This is to certify that the
dissertation entitled

AN EXPLORATORY STUDY OF THE USE OF MUSIC THERAPY
IN TEACHING MATHEMATICAL SKILLS
TO INDIVIDUALS WITH WILLIAMS SYNDROME

presented by

Eunmi Emily Kwak

has been accepted towards fulfillment
of the requirements for the

Ph.D degree in Music Education

Major Professor's Signature

12/02/2008

Date

AN EXPLORATORY STUDY OF THE USE OF MUSIC THERAPY IN TEACHING MATHEMATICAL SKILLS TO INDIVIDUALS WITH WILLIAMS SYNDROME

By

Eunmi Emily Kwak

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Music Education

2008

ABSTRACT

AN EXPLORATORY STUDY OF THE USE OF MUSIC THERAPY
IN TEACHING MATHEMATICAL SKILLS
TO INDIVIDUALS WITH WILLIAMS SYNDROME
By

Eunmi Emily Kwak

This study was designed to develop effective music therapy strategies to teach mathematical concepts to individuals with Williams Syndrome (WS) by using their affinity and abilities in music as instructional aids. WS is caused by a microdeletion of 16 – 23 genes on chromosome 7q11.23. These missing genes cause common facial appearance, similar physical characteristics, common cognitive and behavioral characteristics, and physiological difficulties, including cardiovascular abnormalities. A well-known trait of people with WS is a pronounced difficulty with mathematics. In addition, individuals with WS are known as music lovers. An "affinity to music" is often used to describe this characteristic. The basic premise for the effectiveness of music therapy intervention for individuals with WS in this study was that, by combining arithmetic with musicing, individuals with WS could be motivated to attend to mathematical tasks and their attention could be held for longer periods, which might enhance their ability to learn and retain the lessons.

A *collective case study* was the methodological framework for the study. The participants in the study were three individuals diagnosed with WS, ranging 10 to 21 years of age. Sessions took place over a 10-week period, once per week for 40 to 60 minutes, in each participant's home environment. All thirty sessions were digitally recorded and transcribed.

The analysis and interpretation of the sessions identified the participants' roadblocks in their mathematical development in metacognition, visuospatial ability, attention, processing speed, and fine motor skills. The severity of these difficulties was shown to vary among the three participants. While many of the effects of these difficulties overlap and are interrelated, the findings suggest that each difficulty requires a different form of intervention. These findings also suggest that music therapy could offer various strategies that assist in coping with the difficulties. Three primary functions in music were identified as being particularity beneficial for mathematical development: music used to advance cognitive development; music used to encourage and motivate; and music used to provide structure for academic learning interventions.

Based on the findings of the study, several suggestions are made for music therapists working with individuals with WS as well as individuals with other genetic disorders. These suggestions include the importance of specific research on the differences in the roadblocks among the various types of genetic disorders and an informed clinical practice based on knowledge, theory, and research with the particular type of genetic disorder. This study suggests that music therapists might need to develop three sets of music therapy interventions: 1) individuals with WS who do not develop the comprehension of magnitude and cardinality; 2) individuals with WS who develop the basic concepts referred to above, but still struggle with operating numbers such as composition and decomposition; and 3) individuals with WS who develop a basic understanding of numbers and operations and are ready to move on to addition and subtraction. This study demonstrated the strong possibility that music therapy can assist individuals with WS in their mathematical development.

Dedication

This dissertation is dedicated to my parents, Changgun Kwak and Youngja Chun, in gratitude for their prayers, support, and trust. I also dedicate this to my Heavenly FATHER for keeping me strong, focused, and seeing the beauty in individuals who are not just like me. Without HIM I could not have completed this project nor come this far.

Acknowledgements

I am sincerely indebted to the faculty, family, friends, and my three participants and their family members. During the 10 weeks of sessions, Angela, Roxy, and Big Red were so sincere and tried to make each session, even through Thanksgiving, Christmas, and family engagements. Thank you Angela, even though you had a cold, even though you just returned from the dental appointment and you still felt the pain and numbness in your mouth, you came to the session. Thank you Roxy, even though you expected your best friend to arrive any minute, you were able to focus on the task. Thank you Big Red. I know I made you uncomfortable at times, but you did not complain. You were so patient and generous with me. The Williams Syndrome Association and parents of individuals with WS were so eager to find a way to help their children and their support and enthusiasm continues to be inspirational.

