice duration and early training positively affect neurological change, even short term exposure to musical experiences may affect the brain. For example, participants who underwent auditory discrimination training sessions showed changes in temporal lobe activations after only one week of training (Habib & Besson, 2009). Rhythmic listening, which requires no advanced training, activates another brain area implicated in memory function: the prefrontal cortex (Thaut, 2008). Furthermore, musical experiences can enhance evoked potentials, suggesting improvements in neuronal firing and synchrony (Habib &

Besson, 2009). Implications for these findings include the potential use of music training to teach and enhance non-musical skills such as working memory performance.

Looking more closely at neurological connections between music experiences and memory, Peretz and Zatorre (2005) found that music listening and performance require a high degree of memory. Music occurs over time, and, often, long sequences or phrases must be held in memory in order to relate one part of a musical piece to another. The process of holding information in working memory to relate it to incoming information transfers to many processes beyond music listening and performance. Peretz and Zatorre (2005) noted that the auditory cortex and portions of the frontal lobe- dorsolateral and inferior frontal areas- are activated during music memory. Further evidence from lesion studies shows that people with specific brain injuries (to the medial temporal lobe or to bilateral auditory cortex areas) can experience music-only memory loss (Peretz & Zatorre, 2005). These findings suggest that music memory is unique, and may be a "specialized subsystem within the framework of working memory" (p. 96). Overall evidence shows that, while music memory may function within its own subsystem, music memory involves areas of the frontal lobe, a brain region associated with general memory and recall (Peretz & Zatorre, 2005). Although music memory may be unique, the process of memory in music performance and listening may also enhance non-musical memory ability.

In two studies looking at young children and musical experience, researchers found that music training positively affected auditory perception (Fujioka, Ross, Kakigi, Pantev, & Trainor, 2006; Trainor, Shahin, & Roberts, 2003). Trainor et al. (2003) and Fujioka et al. (2006) both found that children as early as 4 years of age who received musical training showed advantages in auditory perception as measured by increases in auditory evoked potentials. Results from both studies suggest that musical training at an early age can have positive effects on "auditory

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cortical development" (Trainor et al., 2003, p. 512). Since language and verbal skills require strong auditory ability, it is possible that music training could also positively affect learning in these domains. Musical performance and listening impacts several brain areas, cortical and subcortical, and across both hemispheres. Changes in the brain are reflected through increases in activation and neuronal firing. Some brain areas activated during music experiences and memory tasks appear to overlap, suggesting that musical experiences can impact non-musical areas of functioning. Even young children recently exposed to musical training show increases in auditory evoked potentials, alluding to potential benefits for other skills that require auditory perception, such as verbal working memory.

***Musical Structure and Memory: Is Music Memory Unique?***

Many of the organizational elements of music including harmony, melody, rhythm, and phrasing give music its innate structure. In turn, this structure may act as an auditory scaffold for memory (Thaut, 2008). One element, rhythm, appears to enhance attention, an aspect of memory formation considered critical in Cowan's embedded process theory (Cowan, 1999; Thaut, 2008). Made of patterns, music is naturally chunked into auditory and time-based phrases that can support memory processing (Moore et al., 2008; Thaut, 2008). In accord with Baddeley's and Cowan's emphasis on chunking and Baddeley's emphasis on rehearsal, musical chunks- when paired with novel information- may aid in rehearsal and recall (Baddeley, 2012: Cowan, 1999; Thaut, 2008). In this way, music itself provides an auditory structure to support memory creation and recall. Do the structural elements of music make music memories unique, or do they simply enhance existing memory processes?

Drawing from the chunking and rehearsal aids inherent in musical structure, Berz (1995) hypothesized that persons with musical training may perform better on music memory tasks due

to improved rehearsal and retrieval strategies. In response to Baddeley's model of working memory, Berz (1995) proposed that, in addition to Baddeley's "visuo-spatial sketch pad" and "phonological loop" there is a "music memory loop" (p. 362). Drawing from research showing that people are able to recall longer chunks of music (up to 180 seconds) than words, and that people can tune out background music while attending to verbal input, Berz (1995) surmised that music memory may be separate from verbal or visual memory. Like Peretz and Zatorre (2005), Berz (1995) sees music memory as unique.

In contrast to the view of unique music memory, Huntsinger and Jose (1991) predicted that all short-term memories derived from a "unitary phenomenon" (p. 5). Study findings showing moderate to high correlations between number recognition and musical tone recognition in 58 elementary aged children support the theory that these types of memories arise from a single system and are not unique (Huntsinger & Jose, 1991). Importantly, the children in the study who had musical training showed better rehearsal strategies, regardless of whether the tasks involved numbers or tones when compared to those without music training (Huntsinger & Jose, 1991). If short-term memories do stem from a common system, then it is possible that musical training could improve encoding and recall strategies in multiple areas, thereby improving overall cognitive ability.

More recently, fNRI investigations into music, the brain and memory have revealed common pathways between music and memory processes (Ferreri, Aucouturier, Muthalib, Bigand & Bugaiska, 2013). In a 2013 study by Ferreri et al., 22 young adults were asked to encode and recall short word lists that were presented either in silence or with background music. Ferreri et al. (2013) found that background music enhanced memory performance. During the music condition, fNRI data showed increased neuronal activations in the left prefrontal cortex

(PFC) and decreased activations in the dorsolateral prefrontal cortex (DLPFC), suggesting greater neuronal encoding in the PFC and increased neuronal synchrony in the DLPFC (Ferreri et al., 2013). Other factors, such as increased attention during the music condition, may also have contributed to neurological and behavioral improvements. Significantly, music enhanced recall while it activated overlapping brain areas. These findings suggest that music and verbal memory occupy shared systems, allowing music to impact memory functioning.

The very building blocks of music- rhythm, melody, harmony- create structured, easily recalled musical phrases. Using these musical units in tandem with non-musical information may facilitate and enhance the rehearsal and chunking associated with memory formation. There is not enough research to determine whether musical memories arise from a unique music memory subsystem, through a single shared system, or through enhanced rehearsal and retrieval techniques (Berz 1995; Ferreri et al., 2013; Huntsinger & Jose, 1991; Peretz & Zattore, 2005). Whether or not music memory is unique, shared neurological networks between music and memory suggest that music can improve memory processes. Since music has the potential to positively affect memory function, one must then consider working memory performance in trained musicians.

### *Music Experience and Memory Performance*

Researchers demonstrated that adults and children with musical training have better verbal memory ability (Chan, Ho & Cheung, 1998; Hogan & Huesman, 2008; Jakobson, Lewycky, Kilgour, & Stoesz, 2008). A number of current studies have found significant correlations between musical training and working memory skills (Chan et al., 1998; Ho, Cheung & Chan, 2003; Hogan & Huesman, 2008; Jakobson et al., 2008; Roden, Kreutz, & Bongard, 2012; TanChyuan & Rickard, 2010). More musical experience also appears to correlate with

more phonological memory ability.  Even after training ends, however, the memory benefits from musical practice endure (Ho et al., 2003).

Adults with musical training perform better than their non-trained peers on verbal memory tasks (Chan et al., 1998; Jakobson et al., 2008).  When looking at visual memory tasks, however, research findings differ.  Investigating the effect of music training on memory ability, Chan et al. (1998) found that, while musicians performed significantly better than non-musicians on verbal memory tasks, there was no significant difference between the groups on visual memory performance.  Musically trained children also performed better than their non-trained peers on verbal memory tasks while demonstrating no significant advantages on visual memory tasks (Ho et al., 2003; Roden et al., 2012).  When assessed over time, children with musical training showed significant increases in verbal memory functioning, although similar advantages were not found for visual memory performance (Roden et al., 2012).  Even when controlling for intelligence and age, children with musical training have demonstrated better immediate recall, delayed recall and recognition than their non-trained peers, suggesting better short and long-term phonological memory strategies (Roden et al., 2012).

In contrast, a study by Jakobson et al. (2008) showed that trained musicians had better performance on *both* visual and verbal memory performance.  According to participant scores on free and cued recall tasks, Jakobson et al. (2008) found that musicians had more efficient learning strategies, including better semantic clustering or chunking of information, which appeared to positively affect both verbal and visual recall.  While there was not enough difference in retrieval scores to suggest that musicians had more efficient *retrieval* of information, their overall higher scores were likely related to better encoding during learning (Jakobson et al., 2008).

When comparing experienced to inexperienced musicians, greater musical experience positively correlated to greater memory skills (Ho et al., 2003; Hogan & Huseman, 2008; Jakobson et al., 2008; TanChyuan & Rickard, 2010).  In the Jakobson et al. (2008) study, researchers found that, within the musician group, participants with more musical training performed better on the recall tasks.  According to findings by TanChyuan and Rickard (2010), level of music training predicted short-term free and cued recall and long-term recall. Similarly, researchers in the Ho et al. (2003) study found that, for children, more years of musical training were indicative of greater verbal memory ability. In the Hogan and Huseman (2008) study, however, the difference between the memory performance and level of experience was small.  It is possible that the more trained musicians were benefitting from greater encoding and learning techniques, which may relate to improved temporal discrimination (Hogan & Huesman, 2008; Jakobson et al., 2008).  Other explanations include that music training improves overall intelligence, which would in turn improve memory and encoding ability.

Improvements in working memory ability appear to endure beyond cessation of musical training (Ho et al., 2003).  In the Ho et al. (2003) study, researchers compared three groups of musically trained children: beginners, those who were continuing music study, and those who discontinued music study.  For children who discontinued music training, verbal memory scores remained constant.  After one year, however, both beginners and those who continued their music training showed further increases in verbal memory (Ho et al., 2003).  Importantly, children who stopped music training continued to have higher levels of verbal memory than non-musically trained children, even though their memory performance did not increase beyond discontinuation (Ho et al., 2003).  It is possible that long-term neurological changes and/or permanent changes in memory encoding and rehearsal techniques contributed to carry-over

beyond training. The effects of musical experience appear to be long lasting, pointing to the potential for long-term benefits.

Although young children are less likely to have several years of musical training and experience, significant improvements in phonological working memory tasks may be possible in the short term. In the Fujioka et al. (2006) study, researchers found that 4- to 6- year olds showed significant improvements in a digit span task after only one year of instrumental music lessons. These improvements exceeded those of age-matched children without musical training. Even short-term early music training can benefit verbal memory and these benefits may aid children with low verbal skills, since musical training on an instrument does not require verbal skills (Fujioka et al., 2006).

In addition to performance based training, nonperformance musical experiences such as music listening and affective musical responses may also positively affect verbal memory (TanChyuan & Rickard, 2010). According to the TanChyuan and Rickard (2010) study, nonperformance musical experiences showed a significant association with verbal recall. In fact, nonperformance experiences predicted all levels of recall used in the study, including recall that involved proactive interference, for which the performance measure did not predict. Out of all nonperformance variables, music listening activity correlated the most with verbal recall (TanChyuan & Rickard, 2010). Music listening also predicted better semantic clustering during learning and recall, which mirrors research on music performance, alluding to improved rehearsal techniques in encoding and recall (TanChyuan & Rickard, 2010). Passive music experiences may improve non-musical functioning, specifically in the areas of memory and verbal recall. Since it is not always practical or possible to train a child or adult through musical

performance, it is important that passive music experiences may produce similar memory benefits.

Music experiences, both performance-based and non-performance-based, may enhance verbal memory ability in both adults and children.  Even music beginners show increases in verbal memory ability within one year of training (Fujioka et al., 2006; Ho et al., 2003).  Furthermore, more musical experience correlates with more verbal memory ability (Ho et al., 2003; Hogan & Huesman, 2008; Jakobson et al., 2008).  Fortunately, improvements can occur in the short-term, and the positive effects appear to linger even after musical training has ended (Fujioka et al., 2006; Ho et al., 2003).  Music training that aims to increase musical achievement and enjoyment may also enhance working memory ability.  In the above studies (Chan et al., 1998; Ho et al., 2003; Hogan & Huesman, 2008; Jakobson et al., 2008; Roden et al., 2012; TanChyuan & Rickard, 2010), working memory enhancement was an incidental benefit of music training rather than the main goal of the musical experience.  Targeted music interventions for the purpose of memory improvement may have similar or greater effects on working memory performance.  Therefore, one must consider studies on the therapeutic use of music to improve working memory.  Music therapy uses the elements of music in a focused and intentional way to enhance non-musical functioning.  One of these therapeutic techniques- musical mnemonics- addresses memory learning and recall.

**Music Therapy and Memory**

*Musical Mnemonics in Adult Populations*

Musical mnemonics involve the use of music to assist in encoding (rehearsing) and recalling information (Moore et al., 2008; Thaut, 2008).  Simple tunes or chants, either familiar or composed, may be combined with novel information in order to add melodic, rhythmic and/or

harmonic structure.  This superimposed musical organization serves to provide temporal chunks, which may assist in memory formation (Thaut, 2008).  In this way, musical mnemonics function as an auditory scaffold or support system, using patterns to facilitate rehearsal and retrieval of novel information.  In an emerging body of research literature, researchers have investigated the effects of musical mnemonics on memory performance in healthy children and adults, and those with illness or disability (Gfeller, 1983; McElhinney & Annett, 1996; Rainey & Larsen, 2002; Thaut, 2010).  First, one must consider the larger set of available research: studies investigating musical mnemonics and memory in adults.

Through an early set of experiments, Wallace (1994) found that music facilitated recall of novel song lyrics better than spoken input.  Over four experiments, Wallace (1994) compared immediate and delayed recall of lyrics that were presented in a variety of ways: sung with repeated melody, spoken, spoken rhythmically, and sung with different melodies.  Interestingly, participants (healthy young adults) were asked to write their responses as opposed to speaking or singing them (Wallace, 1994).  In this way, recall required additional steps that were not involved in encoding.  Overall, participants who heard the lyrics sung to a repeated melody recalled significantly more than in any other condition.  Rhythmic speech was less effective than the combination of rhythm and melody used in the sung condition (Wallace, 1994).  While rhythm alone can improve attention and arousal, these findings suggest that melody provides additional cues that may aid in memory encoding and retrieval (Thaut, 2008).  When the melody was sung only once, however, spoken input was more effective at facilitating recall (Wallace, 1994).  Perhaps, as these findings suggest, melodies are only effective mnemonics when they are familiar or are repeated enough to be easily learned.

In a similar study with healthy adults, McElhinney and Annett (1996) compared sung versus spoken presentations of novel lyrics. Over three trials, participants (N=20, average age= 20.75) listened to a tape recording of either a Billy Joel song or the lyrics of the same song, spoken by a male voice. After each hearing, participants wrote down as many of the song lyrics as they could recall. As in the Wallace (1994) study, results showed that participants who heard the lyrics sung recalled significantly more lyrics, overall, than those in the spoken condition (McElhinney & Annett, 1996). Although after the first trial the music group recalled more lyrics than the spoken group, there was not a significant difference in the number of recalled lyrics between the two groups from the first attempt. After trials two and three, however, the music group recalled significantly more lyrics and was able to chunk the song into larger groups of text (McElhinney & Annett, 1996). This suggests that musical mnemonic cues, while effective, were more helpful with repetition. Also, McElhinney and Annett's discovery of greater chunking in the sung condition supports the theory that musical mnemonics may assist in rehearsal of information, further optimizing retrieval (1996).

In another study looking at healthy adults, Rainey and Larsen (2002) conducted two experiments on the effects of musical mnemonics on short and long-term memory. For the first experiment, Rainey and Larsen (2002) put unfamiliar and seemingly unconnected texts (the players list for two major baseball teams and made-up names) to familiar melodies. Participants saw and listened to the texts either sung or spoken and were allowed to listen to the lists as many times as it took them to verbally recall it completely. One week later, subjects were asked to recite the list and if they could not completely recall it, they were asked to again listen to the sung or spoken text until they could completely list the text (Rainey & Larsen, 2002). There was no significant difference in number of repetitions for either the sung or spoken group to initially

learn the texts accurately (Rainey & Larsen, 2002). On relearning, however, participants who heard the text sung needed significantly fewer repetitions than the spoken group to accurately recall the list (Rainey & Larsen, 2002).

In Experiment 2, the procedure was the same, but there were three conditions: sung text, spoken text, and visual only text (Rainey & Larsen, 2002). Unlike Experiment 1, the sung and spoken conditions in this experiment did not have visuals of the word accompanying the auditory input. Initial learning was significantly quicker (fewer repetitions) for the visual condition, but for the one-week follow up, the music group again needed significantly fewer repetitions to recall the list than the visual or spoken groups (Rainey & Larsen, 2002).

For both experiments, musical mnemonics seemed to improve long-term recall, but did not have a significant effect on immediate recall. Rainey and Larsen (2002) suggested this might relate to participant musicality (or lack thereof). In line with the findings of McElhinney and Annett (1996), the positive influence of music on longer-term recall could have been the result of greater rehearsal by the participants.

Contrary to the findings of Wallace (1994), McElhinney and Annett (1996) and Rainey and Larsen (2002), Racette and Peretz (2007) found that the presence of melody during encoding and recall interfered with immediate and delayed recall. Over two experiments, young adult musicians and non-musicians were asked to recall song lyrics that were either sung or spoken with the song melody sung on "la" in the background (Racette & Peretz, 2007). Participants were asked to either sing or speak back the lyrics. In both experiments, spoken recall was better and more accurate than sung recall. In experiment 1, delayed recall was also better for the spoken condition, although these results were not significant (Racette & Peretz, 2007). Since music impaired verbal recall, Racette and Peretz (2007) surmised that participants processed the

melody and lyrics separately, creating a dual memory task.  While these study findings do not

support earlier research evidence (McElhinney & Annett, 1996; Rainey & Larsen, 2002; Wallace

1994), it is important to note that Racette and Peretz (2007) used both an unfamiliar melody and

text, requiring the participants to learn both lyrics and musical pitches.  It is possible that a

familiar melody would have functioned better as an auditory scaffold, supporting lyric recall

instead of distracting from it.

Overall, research investigating musical mnemonics with healthy adults has mixed

findings.  Musical mnemonics may be more effective when the melody is repeated (Wallace,

1994; McElhinney & Annett, 1996), may be effective for long-term recall (Rainey & Larsen,

2002), or may not be effective at all (Racette & Peretz, 2007).  Significantly, three of the four

studies showed promising results, pointing to potential effectiveness of musical mnemonics for

verbal recall.

Concerning the use of musical mnemonics for adults with disease, four studies

investigated the effects of musical mnemonics on memory performance in adults with Multiple

Sclerosis (MS) and two studies looked at similar effects in persons with Alzheimer's disease

(AD).  Simmons-Stern et al. (2010) found that sung lyrics were recalled with significantly

greater accuracy than spoken lyrics in adults with AD, although a comparison group of healthy

older adults performed slightly better in the spoken condition (these findings did not reach

significance).  It is possible that music increased neuronal synchrony and/or attention in those

with AD, allowing them to compensate for impaired encoding and arousal.  The same effects,

however, did not impact the healthy adults (Simmons-Stern et al., 2010).

In a 2012 case study on a female with AD, Moussard et al. found that sung lyrics to both

familiar and non-familiar melodies facilitated long-term recall better than spoken input, but did

not aid in immediate recall.  While these results reflect only one person's recall ability, findings support evidence from Rainey and Larsen (2002).  While the dual task of learning a melody and lyrics may initially interfere with recall (Racette & Peretz, 2007), relearning through music may be stronger and more durable (Moussard et al., 2010; Rainey & Larsen, 2002).  These findings suggest more thorough encoding and better retrieval strategies in musical mnemonic learning, which could explain improved long-term recall.