Next, I want to express my gratitude to my extraordinary committee: to Dr. Frederick Tims, my advisor and mentor, for his thoughtful and genuine care, guidance, and enthusiasm about the subject matter, and for his trust in me during the most difficult times; to Dr. Mitchell Robinson, for his endless guidance with the qualitative research methodology, and for his genuine care about not only the academic aspects but also 'Emily' as a person; to Dr. Cynthia Taggart, for her productive and constructive comments on my dissertation and her high expectations for my project; to Dr. John Kratus, for his facilitating critical thinking and inspiration. I am also thankful to the College of Music, and the Graduate School for supporting my research through several generous fellowships and assistance for participation in conferences which shaped my dissertation.

Thank you to the Williams Syndrome Association and Terry Monkaba, their executive director, Tia Sager, the program director of the Association, and the Whispering Trail Camp, music camp for individuals with WS, for their enthusiasm, support, and encouragement to make an impact on WS research. The idea for this research came to me at the 2006 WSA convention, and I finished the very last page of my dissertation at the 2008 music camp. It was very meaningful to finish the paper while I was surrounded by 66 individuals with WS; no other place could have been better to do this. Thank you to the Camp Staff for understanding and encouraging me to finish and for checking on me.

Thank you to my family and my friends. I also appreciate Hayng Eun Lee, who is my dear friend who drew numerous illustrations whenever the need arose; Jae Heung Kwak, my brother, who became my computer consultant; and Jiyeun Lee, my dear friend and fellow music therapist for helping with music notation and tedious behind the scenes jobs. Their knowledge, skills, and time ensured the completion of this dissertation. I want to say a special word of thanks to my friends, Rick Mulligan, Jessica Schaub, and Wendy van Gent. They shared their time, and energy, and providing encouragement through on the actual writing process. I would like to thank my MOTHER and FATHER for helping, supporting, and being patient with me as I completed my long journey. Finally, I want to thank my heavenly FATHER who made me, guides me, and is with me always.

In the beginning God created the heavens and the earth. Genesis 1:1

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PROLOGUE

"Buying a Cup of Coffee"

July 2006: Richmond, Virginia

I attended the Williams Syndrome Conference in Richmond, Virginia, to gain a better understanding of Williams Syndrome (WS) and to learn what current treatments and interventions were available for individuals with WS. The Williams Syndrome Association (WSA) National Conference is a family-oriented conference that was designed to share information with parents as well as those who work with WS. Individuals with WS, their family members, researchers, educators, therapists, and volunteers for the conference inundated the hotel. The atmosphere was friendly, warm, and busy, like a huge family reunion. I enjoyed talking with individuals with WS, and meeting their parents and other therapists. Then it happened; I was waiting to buy a cup of coffee at a Starbuck's coffee shop in the conference hotel just 10 minutes before an afternoon session began, and the man in front of me had WS and loose change. His cup of coffee came to $3.72 and he was trying to count coins to pay for it. Anyone else would have handed the cashier $4.00 and received change. Although I felt sympathetic to his situation, I was in a rush and stuck in line behind him. I could sense the frustration of the others waiting. It was at that moment that I discovered a way I might help individuals with WS. As a music therapist, perhaps I can help them with one of the little life skills that can make a difference in their acceptance in society. And so began my journey on the road to discovering the real face behind Williams Syndrome.

CHAPTER I

INTRODUCTION

My journey with Williams Syndrome (WS) actually began 6 years before my experience in Richmond, Virginia. My interest in WS was stimulated after watching a television documentary about an individual with WS. Her name was Suzie, and she was still non-verbal at the age of seven, had very limited cognitive function, and a feeding tube directly connected to her stomach due to her inability to swallow. In the documentary, her brother tapped a large can with a stick while he worked on his homework near her. While he tapped, Suzie rolled in her bed with a euphoric smile on her face; the narrator commented on how amazing it was to see someone this happy from such a simple sound. From a music therapist's point of view, this incident clearly illustrated a sound-based fixation. Suzie's reaction made me wonder if it might be possible to use this fixation for therapeutic purposes by employing different sounds. It also made me wish for a chance to work with her. Although I had no particular knowledge about WS when I watched the documentary, that moment inspired me to learn more about this disorder, and started me on my long journey of studying WS and music therapy.

Williams Syndrome (WS) is caused by a microdeletion of at least 16 – 23 genes on chromosome 7q11.23. These missing genes cause similar physical characteristics and physiological difficulties, including cardiovascular abnormalities. This subset of genes is thought to be partially responsible for cognitive ability, linguistics, social interaction, behavior, and visuospatial perception. The combined variances within these domains are recognized as the phenotype of WS. While the medical description of this phenotype may seem clear on paper, the reality is much more complicated when observing the related phenomena. Those with WS have been a puzzle because of the inconsistencies in the manifestation of their individual abilities and limitations. Semel and Rosner (2003) illustrate this difficulty: "How is it possible to conceptualize a group of children who test as though retarded, speak as though gifted, behave sometimes as though emotionally disturbed, and function like the learning disabled?" (p. 1). Individuals with WS are initially perceived to have standard or higher intelligence because of their exceptional verbal skills. The well-known example in WS literature is "the elephant description" by a 15 years old girl with WS. "It has a long trunk that can pick up grass or pick up hay… you don't want an elephant as a pet, you want a cat or a dog or a bird." (Full Scale IQ of 49, Verbal 1Q of 52, and performance IQ of 54) (Bellugi & George, 2001, p. xii). This communication skill is illusory to some degree, but the apparent communication abilities in individuals with WS can mislead individuals who are the parents or work with individuals with WS into assuming a higher level of function than may actually be present. In one moment, they seem competent, but in the next they reveal an astonishing inability to handle mundane tasks, especially those involving mathematics or visuospatial cognition. It is a profound experience to witness a 21 year old male, who communicates well and appears to be "normal," calculate the value of a quarter and two pennies as three cents, rather than twenty-seven cents, and who cannot put the power plug into the wall outlet. When children with WS are young—those who have not yet started elementary school—their strength in language and communication give their family members hope

that they may be capable of functioning independently later in life. Unfortunately, this strength in verbal skills is one small peak in the topographical map of their functional domains. Their cognitive ability is usually more limited than first perceived and can lead to strain and disappointment for families and caregivers. Individuals with WS exhibit strengths in language, music, storytelling, sociability, and face processing, while they exhibit weaknesses in mathematics, abstract concepts, and visuospatial cognition.

A well-known trait of people with WS is a pronounced difficulty with mathematics. However, there is little detailed information about, and research into the specific causes of these difficulties, including specific problem areas, average functional levels, and possible coping mechanisms. Speculation on mathematical impairment suggests that the difficulties are due to visuospatial deficits and abnormalities in the structure of the parietal lobe (Ansari & Karmiloff-Smith, 2002; O'Hearn & Landau, 2007; Paterson, Girelli, Butterworth, & Karmiloff-Smith, 2006). Research on 28 subjects (14 with WS and 14 mental-age matched participants) using a standardized test showed that, while individuals with WS have relatively strong verbal math skills, such as reading numbers, the participants exhibited weaknesses related to spatial aspects such as the mental number line and representations of magnitude. While the participants' chronological mean age was 17 years, 9 months (the oldest 38 years 10 months and the youngest 10 years 5 months), their age-equivalency based on Test of Early Mathematical Ability (TEMA-s) scores were 6.1 to 8.6). One participant was outside the age range for the test i.e., his equivalent age was older than 8.11 (O'Hearn & Landau, 2007).

During the preparation of this study, I had the opportunity to interact with children with special needs, individuals with WS, and typically developed individuals (TDI). During these preparatory interactions, I experimented using various musical interventions to get a sense of the range of responses for different functions and ages. While working with Zach, an 11 year old who is developmentally delayed, we sang a song meant to promote the use of addition.

How much is ____ + _____
I don't, I don't
What should I do?
What should I do?
Let's count together.
1, 2, 3, 4, 5, _____________
That's right. You are right!

Zach demonstrated proficiency with simple addition: 1 + 2, 3 + 5, 4 + 4, etc. After working on these specific questions, I thought that "1 + 1" would be the easiest equation for him to solver. However, when I held up two index fingers, Zach proudly announced, "*Eleven!*" His answer demonstrated confusion between quantity and the actual symbol of the Arabic numeral for "1." This incident indicated that the difficulties in mathematics for individuals with learning disabilities, including WS, might be much more complex and may be rooted at a deeper level than mere performance of addition and subtraction. Information about the mathematical development of WS is limited and it was difficult to predict what issues might manifest during experimental interaction. The incident with Zach strongly suggested the need to study the mathematical development of young children and review techniques used to teach mathematics to children with special needs.