Investigating the use of musical mnemonics for persons with MS, Thaut et al. (2005) conducted two experiments using EEG scans to assess brain activation during learning and recall of either sung or spoken word lists in healthy adults and adults with MS.  Experiment 1 looked at 20 young adults who listened to a sung or spoken 15-word list from the Rey Auditory Verbal Learning Test (RAVLT) and were then tested for immediate and delayed (20-minute) recall (Thaut et al., 2005).  For this study, participants were asked to speak back their responses, whether or not they heard the lists spoken or sung. While behavioral indicators showed no significant difference between the two groups, EEG results showed that each learning condition accessed different oscillatory networks in the brain (Thaut et al., 2005).  For the singing condition, cortical and subcortical activation was more spread across the hemispheres, whereas for the spoken condition, neuronal activation was typically one-sided.  EEG results suggest that music learning may involve greater organization and chunking of material.  Further investigation through EEG revealed that the music condition elicited greater neuronal synchrony, specifically for the long-term (20 minute) trial (Thaut et al., 2005).

For Experiment 2, Thaut et al. (2005) looked at 40 patients with MS.  Again, participants listened to a 15-word list from the RAVLT either sung or spoken. Unlike experiment one, the

participants in this study who were exposed to the singing condition were asked to sing their responses. Results were as follows:

A) For short chunks of words (two-word pairs), those in the music condition performed significantly better than their spoken condition counterparts.

B) There was no significant difference, however, for longer chunks of words.

C) All participants showed a significant change in accurate recall from the first to the last trial.

D) As in Experiment 1, EEG results showed greater synchrony in the music condition. This is especially interesting, because MS causes demyelination, which weakens the connections between neuron networks, making neural synchrony more challenging (Thaut et al., 2005).

It is possible that behavioral changes were not observed in Experiment 1 because participants in the sung condition were asked to speak the word list during recall. If internal rehearsal was sung, then speaking the list could have created an additional step during decoding (recall) (Thaut et al., 2005). It appears that music aids in memory and learning by imposing temporal structure on information (Thaut et al., 2005).

Expanding on the Thaut et al. (2005) study, Moore et al. (2008) used the same pool of participants and study design to measure the recognition portion of the RAVLT. In contrast to the recall and EEG results measured by Thaut et al. (2005), Moore et al. (2008) found no significant differences in list recognition between the sung and spoken groups. Possible reasons could have been too few learning trials (the study used 10 trials), subjects with MS that was too advanced to fully benefit from memory strategies, and the possibility that the chosen melody was

not familiar enough to participants.  Interestingly, subjects in the sung condition who had higher cognitive skills benefitted more from the music mnemonics (Moore et al., 2008).

In a similar study looking at musical mnemonics and verbal memory in persons with MS, Thaut et al. (2008) assessed 20 patients with MS who listened to identical RAVLT word lists, either sung or spoken.  The musical condition used a newly composed (non-familiar) melody that was simple and repetitive.  Results were measured as the number of word chunks accurately recalled in the correct order (ranging from two to seven words) (Thaut et al., 2008).  Study results showed highly significant differences between the music and non-music groups (Thaut et al., 2008).  Participants who heard the word lists sung recalled significantly more words in the correct order, than those in the spoken group.  Interestingly, those in the spoken group appeared to perform worse over the three trials, as their accuracy decreased in the last two trials (Thaut et al., 2008).

A current study conducted by Thaut, Peterson, McIntosh and Hoemberg (2014) showed similar results.  When 54 patients with MS were randomly divided into two groups and asked to recall a RAVLT word list, those who heard the list sung showed significantly better verbal recall than those who heard the list spoken (Thaut et al., 2014).  As in the Thaut et al. (2005) study, EEG results from the music group showed improved neurological synchrony (Thaut et al., 2014).

Considering that MS is a degenerative disease and causes cognitive impairments, the evidence of increases in verbal learning through musical input are significant (Thaut et al., 2005; Thaut et al., 2008; Thaut et al., 2014).  It is possible that musical learning uses different neurological pathways than verbal learning alone.  Findings from Thaut et al. (2005) and Thaut et al. (2008) suggest that music aids in memory and learning by imposing a temporal structure on information.  The inherent structure of musical stimuli appears to aid in the memory rehearsal

technique of chunking.  Music innately chunks information into rhythmic and melodic units, potentially aiding in the organization of non-musical input for memory and learning.

### *Musical Mnemonics in Child Populations*

Musical mnemonics can enhance memory functions in healthy adults and those with MS and AD (e.g., Rainey & Larsen, 2002; Simmons-Stern et al., 2010; Thaut et al., 2008), suggesting similar benefits for healthy children and those with disabilities.  A review of the literature revealed no discoverable studies on the use of musical mnemonics with children after the year 2000.  The existing early research, however, suggests potential positive effects of musical mnemonic rehearsal on memory ability (Claussen & Thaut, 1997; Gfeller, 1983; Gingold & Abravanel, 1987; Wolfe & Hom, 1993).

While research support is limited to two studies, it appears that well-matched and familiar musical mnemonics support verbal memory recall in typically developing children (Gingold & Abravanel 1987; Wolfe & Hom, 1993).  Musical input appears to be more effective than spoken input, as preschoolers (age = 5 years) in a 1993 study by Wolfe and Hom learned sung telephone numbers in significantly fewer trials than when the numbers were spoken. Furthermore, familiar music appeared to be more effective than non-familiar music for both initial learning and recall (Wolfe & Hom, 1993).  When melody, rhythm and song phrasing match the natural phrasing of the novel input (lyrics), long-term verbal recall improved in young children (Gingold & Abravanel, 1987).  Conversely, when using poorly matched music that violated the natural rhythm and phrasing of the intended lyrics, children in the Gingold and Abravanel (1987) study not only showed decreased recall, they were so upset that they could not even complete the tasks.

It appears that music—especially familiar music—can assist children in learning non-musical information.  In the Wolfe and Hom (1993) study, musical mnemonics may have

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functioned as a motivator for children to attend to and rehearse novel information (Wolfe & Hom, 1993). Both of these notions would align with Cowan's and Baddeley's memory models (Baddeley, 2012; Cowan, 1999). It is important to note, however, that for the Wolfe and Hom (1993) study, only 10 out of 23 participants were able to complete the six trials. The challenging and repetitious nature of the procedure and attention demands placed on the children may have been too great for these 5-year olds. Perhaps a simpler design would have allowed more children to complete the study. Study design and sample size aside, the findings tentatively suggest that musical mnemonics may be effective memory aids for typically developing children.

Considering the results from both studies, it appears that musical setting matters. Familiar music was more effective than non-familiar music, and poorly matched music did more harm than good (Gingold & Abravanel, 1987; Wolfe & Hom, 1993). The fact that actively distracting and illogical music hinders recall, however, is unsurprising. Music enhances non-music functioning when the musical elements of rhythm, melody, harmony and phrasing serve to support the non-musical information (Thaut, 2008). The logic and structure of musical idioms seem to facilitate attention and enhance the rehearsal and chunking that support memory functioning (Thaut, 2008; Thaut et al., 2008; Wolfe & Hom, 1993).

In one of the two existing studies on the use of musical mnemonics for children with special needs, Gfeller (1983) conducted two experiments. Both experiments included 60 participants (aged 9 to 11.9 years), 30 of who had a learning disability (LD) while the other 30 were typically developing (TD). For the initial experiment, all 60 children were presented with either spoken or sung multiplication tables. The sung material was composed and, therefore, unfamiliar. Results were measured as a comparison between pretest and posttest scores on the multiplication problems. Gfeller (1983) found that typically developing students performed

better than those with a learning disability.  And, contrary to other study findings, those in the verbal only group (no music) performed significantly better on posttest recall (for both TD and LD children) (Gfeller, 1983).

In a follow-up experiment, each child attended four different rehearsal sessions: a) verbal rehearsal/repetition b) verbal rehearsal/repetition with modeling and cues c) musical rehearsal/repetition and d) musical rehearsal/repetition with modeling and cues (Gfeller, 1983). Posttest results showed that using musical rehearsal with modeling and cues resulted in significant improvements in recall, while the other conditions did not show a significant increase (Gfeller, 1983).  It is possible that because the second experiment involved more extended rehearsal, the musical cues were more effective than for the brief rehearsal in the initial study. Also, in line with Wolfe and Hom (1993) the use of non-familiar music may have hampered (or at least not helped) recall.

Although published in 1997, Claussen and Thaut's study is the most recent known study on musical mnemonics for children with special needs.  Claussen and Thaut (1997) looked at the effects of familiar music rehearsal and verbal rehearsal on recall with late elementary-aged children (N=21) who had learning disabilities.  Similar to Gfeller (1983), Claussen and Thaut (1997) also assessed recall of multiplication tables.  During the procedure, each child heard the multiplication table, either spoken or sung to a familiar tune. Following all rehearsal sets, results were measured through post-test scores (Claussen & Thaut, 1997).

Statistical results showed that participants in the familiar music condition had greater recall than those in the spoken condition (Claussen & Thaut, 1997).  Familiar music may have functioned as a "preexisting framework" through which children could pair the new information allowing for improved retrieval (Claussen & Thaut, 1997, p. 63)

Other explanations for greater recall during the music condition include improved attention through the novelty of rehearsal strategy and the organizational effects of rhythm, which may have created a temporal structure for the numbers.  Furthermore, the innate musical repetition of melody and rhythm, which is not present in the verbal information alone, could have facilitated greater chunking of information (Claussen & Thaut, 1997).

**Conclusions**

When considering musical mnemonics and childhood populations, the existing research support is minimal.  Studies used relatively small sample sizes and investigators discovered conflicting results.  Overall, looking at the larger body of literature on music, musical mnemonics, and memory functioning lends more substantial support.  Though the literature is not complete enough for strong assumptions, it appears that musical mnemonics enhance memory through increased attention, additional temporal structure and improved rehearsal and retrieval strategies such as chunking (Baddeley, 2012; Cowan, 1999; Thaut, 2010).  Familiar music appears to be more effective than newly composed music (Claussen & Thaut, 1997; Gfeller 1983; Wolfe & Hom, 1993).  And, musical mnemonics that incorporate phrases, rhythms and melodic lines that oppose the natural chunking/phrasing of the verbal input can deter recall ability (Gingold & Abravanel, 1987).  Existing findings point to a potential for efficacy, but the lack of studies on musical mnemonics and childhood populations- especially children with developmental delays- suggests a strong need for future research.

While there may be several reasons why this population is underserved in the literature- challenging subjects, wide variety of developmental delays and diagnoses, underfunded programs, etc.- children with developmental disabilities appear to have a significant need for academic support (Schuchardt et al., 2010; Spanoudis & Natsopoulos, 2011; van der Schuit,

Segers, van Balkom, & Verhoeven, 2011).  Since working memory correlates to educational attainment, it follows that interventions in memory functioning may enhance other areas of academic need (Gathercole et al., 2004; Hecht et al., 2001; Michalczyk, et al., 2013; Preßler et al., 2013).  Existing research on the use of musical mnemonics to improve working verbal memory for children with developmental delays shows promise, but further investigation is sorely needed.  Therefore, this study aims to examine the effect of musical mnemonics on verbal memory in children with developmental delays.

CHAPTER III: METHOD

**Research Design**

Using a randomized controlled trial experimental design, this study investigated musical mnemonics versus spoken input on verbal memory and recall in preschool children with developmental delays. Through an online randomizer, participants were assigned to either the control group (spoken input) or the experimental group (musical mnemonic input) (Urbaniak & Plous, 2013). The effect of the independent variable- the melodic and rhythmic phrasing incorporated in the musical mnemonic- was tested on the dependent variable- accuracy of serial order digit recall.

Over the course of five hearings ("trials"), the participants learned a random seven-digit number. Numbers were chosen as opposed to words for this study because children with developmental delays often have speech/language deficits. Using words may test a child's vocabulary knowledge or articulation as opposed to his/her memory. On the other hand, children are frequently exposed to single-digit numbers and use them throughout the school day. Furthermore, using numbers may make it easier and more accurate to assess a child's number-naming ability in a prescreening. A seven-digit number series was chosen because it fits within Baddeley's six to seven digit limit for serial order recall (Baddeley, 2012). The opening phrase of the tune "Old MacDonald" served as the familiar musical mnemonic. A seven-note line ("Old MacDonald had a farm"), the rhythm and melody matched the seven-digits of the number sequence and can be perceived as one musical phrase, or chunk. In this way, the use of music may support Baddeley (2012) and Cowan's (1999) theory that chunking enhances encoding. Five

hearings were chosen to allow for learning over time and to allow for more data gathering. Video recording was used for all trials in order to assess for inter-rater reliability.

Approval to conduct research was gained from the university Institutional Review Board (IRB). Due to the young age of the participants, informed consent was obtained from each participant's parent or legal guardian prior to any study procedures. Assent was also verbally obtained from all participants prior to the start of the study.

**Participants**

Fifty-four children were recruited to participate in this study (see Appendices A, B, and C for recruitment and consent information). Of the 54, 42 met inclusion criteria and were therefore included in the study. Two students were removed from the trial because they left the country before data collection began. Ultimately, 40 children (24 boy and 16 girls) participated in the study (see Figure 1). All children were currently enrolled in an early childhood special education center in the state of New York. Students ranged in age from 3 to 5 years old. Demographically, children in this program were mostly from non-English speaking, low-income homes (73% English-language learners; 88% with free or reduced lunch). Children were chosen to participate in the study based on results of a prescreening process. Prescreening assessed a) the child's score on the standardized Vineland-II Adaptive Behavior Scales b) the child's ability to audibly recognize and verbally reproduce single digit numbers, and c) recognition of "familiar" melody.
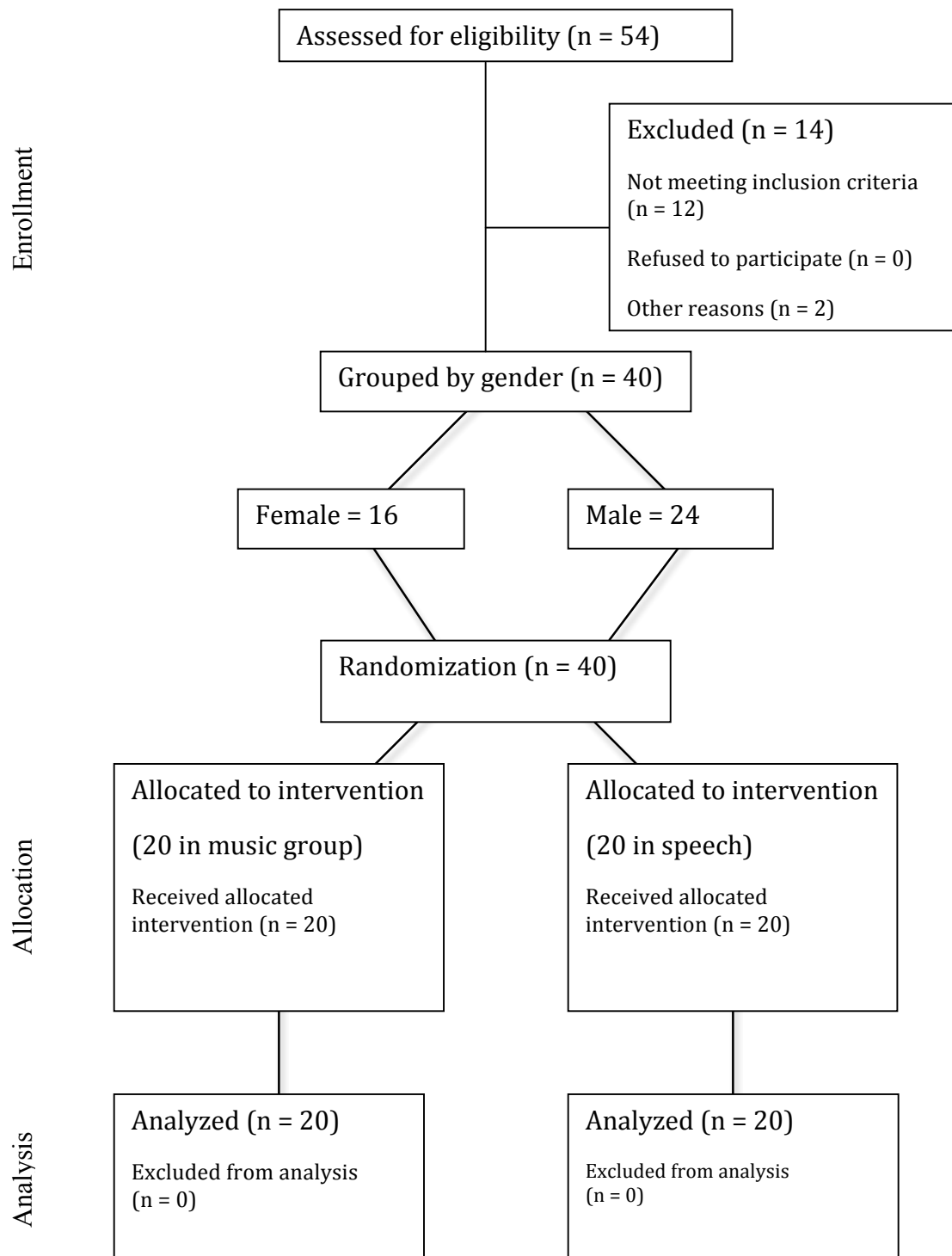
*Figure 1.* Participant flow chart.

**Exclusion/Inclusion Criteria**

Once informed consent was received, the investigator determined the child's score on a validated, standardized assessment by reviewing the child's Individualized Education Program (IEP). As a faculty member at the early childhood center, the investigator had authorization to review IEP files, but only reviewed files for children whose guardians had given informed consent. Since this study addressed verbal ability through verbal recall, and the majority of children in the program present with language delays, a communication assessment was consulted as part of the selection process. The Vineland-II Adaptive Behavior Scales is an assessment tool used to measure an individual's functioning level and to identify developmental delays. The Vineland-II assesses four domains: communication, socialization, motor skills and daily living skills (Sparrow, Cicchetti & Balla, 2008). Reliability scores for internal consistency and test-retest consistency for the Vineland-II range from good to excellent: "high .80's to mid .90's" and "low .80's to mid .90's" respectively (Stein, 2010, Technical, para. 2, 3). When compared for validity to the Adaptive Behavior Assessment System (ABAS-II), the Vineland-II correlated in the moderate range (".52 to .70") (Stein, 2010, Technical, para. 9). A reliable and moderately valid measure, the Vineland-II is a commonly used and readily available assessment for children in this program.

While it would be ideal to include only children with a set range of scores on a variety of standardized assessment tools, due to the nature of evaluations for children in preschool special education programs, numerically comparable results are often unavailable. For example, some children are not given standardized scores on language ability and/or intelligence because they do not speak English in the home. Many standardized assessments are not validated for second language learners, and are, therefore, infrequently used and contain unreliable data. In the case of

the Vineland-II, more general ranges ("low," "average") are used in place of defined scores.

Furthermore, many preschool-aged children will not receive a "formal" diagnosis until they

reach Kindergarten, making inclusion criteria based on diagnosis impractical.

To ensure a homogenous sample, all study participants needed to have a Vineland-II

assessment on file in their IEP with a rating of "low" or "moderately low" in the communication

domain. Children with informed consent and available Vineland-II scores were verbally asked

for assent. Upon affirming his/her willingness to participate, each child engaged in a brief

prescreening process.

During the prescreening, each child was asked to sing or hum along with the familiar tune

("Old MacDonald"). To assess for number-naming ability, each child was presented with the

numbers 0-9 in non-sequential order, and was asked to recognize (point to) and verbally identify

each number. If a child did not recognize the familiar tune and/or was unable to identify the

numbers 0-9 that child was excluded from the study.