Individuals with WS enjoy music, possess an affinity to music, or are described as music lovers. Not all individuals with WS can play instruments or sing well, but each has an affinity for music. A majority of individuals with WS show distinguished abilities in music, such as melody memorization or rhythmic ability. Additionally, a higher percentage of individuals with WS have demonstrated absolute pitch than in the general population (Lenhoff, Perales, & Hickok, 2001; Semel & Rosner, 2003). Although many individuals with WS cannot learn to read and write music because of their cognitive limitations and visuospatial difficulties, they can sing, compose, improvise, and play musical instruments, especially percussion and keyboard-based instruments. At music camps for individuals with WS, such as Whispering Trails Camp in Grand Rapids, Michigan, and Berkshire Hills Music Academy Summer Camp in South Hadley, Massachusetts, there are usually more than enough drummers, keyboard players, guitarists, and singers to organize two or three bands. Because of this musical proficiency, the recreational and occasionally vocational use of these abilities has been strongly supported by parents and advocates. However, limited attention is given to their affection for, and affinity to music as a means for assisting in the intervention of specific limitations.

There are a variety of resources and materials used to teach academic concepts to children with special needs, the greatest concentration of which are from preschool through second grade. However, few materials exist to help children with cognitive limitations when they reach their preteen and teen years. While many children with WS do not progress beyond a certain level of cognitive function, their physical and emotional development continues, and age-appropriate educational material may be the first key for successful intervention. At a mathematics workshop for children with WS at the WSA conference, one presenter introduced hands-on materials to teach mathematical concepts, specifically the "touch" method for counting. These materials included illustrations that were

respo

insul

age-a

sense

confi

mate

chall

awar

age-a

woul

sim

lingi

walk

phon

speec

decre

yea

de el

decre

were "cute and cuddly"—directed towards younger users. One mother in attendance responded that her son would not use these materials because he would perceive them as insulting: they were designed for younger children.[1] This strongly suggests that the use of age-appropriate learning materials is imperative in order to respect individuals with WS' sense of self-esteem and to reinforce cognitive development without jeopardizing confidence. Music therapy literature emphasizes the use of age-appropriate songs and materials, but this is often difficult to put into practice in cases with cognitively challenged populations. Individuals with WS are especially sensitive to others and keenly aware of their limitations, and reactions from the public to their limitations. Developing age-appropriate materials for individuals with WS within their limited cognitive function would be challenging but highly rewarding.

A number of examples exist that demonstrate the use of sounds and music to stimulate action or as an educational aid, especially with pre-Kindergarten children. Jingling keys have been used to attract a toddler's attention and can promote crawling or walking; modified song lyrics enhance the memorization of the spelling of last names, phone numbers, and addresses; and nursery rhymes are a way to advance language and speech development (Sforza, 2006). Unfortunately, the use of music as a teaching tool decreases or stops during the early elementary school years, somewhere between 8 and 10 years of age, when academic concepts became more complicated and children start to develop their own strategies. The utility of music as a mnemonic and teaching tool decreases as children advance through elementary school. Because of the lack of

---

[1] The mother who sat next me said to herself, *"Charley wouldn't even touch those things."* After the workshop, I asked her how old her son was and the reason for her statement. She explained that Charley was 12 years old, and even if he could not do simple addition, he did not want to use workbooks with '*childish*' illustrations or *kids* stuff, and he was highly sensitive about using the same material as his younger sister.

research, theory, and practice with regard to the WS population, music therapists, as well as educators, are not quite certain of the most effective approach to facilitate cognitive development for individuals with WS.

The efforts and practice of music therapy deal with a broad range of psychological, emotional, and physical issues. However, the existing body of research used for children with WS was initially developed for children with special needs. The current methods and practices used for WS are taken directly from this prior research, but they do not address the specific needs of individuals with WS in relation to their cognitive development and neurology. According to Duerksen (1968), research, theory, and practice should stand together like a tripod. Theory is needed to explain existing phenomena, research must validate or disprove theory, and methods must be developed from validated theory to be used in practice. The outcomes of practice suggest modifications and revisions to existing theory and the development of new ideas (Wheeler, 2005). Thus far, methods used with the WS population are based on music therapy directed towards individuals with cognitive challenges. Work with individuals with WS indicates that the traditional methods used for cognitive impairment do not correspond to the expected outcomes for clients with WS. Because of the unique characteristics of individuals with WS, music therapy interventions require new research in order to develop more effective methods to increase positive outcomes.