**Study Format**

In an effort to mirror previously conducted studies on musical mnemonics, this study

incorporated the format used in the Rey Auditory Verbal Learning Test (RAVLT) (Moore et al.,

2008; Thaut et al., 2005; Thaut et al., 2008). The RAVLT is used to test for verbal learning and

memory. The RAVLT test consists of a 15-word list and incorporates a learning phase,

distraction task, immediate recall ("M1"), recall after a 10-30 minute delay ("M2"), and

recognition (Mackler, 2001). As the RAVLT is norm-scored for populations aged 7- 89 and can

require about 30 minutes to fully conduct, accommodations were made in the interest of time

constraints and a younger population (Mackler, 2001; Van der Elst, van Boxtel, van Breukelen,

& Jolles, 2005). Specific accommodations included using digits in place of words, decreasing

the number of input items from 15 to seven, and decreasing the time spent before delayed recall

from 10-30 to five minutes.  This last change allowed for more efficient (shorter) trials, and,

therefore, a greater sample size.  Also, since young children have shorter attention spans than

older children and adults, ten or more minutes of wait time may go beyond their ability to focus

and engage.  A comparison of the two test formats is illustrated in Figure 2.

| | RAVLT | Revised Format |
|---|---|---|
| Input | 15-word list | 7-digit random number |
| Number of hearings/trials | 5 | 5 |
| Learning Phase | Record responses after each hearing | Record responses after each hearing |
| Distraction Activity | Other word list | 1 minute song |
| Immediate Recall (M1) | Following Distraction | Following Distraction |
| Delayed Recall (M2) | 10 to 30 minutes | 5 minutes |
| Recognition Task | Yes | No |

*Figure 2:* Format comparison chart

**Procedure**

Upon informed parental consent and participant assent, specific participant demographics

were obtained and prescreening completed.  Following the pre-screening process, each child who

met inclusion criteria was divided into groups based on gender (male, female).  These groups

were then put into an online randomizer to ensure that, while participants were randomly

assigned to the music or non-music group, both study groups were equally matched by gender.

Each participant received a number assignment to ensure anonymity and to organize results.

Group A (n=20, boys= 12, girls= 8) heard the seven-digit number in spoken format (control).

Group B (n=20, boys= 12, girls= 8) heard the number in sung format (experimental). Both

groups heard the same randomly generated, non-repetitive seven-digit number (3,6,5,1,4,2,7).

All input, whether spoken or sung, was presented at 72 bpm and was pre-recorded by the

investigator. Sung numbers matched the opening phrase of "Old MacDonald." All recordings

were made using Logic Pro and were played via an iPod through iHome speakers. All sessions

were videotaped for follow up review. During each session, the researcher played the pre-

recorded number five times ("trials"). Immediately following each trial, the child was asked to

recall as much of the number as they could (learning phase). Following a brief distraction

activity in which the investigator invited the child to sing along with a recording of a children's

song ("Twinkle, Twinkle"), the child was asked to sing or speak back the digit sequence

(immediate recall).

After immediate recall, each child was prompted to choose from a selection of

instruments (shakers, castanets, rainstick, cabasa, drum, and ocean drum) to play with for five

minutes. Following the five-minute delay, the child was again asked to recall the seven-digit

number (delayed recall). The number of correct consecutive digits was recorded for each of five

trials, immediate, and delayed recall. Scores from each session were compared within group and

across groups. An example of the scoring chart used for each participant is illustrated in Figure 3.

| Participant # | Trial 1 | T 2 | T 3 | T 4 | T 5 | Immediate Recall | Delayed Recall |
|---|---|---|---|---|---|---|---|
| Response | | | | | | | |
| Absolute Recall | | | | | | | |
| # Correct | | | | | | | |

*Figure3:* Participant performance chart.

**Data Analysis**

As shown in Table 2, all responses were scored based on both absolute recall and the number of accurate serial order digits recalled. Absolute recall accounted for any correctly recalled number, regardless of serial order. In order to give participants credit for recalling digits in the correct order at the start, middle and end of the number sequence, serial order recall was measured based on accuracy from the start and from the end of the sequence. Also, if a student put a number in the correct placement within the sequence or grouped 2 or more numbers together in the correct sequence, this was counted as correct. For example, a response for the target number {3,6,5,1,4,2,7} of {3,1,4,2,7} would have an absolute recall score of five, and a serial order score of four to account for the first correct digit {3} and the final three correct digits {4, 2, 7}. Similarly, a response of {4, 6, 5, 8, 9, 2, 7} would receive an absolute score of five, and a serial order score of four, with two points for putting the {6,5} in the correct part of the sequence and two points for ending with two correctly sequenced digits {2,7}. Using video footage from all sessions, the researcher and an inter-rater observer compared data collection results (see Appendix E for individual recall data).

Data was analyzed using IBM SPSS for Mac. Analysis determined changes in individual scores within groups and compared total scores across groups. To ensure the randomization and equality of the two groups, the investigator conducted parametric analysis on group demographics. Mean absolute recall scores of immediate, delayed, and overall average recall were compared using t-tests. Since there was evidence of skewness in the serial order data, overall differences between the two groups on mean scores of immediate, delayed, and overall average recall were measured using the non-parametric Mann Whitney U test. Individual results for serial order recall over time, both between and within groups, were assessed using the

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Friedman's Test- a non-parametric version of the Repeated Measures ANOVA. Post hoc

analysis was conducted using the Wilcoxon Signed Rank Test using a Bonferroni correction. In

order to test for the effect of age on immediate, delayed and overall average absolute recall, the

investigator compared scores for 3-4 year olds and 5-year olds using a t-test. The effect of age

on serial order recall was tested using the Mann Whitney U to account for skewness. For all

statistical analysis, excluding post hoc analysis, alpha was set at 0.05.

## Results

### *Participant Demographics and Inter-Rater Reliability*

As previously noted, the music and non-music groups were matched by gender prior to

beginning the trial. T-tests of group demographics showed that the groups were well matched

for age and VABS-II score between the music and the non-music group, $p= 0.946$ and $0.811$

respectively. See Table 1 for demographic statistics. Comparison of scores between the

researcher and the inter-rater observer showed high correlation on all measures (Intraclass

Correlations ranging from 0.885-0.997). Therefore, the initial set of data was used for analysis.

Table 1

*Descriptive Statistics, Demographics*

|  | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Age in Months Group A | 20 | 40 | 63 | 53.80 | 6.732 |
| Age in Months Group B | 20 | 39 | 64 | 55.65 | 6.930 |
| Vineland Verbal Score Group A | 20 | 0 | 1 | .60 | .503 |
| Vineland Verbal Score Group B | 20 | 0 | 1 | .85 | .366 |

***Outcome Measures***

An independent t-test was conducted to compare absolute recall between the music and non-music groups on three sets of data: immediate recall, delayed recall, and overall average recall. The overall average included accuracy scores from the five initial trials as well as scores from immediate and delayed recall. There was no significant difference in scores for immediate, delayed or overall average recall between the music and non-music groups (Immediate: $t(38)=$ 0.655, $p=$ 0.516; Delayed: $t(38)=$ 0.505, $p=$ 616; Overall: $t(38)=$ 0.851, $p=$ 0.400).

In order to compare accurate serial order recall on the same three sets of data (immediate, delayed, and overall average recall), the Mann Whitney U test was conducted. There was no significant difference in scores for immediate recall or delayed recall between the music group and the non-music group (Immediate: $p=$0.495, Delayed: $p=$ 0.355). Similarly, there was no significant difference in overall average scores between the two groups ($p=$ 0.738). See Tables 2 and 3 for comparative group statistics. Figures 4 and 5 show participant absolute and serial order recall across each trial.

Table 2

*Means and Standard Deviations for Immediate, Delayed and Overall Average Absolute Recall*

| Variable | Music Group (n= 20) M (SD) | Non-Music Group (n = 20) M (SD) |
|---|---|---|
| Immediate | 3.30 (2.618) | 3.80 (2.191) |
| Delayed | 3.75 (2.807) | 4.15 (2.159) |
| Overall Average | 3.450 (1.590) | 3.871 (1.542) |

Table 3

*Means and Standard Deviates for Immediate, Delayed and Overall Average Serial Order*
*Recall*

| Variable | Music Group (n= 20) M (SD) | Non-Music Group (n = 20) M (SD) |
|---|---|---|
| Immediate | 1.10 (1.997) | 1.10 (1.518) |
| Delayed | 0.85 (2.064) | 0.95 (1.387) |
| Overall Average | 1.279 (1.068) | 1.207 (1.124) |



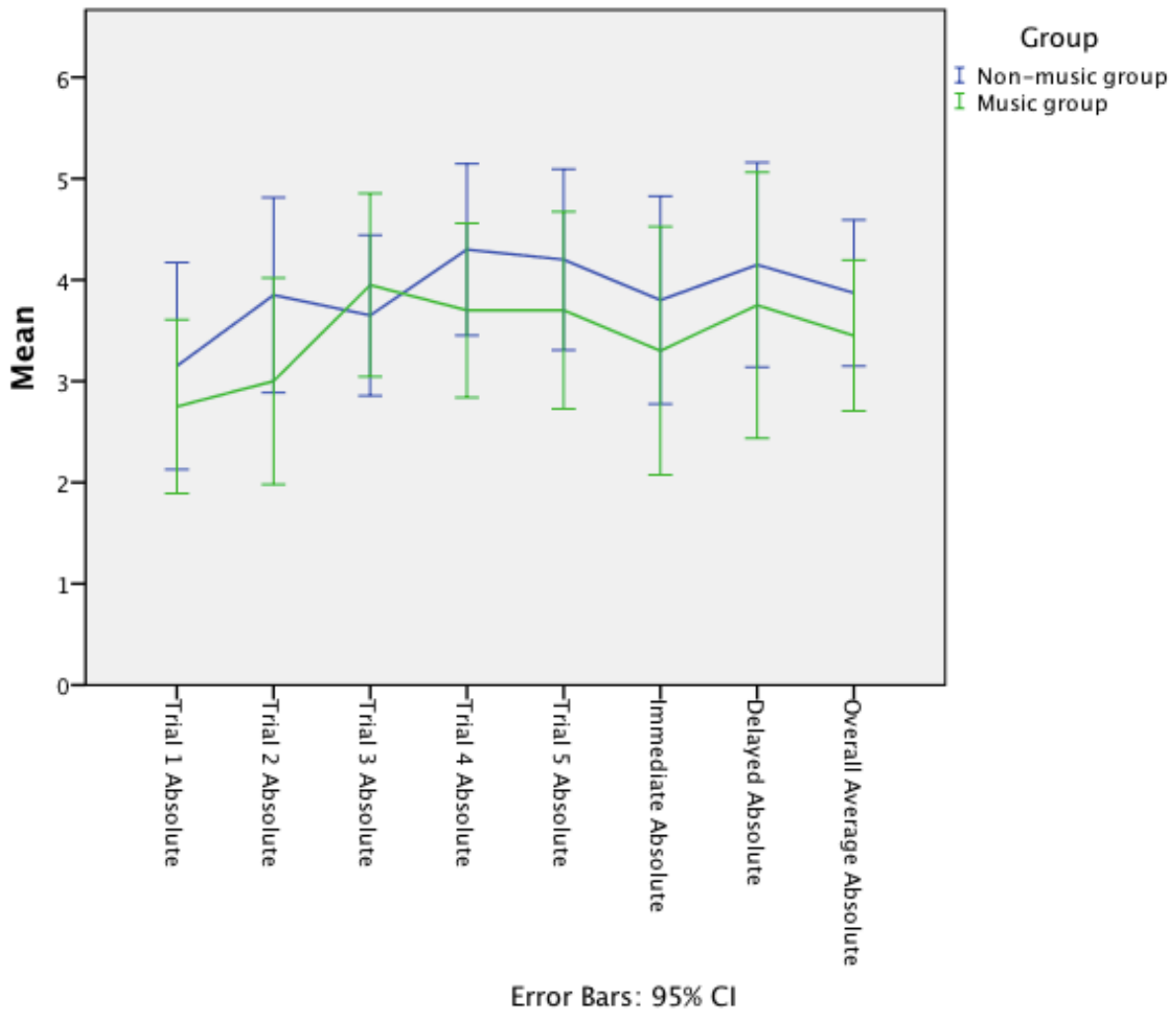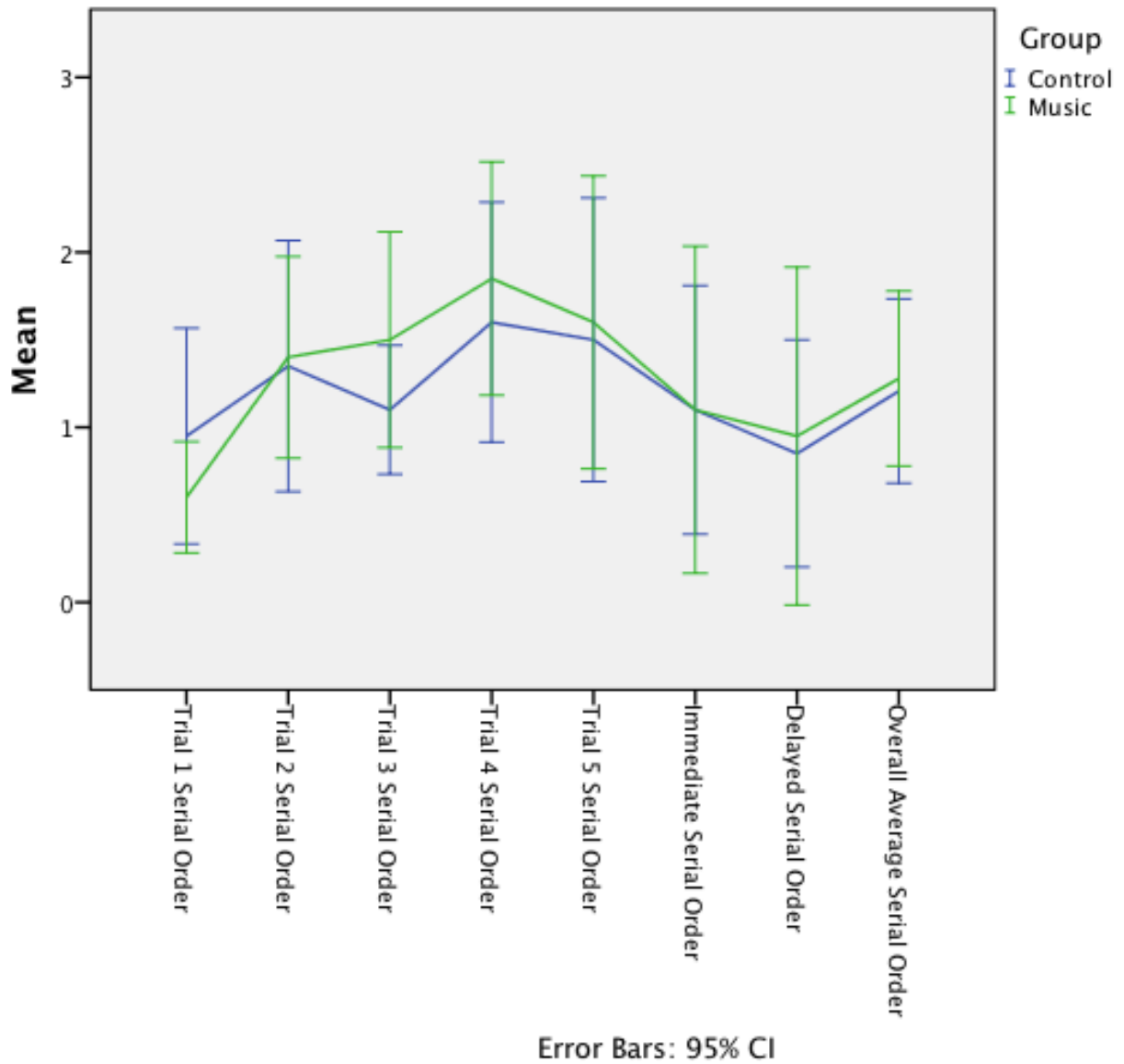*Figure 4.* Absolute Recall for the Music and Non-Music Groups

*Figure 5.* Serial Order Recall for the Music and Non-Music Groups

Results from the Friedman's Test, however, showed a statistically significant difference in individual recall scores over time, $\chi^2(6) = 33.386, p = 0.000.$ Post hoc analysis using the Wilcoxon Signed Rank Test was conducted to find where the significance lay. Since the post

hoc analysis ran 21 separate comparisons, a Bonferroni correction, resulting in a significance of $p<0.002$, was used. For the majority of the two-way comparisons, there was no significant difference. A significant difference in recall was found between Trial 1 and Trial 4 ($Z = -3.354$, $p= 0.001$), with higher recall scores in Trial 4. Similarly, recall in Trial 5 was significantly greater than Delayed Recall ($Z= -3.188$, $p= 0.001$).

Looking at the effect of age on absolute recall, t-tests revealed a significant difference in absolute delayed recall, with the 5-year olds ($5.50 \pm 2.023$) showing significantly better recall than the 3-4 year olds ($3.29 \pm 2.386$), $t(38)= -2.806$, $p= 0.008$. For both absolute immediate and overall average recall, no significant difference was found between the groups (Immediate: $t(38)= -.774$, $p= 0.444$; Overall: $t(38)= -1.803$, $p= 0.079$). In order to assess the effect of age on serial order recall, a Mann Whitney U test was conducted. There was a significant difference in immediate serial order recall ($p= 0.049$). No significant effect of age was found for delayed or overall average serial order recall ($p= 0.192, 0.389$, respectively). See Figures 6 and 7 for graphs of participant recall based on age.
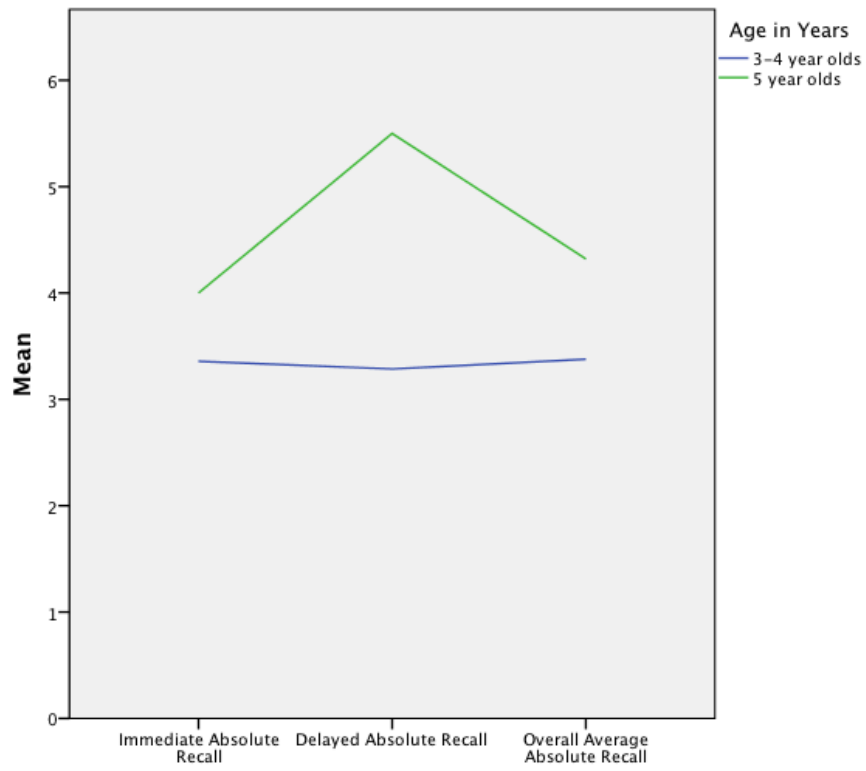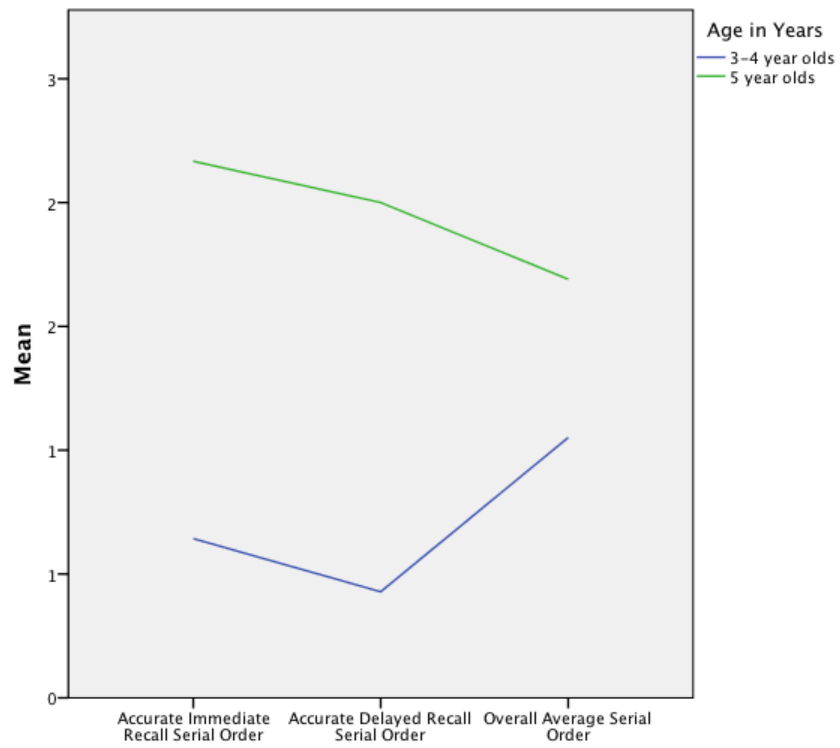
*Figure 6.* Absolute Recall by Age