WS research has expanded and intensified in the past two decades, especially since the diagnostic method for WS was discovered in 1993. However, there remain many questions regarding this syndrome. Information about WS has continued to evolve and grow in direct relation to the technological developments of neurology and genetic research (Martens, Wilson, & Reutens, 2008; Mervis & Morris, 2007). Theories of the various characteristics of WS have been refined, challenging previous theories and provoking more debate and discussion. A review of the current literature on WS focuses primarily on a single characteristic or domain such as particular language characteristics, visuospatial characteristics, or attention difficulties. The literature seldom relates these characteristics across domains. While it is indispensable to have focused research on each of the domains, it is essential to connect these issues because individuals with WS are more than the sum of these individual parts. Results of this diverse research must be integrated and a holistic approach taken when considering the experiences of those with WS. The problems those with WS experience with mathematics may not be solely based on cognitive difficulties. They may be the result of interwoven factors that include functional areas such as language, visuospatial relations, or the interplay from additional emotional and psychological issues.

My undergraduate training in mathematics led me to work for several years as a computer programmer. The logic and structure of algorithms and code drew me to programming in much the same way that the structure of musical notation and sequences underlie my love of music. Eventually I discovered that music blended with my tendency to want to help others and I began to pursue an education in the field of music therapy.

Before I learned details about WS, I was already falling in love with these individuals because of their affection for music. I was amazed by their fascination with sound and the way I could use music to communicate with them. During the earliest sessions with my first WS client, I felt like a music teacher who had stumbled upon a musical prodigy. That client only had to listen to a song or selection a couple of times before he could repeat it back exactly. He could imitate complicated rhythms and patterns and maintain a musical dialogue with me, something of which few adult musicians are capable—and he was only 5 years old.

Several other clients with WS have demonstrated similar talents in various degrees. They were entranced by new sounds and instruments and mesmerized by the sounds of finger cymbals, a gong, a rain stick, and a thumb piano. My limited piano playing was enough to enthrall them just like a world-famous pianist engages their audiences. Music makes these individuals happy. In fact, when music is involved, their behavior significantly improves. When I became more deeply involved with individuals with WS and spent more time with them outside of sessions, such as working at the music camp for individuals with WS, and attending their conferences and gatherings, I witnessed the desperation, frustration, and agony that are often part of their daily lives. Those behaviors do not typically emerge while individuals are happy and content. During musical therapy sessions when the clients are enveloped by music, they seldom showed frustrations and limitations such as uncontrollable tamper-tantrums, emotional roller-coasters, and obsessive-compulsive behaviors.

"They are smart enough to know that they are different," said Dr. Barbara Pober, director of Williams Syndrome Clinic at Massachusetts General Hospital in a TV documentary about WS (CBS, 1997). One of the statements repeated during the documentary was that persons with WS did not feel that they "fit in." When they are with other individuals with WS, they feel a sense of belonging and can relate to and understand each other. There is a sense of hopelessness, 'there is nothing I can do to improve this condition,' or, 'I tried this and that, and nothing has been working.' These are devastating feelings. Perhaps the love of music in individuals with WS can be used to augment their ability in mathematics, and be a significant breakthrough that could make their lives and their parents' lives more manageable.

Today's materialistic and product-oriented society does not always comprehend individuals with WS' inabilities in certain areas. I can empathize with the day-to-day interactions and prejudices someone with WS might experience. English is not my mother tongue and I have found over the past ten years in the United States that this can cause a range of negative responses. I am not perceived as foreign, necessarily, but as "language-impaired" and this sometimes translates into being treated as ignorant or as less than competent, something a person with WS experiences intimately. The fact that I am normal in my native Korean society does not help me feel any better. Shifting from my linguistic challenges to individuals with WS' mathematic obstacles, I might claim that I have experienced something similar because of the perceived lack of ability, allowing me to relate to how they might feel in their daily lives.

This study's major focus was to observe the relationship between teaching mathematical concepts and music-related activities. The mathematical difficulties of clients with WS were compared with a range of ages provided through the literature review. No specific research exists, but the literature suggests that roadblocks for the mathematical development of individuals with WS may include language limitations, difficulties with abstract concepts, attention deficits, visuospatial difficulties, and fine motor control problems. During the course of the study, these factors were considered for each of the participants and compared to existing literature. The purpose of this study is to better understand mathematical difficulties within individuals with Williams Syndrome and to find ways to use their affinity for music to compensate for mathematical deficits.