*Figure 7.* Serial Order Recall by Age

CHAPTER IV: DISCUSSION AND CONCLUSION

**Discussion**

The purpose of this study was to investigate the effects of musical mnemonics compared to spoken input on verbal memory in preschool children with developmental delays. The researcher aimed to answer three questions:

1. Will musical mnemonics be more effective than spoken input for immediate recall of a novel number sequence?

2. Will musical mnemonics be an effective tool for delayed memory recall?

3. Will there be a statistically significant difference in participants' ability to recall a number sequence between the music group and the spoken input group?

On all accounts, the null hypothesis was retained: there was no significant difference between the music and the non-music group.

*Discussion of the Statistical Results*

Although there may be several factors that contributed to recall, hearing the digit sequence sung or spoken had no discernible effect on participant recall. For absolute recall, the participants in the non-music group had slightly better mean scores on immediate, delayed and overall average recall, though none of the differences reached significance. Serial order recall was across groups for immediate, delayed and overall average recall. As shown in Table 3, the overall average recall for both groups of participants was approximately one digit. Average immediate recall was the same for the music and non-music groups, while the non-music group performed slightly better on delayed recall. For serial order recall, the music group performed slightly better overall than the non-music group, suggesting that the participants in the music

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group had better serial order accuracy during the learning trials. These differences were so slight, however, that any firm conclusions cannot be made.

When looking at individual recall over time, however, some differences did emerge. There was a significant increase in recall between the first and fourth repetitions during the learning phase. This may suggest learning over time and improvements with rehearsal in both the music and non-music conditions. Recall during the fifth trial was significantly higher than delayed recall, which is not surprising since one would expect better recall directly following the fifth hearing of a number sequence. Since delayed recall followed a five-minute distraction activity, it seems likely that recall would decline.

There were some notable differences in participant recall based on age. On all measures, 5-year olds out-performed their 3-4 year old counterparts. For both delayed absolute recall and immediate serial order recall, the differences reached significance. These results suggest increased working memory ability as children age, supporting Baddeley (2012) and Cowan's (1999) developmental view of working memory. The older children had more school experience, and therefore may have had more exposure to numbers, memorization games, and overall learning opportunities.

Overall data suggests that the novel number sequence was challenging for all participants, regardless group or age. Absolute recall was higher than serial order recall, but there may have been an element of guesswork inherent in the absolute scores. In a 7-digit non-repeating number sequence, a participant has a 70% chance of saying a correct number, which may have contributed to the higher absolute scores. If a participant merely counted from one to seven in numeric order ("1,2,3,4,5,6,7"), that technically counted as accurate absolute recall. Perhaps the child recognized that there were seven digits, and the sequence ended on the number

seven, leading him/her to count up to seven over several trials (see Appendix E for participant recall data). It is interesting to note, however, that many participants recalled less than seven digits for most or all of their recall attempts, suggesting that they were not able to retain seven digits, whether or not in serial order.

Some participants attempted recall only minimally and a small portion of participants (n=3) did not accurately recall any of the digits over the entire trial. On the other hand, there were nine participants who, at various points during the trial, could recall four or more digits in accurate serial order. Two participants recalled up to six digits in the correct order and one child (in the music group) was able to accurately recall all seven digits in serial order. These outliers and the overall low recall scores most likely contributed to the highly skewed nature of the serial order results.

There are several possible reasons for such low recall rates. Some participants could recall multiple correct digits on a few trials, but would recall nothing on others, bringing their average score down. Although the researcher made efforts to make the trials comfortable and "play"-like for participants, it is possible that the test-like nature of the study made the participants nervous and less likely to respond. Also, one could argue that a seven-digit sequence is too long for such young participants. While seven-digit forward recall is frequently used in the literature and coincides with Baddeley's (2012) six-to-seven digit recall limit, this does not take into account the young age of the participants. It is possible that a shorter novel number sequence would have yielded higher levels of recall. Many participants appeared overwhelmed by the long digit sequence, with one participant remarking "Whoa! That's a lot of numbers!"

Interestingly, many participants consistently recalled the last one or two digits of the sequence, suggesting that the children were able to recall and learn at least some of the sequence (see Appendix E). Conversely, some participants consistently recalled three or four-digit sequences that were incorrect, suggesting they had initially mis-learned the sequence, but persisted in recalling the wrong digits. This lack of awareness or inability to accurately recall the digits may relate to the participants' developmental delays. Since poor working memory and recall is found in children with a variety of disabilities (Schuchardt et al., 2010; Spanoudis & Natsopoulos, 2011; van der Schuit, Segers, van Balkom, & Verhoeven, 2011), it is possible that the overall low recall scores are attributable to participants' disabilities.

A final consideration is the tempo at which the numbers were sung and spoken. Musical mnemonics work well when they serve as a scaffold by chunking input (Baddeley, 2012; Cowan, 1999; Thaut, 2010; Thaut et al., 2005; Thaut et al., 2008) and when they use familiar music (Wolfe & Hom, 1993; Gringold & Abravanel, 1987). All the children in the study knew the mnemonic tune, but it is possible that the tempo affected their ability to adequately chunk the numbers. While the tempo was chosen in order to be slow enough for clarity, but not so slow as to lose the cohesive musical phrase, it is possible that a slower or faster tempo would have better supported recall.

***Comparisons Between Present Study and Previous Research***

While previous studies have shown a positive effect of music on recall in adults (eg., Rainey & Larsen, 2002; Thaut et al., 2005) and in children (Claussen & Thaut, 1997; Gfeller, 1983; Gingold & Abravanel, 1987; Wolfe & Hom, 1993), results from this study do no support the use of musical mnemonics as a tool for delayed memory recall. Both the music and the non-music groups showed similarly low levels of accurate recall. Interestingly, a few of the children

in the music group sang along with the recording, suggesting an attempt to rehearse. This would coincide with Baddeley's (2012) emphasis on rehearsal in working memory and Tam et al.'s (2010) view that young children typically engage in overt or "out-loud" rehearsal until they are about seven years old. Overt rehearsal was not observed in the non-music group. Since the task appeared to be too challenging for the participants, however, it is not possible to confirm whether or not musical mnemonics could be an effective way to enhance delayed recall.

Wolfe and Hom (1993) used seven-digit phone numbers to test musical mnemonics on recall, and did find a significant benefit to using familiar music as a memory scaffold. There were distinct differences between these two studies. Wolfe and Hom (1993) studied only typically developing five year olds, and they used six different seven-digit phone numbers over the course of multiple learning trials. The present study looked at 3-5 year olds with developmental delays and included fewer repetitions. Wolfe and Home (1993) reported, however, that only 10 of the 23 participants were able to complete the task, further suggesting that a seven-digit number sequence may be too challenging for a young population.

When comparing this study to previous research on musical mnemonics and memory, it is important to note that this study used younger participants than any earlier known study. And, the only other studies that looked at children with special needs included only older-elementary aged participants (Claussen & Thaut, 1997; Gfeller, 1983). There are potentially many reasons why young children, particularly those with disabilities, are under-represented in the literature. By their very nature, young children are unpredictable and may be affected by any number of outside factors such as mood, energy level, how much sleep they had the night before, health, etc., which may impact their performance. And, the nature of diagnosing and grouping young children with delays is fraught with challenges, including lack of age-appropriate assessments

and a lack of standardized and validated measures for non-native English speakers. Due to the lack of research on working memory and young children, reliable and tested study procedures were not available, making adequate measures of participant performance a challenge. For this study, a study format intended for older children and adults- the RAVLT- was modified to better fit the capabilities of preschoolers. Although the RAVLT has been used in previous research on music and memory (Thaut et al., 2005; Thaut et al., 2008), it is possible that further modification of the RAVLT or a different study design may have resulted in better outcomes for this population.

Furthermore, the children in this study had developmental delays, and all had low or moderately low verbal scores on the VABS-II. Since poor working memory appears to be connected to low verbal ability (Gathercole et al., 2004; Hecht et al., 2001; Michalczyk, et al., 2013; Preßler et al., 2013), it is possible that the children in this study needed more repetition and/or a shorter digit sequence to benefit from musical mnemonics. It is important to note, however, that all participants appeared to understand the process of the study, and were compliant and appeared comfortable during both the one and five minute delays. The overall study design, therefore, is sound. Certain changes, such as increasing the number of learning trials and shortening the digit sequence, may result in better recall and more normalized results.

### Study Limitations

While this study used a randomized format, a good sample size, and had strong inter-rater correlations, there are some limitations to report. The highly skewed results for serial order recall limited the researcher to non-parametric analysis of that data set. And, overall low responses suggest the task was poorly matched to the participants' capabilities. Although the participants were well matched for age, gender, and VABS-II scores, the nature of disability

classification in early education leads to difficulties in grouping children based on their specific disability.  It is possible that the participants in this study will go on to vastly different diagnoses and classifications when they enter elementary school, which may have impacted their performance in this study.

### *Clinical Implications and Suggestions for Future Research*

The overall lack of difference between the two groups leaves little room for clinical implications.  It does appear, however, that young children with developmental delays struggle to recall digit sequences, which may point to difficulties in recalling other verbal input.  These challenges should be considered when designing therapy interventions.  Since previous research shows a correlation between working memory deficits and disabilities (Gathercole et al., 2004; Hecht et al., 2001; Michalczyk, et al., 2013; Preßler et al., 2013), therapists should consider a child's working memory ability if he/she has a developmental disability.

Although the current study does not add support to the use of musical mnemonics to improve verbal recall, previous studies have shown the efficacy of music as a memory tool (eg. Gfeller, 1983; Moore et al., 2008; Thaut et al., 2008).  Since musical mnemonics are used in the clinic and the classroom, and are *assumed* to be effective, future research should continue to pursue measurable data that will demonstrate whether or not this form of music therapy is truly an efficient memory support.  Noting the continued gap in music therapy research (and research in general) for early childhood populations with special needs, future studies should include this under-represented group.  Specifically, research should incorporate the format used in the present study, but with a shorter digit sequence and/or more learning trials.  Future researchers should also consider running the study with typically developing children to gather a baseline for expected performance from which to compare children with developmental delays.

**Conclusion**

In summary, the outcomes from this study did not show a significant effect of musical mnemonics on verbal recall in preschoolers with developmental delays. Neither form of input-spoken or sung- led to high levels of serial order recall. Absolute recall scores, though higher than serial order, were also low for both groups. These results suggest that the task itself was too challenging, and/or that children with delays have significant challenges when asked to recall verbal input. It is not possible to make strong conclusions for or against musical mnemonics based on the overall low results. There was, however, a significant effect of age on absolute delayed recall and serial order immediate recall. Five-year old participants performed better than their 3-4 year old counterparts on both measures, suggesting improvements in memory over the course of development. These results support previous studies on the developmental nature of memory and recall (Baddeley, 2012; Cowan, 1999; Tam et al., 2010).

Although the null hypothesis was not rejected for any of the three research questions, some useful information can be gleaned from the present study. Future researchers can draw on this study design and improve upon it, thereby adding to the small body of literature on musical mnemonics and young children. Working memory is an essential part of the learning process and is linked to academic achievement. Therefore, working memory deficits in young children and means for enhancing working memory deserve continued attention from researchers, educators, and therapists.

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Appendix A

Verbal Recruitment Script

Hello, my name is Audrey, and I'm the music therapist here at HeartShare. I am getting my masters in music therapy at Colorado State University. I am conducting some research towards my degree on music and verbal memory and recall. The title of the project is "The Effect of Musical Mnemonics on Learning and Recall in Preschool-aged Children with Developmental Disabilities." The Principal Investigator is Dr. Blythe LaGasse, my advisor and assistant professor in the music therapy department and I am the Co-Principal Investigator.

We would like to include your child in this study. Your child will be asked to listen to a recorded seven-digit number either sung or spoken. The number will be played five times. Your child will be asked to remember the number by repeating it. Your child will also be asked to sing a children's song and play some instruments for a few minutes. Afterwards, your child will be asked to remember the number one last time. Participation will take approximately 15 minutes. You and your child's participation in this research is voluntary. If you decide to allow your child to participate in the study, you may withdraw your consent and stop participation at any time without penalty.

Would you like your child to participate?

If yes: Proceed.

If no: Thank you for your time.

We will not collect your or your child's name or personal identifiers. When we report and share the data with others, we will combine the data from all participants. There are no known risks or direct benefits to you, but we hope to gain more knowledge on music therapy techniques to improve memory and recall.

(Give parent consent form, and point out relevant contact information.)

Appendix B

## Consent to Participate in a Research Study
## Colorado State University

**TITLE OF STUDY:** The effect of musical mnemonics on learning and recall in preschool-aged children with developmental disabilities

**PRINCIPAL INVESTIGATOR:** A. Blythe LaGasse, PhD, Assistant Professor, Music Therapy Department;  Blythe.lagasse@colostate.edu

**CO-PRINCIPAL INVESTIGATOR:** Audrey Selph, Candidate for Master's in Music, Music Therapy, Mailing address: 1825 Bath Ave., Brooklyn, NY 11214, Phone: (718) 238-4637; Audrey.selph@colostate.edu

**WHY IS YOUR CHILD BEING INVITED TO TAKE PART IN THIS RESEARCH?** This study will look at memory and recall in 3-5 year old children who have a developmental delay or disability. Children attending HeartShare First Step, who have a developmental delay or disability, and who receive parental consent, will be invited to participate in this study.

**WHO IS DOING THE STUDY?** Audrey Selph, HeartShare First Step's music therapist, will be conducting the study as part of her master's thesis.

**WHAT IS THE PURPOSE OF THIS STUDY?** The purpose of the study is to look at recall of a sung or spoken seven-digit number to see if the use of music positively affects memory.

**WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST?** The study will take place at HeartShare First Step.  Your child will go to the music room for the study. It will take about 15 minutes to complete the session.

**WHAT WILL YOUR CHILD BE ASKED TO DO?** Before the session begins your child will be asked to recognize and say the numbers 0-9.  Your child will also be asked if he/she recognizes a familiar children's song "Old MacDonald." This song will be used in the study.  Your child will be asked to listen to a recording of a seven-digit number, either sung or spoken.  The number will be repeated five times.  Your child will be asked to remember that number by repeating it to the music therapist.  The child will also be asked to sing a children's song and play instruments (drum, shakers, ocean drum) for a short period of time before recalling the number one last time. Videotape will be used in this study in order to review study results.  The video will be aimed at the researcher and will not show your child's face.  All video materials will be securely stored under lock and key by Ms. Selph.

**WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?** There are no known risks associated with the study. It is not possible to identify all potential risks in research procedures, but the researcher(s) have taken reasonable safeguards to minimize any known and potential, but unknown, risks.

**ARE THERE ANY BENEFITS FROM TAKING PART IN THIS STUDY?** While there are no direct benefits to participating in this study, the results from this study may help in the development and improvement of music therapy techniques that use music to improve memory and recall.

**DOES MY CHILD HAVE TO TAKE PART IN THE STUDY?**  Your child's participation in this research is voluntary. If you or your child decides to participate in the study, you may withdraw your consent and stop participating at any time without penalty or loss of benefits to which you are otherwise entitled.

**WHO WILL SEE THE INFORMATION THAT I GIVE?** We will keep private all research records that identify you and your child, to the extent allowed by law. Your child's information will be combined with information from other children taking part in the study. When writing about the study to share it with other researchers, we will use the combined information we have gathered. Your child will not be identified in these written materials. We may publish the results of this study; however, we will keep you and your child's names and other identifying information private.

Before the study begins, Ms. Selph will look at your child's IEP files to see his/her scores on the Vineland-II assessment.  These scores will help determine if your child has the communication skills needed for the study.  Only Ms. Selph will access IEP files.  All IEP file information will remain private.

We will assign a code in place of your child's name (Ex. Participant 1c).  The code number will be used on all study documents. The only place your child's name will appear is on this consent form and in data that links your child's name with his/her code.  Only the investigator will have access to this information, and all data will be kept locked for the duration of the study and for 3 years following completion of the study.  Following that time, the information will be destroyed.


**WHAT IF I HAVE QUESTIONS?**
Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now.  Later, if you have questions about the study, you can contact the investigator, Audrey Selph at (718) 238-4637. If you have any questions about your rights as a volunteer in this research, contact the CSU IRB at: RICRO_IRB@mail.colostate.edu; 970-491-1553. We will give you a copy of this consent form to take with you.

Your signature acknowledges that you have read the information stated and willingly sign this consent form.  Your signature also acknowledges that you have received, on the date signed, a copy of this document containing __2__ pages.


PARENTAL SIGNATURE FOR MINOR

As parent or guardian I authorize _____ (print name) to become a participant for the described research.  The nature and general purpose of the project have been satisfactorily explained to me by _____ and I am satisfied that proper precautions will be observed.


_____
Minor's date of birth


_____
Parent/Guardian name (printed)


_____          _____
Parent/Guardian signature                                             Date

Appendix C

Verbal Assent Script

Hi!

I'm Ms. Audrey, the music therapist here at school.  I am doing a study on kids like you.  If you say it is okay, we will walk to the music room, listen to some numbers on the ipod and see if you can remember them.  We will also play with some instruments and sing a song together. Is it okay if we go play in the music room today?

Appendix D

Study Script

Okay _____ (child's name), today we are going to play a game.  In this game, you are going

to listen really closely to some numbers.  After you listen, it will be your turn to say the numbers.

You need to listen as hard as you can, and try your best to remember the number and say it back

to me.  So, the speaker "says" the number, and you repeat it back to me. We're going to listen

and say the number 5 times.  You ready?

Okay. Let's listen. (Listen to the recorded number)

Now, it's your turn.  You say the number. (Child response)

Okay, let's listen again.

(Repeat after each initial hearing)

(Following 5 initial hearings….)

Nice job.  Now, let's sing "Twinkle Twinkle" together with the music (i.e., recorded song on

iPod, recorded to last 1 minute).

Remember that number we heard earlier?  Can you try your best to say it to me again?  (Child's

response) Thanks!

I have a lot of cool instruments here for you to try.  You have 5 minutes to play with them for

fun.  Here's the timer.  I'll let you know when the five minutes is done.  Go ahead and play!

(Following 5 minutes of child-directed play)

That was fun.  I wonder if you still remember the number we heard before?  At the very

beginning, we heard a number 5 times. Can you say it to me one more time?

Excellent!  Thanks so much for playing my game with me.  Let's go back to class.