An instrumental collective case study method was chosen for these purposes. The close examination was performed with three participants to provide detailed and in-depth information of specific problems with mathematics. During the course of this study, three questions guided my investigation: What are the roadblocks in the mathematical development of individuals with WS? What can they do and not do mathematically?; Based on existing music therapy theories for individuals with special needs as described in music as a therapeutic medium, are there some possible music therapy interventions that can serve as strategies to help individuals with WS in terms of their mathematical development?; and How do individuals with WS respond to music therapy interventions to overcome their mathematical learning obstacles? Are these interventions useful or effective for their needs?

CHAPTER II

REVIEW OF RELATED RESEARCH

In the previous chapter, the general descriptions of individuals with Williams Syndrome (WS) and reasons for conducting research on this issue were discussed. In this chapter, the discussion focuses on more detailed information about WS characteristics, especially those related to genetic and neurobiological factors, mathematical development in the general population and WS population, current music therapy theory for individuals with cognitive challenges, and parents' concerns in WS education.

Descriptions of Williams Syndrome

WS was first described by Fanconi, Giradet, Schlesinger, Butler, and Blade (1952) based on their observations of patients with infantile hypercalcaemia with short stature and congenital malformations (Bellugi, Lichtenberger, Jones, Z., & St. George, 2001; Mervis & Morris, 2007; Morris, 2006; Semel & Rosner, 2003). WS is named after J. C. R. Williams, a British cardiologist in New Zealand, who described a group of children with heart defects (supravalvular aortic stenosis, SAVS), cognitive impairment, and "pixie-like" or "elfin-like" dysmorphic facial features in 1961 (Bellugi et al., 2001; Mervis & Morris, 2007; Morris, 2006). In Germany, Beuren and colleagues also separately identified the syndrome based on SAVS, peripheral pulmonary stenosis, mental retardation, and similar facial appearance in 1962. The label Williams-Beuren Syndrome is the term primarily used in Europe (Morris, 2006). The etiology and epidemiology of WS has puzzled experts. The causes of WS range from a vitamin D deficiency or calcium teratogenesis in early-years (Friedman & Roberts, 1966), to chromosome anomalies (Burn, 1986), and finally to the missing elastin gene (ELN) in chromosome 7 identified as the causative gene for SVAS (Ewart et al., 1993; Lowery et al., 1995; Morris, Loker, Ensing, & Stock, 1993). When the diagnostic method for WS was defined in 1993, scientists were excited to be able to end the many years of speculation about the etiology of WS and about the possibility of focusing on this genetic disorder to study molecular genetics profiles and neuropathology (Bellugi et al., 2001; Semel & Rosner, 2003). Information about WS has significantly and rapidly changed based on increasing research.

WS is currently defined as a disorder that arises from a hemizygous deletion on the long arm of chromosome 7q.11.23 (Donnai & Karmiloff-Smith, 2000; Morris, 2006). The deletion is approximately 1.3 Mb and includes at least twenty-three genes (Partsch et al., 1999). WS is associated with "elfin-like" facial features and physical appearance, heart and blood vessel problems, infantile hypercalcaemia, growth and developmental retardation, and difficulties in gross motor and fine motor skills to various degrees (Bellugi et al., 2001; Mervis & Morris, 2007; Semel & Rosner, 2003). The cognitive profile of individuals with WS exhibits complex patterns. WS literature uses terms such as "strengths and weaknesses," "peaks and valleys," "puzzle," and "uneven" to describe the WS' cognitive profile (Lacro & Smoot, 2006; Semel & Rosner, 2003). Individuals with WS show salient abilities in phonological skills, storytelling, music, face recognition, and sociability. In contrast, individuals with WS display uneven skills within language ability, difficulties in visuospatial abilities, deviations in the sensory system, and unusual social behavior (Mervis & Becerra, 2007). Figure 1 illustrates an overview of major characteristics of individuals with WS. These characteristics will be discussed in detail in the following chapter.

Neurological

- Average IQ (range 40-80)
- Mild neurological dysfunction
  - Tight hell cords
  - Poor coordination
- Hyperacusis
- Harsh, brassy or hoarse voice

Neurocognitive

- Friendly, loquacious personality
- Enhanced musical ability
- Relatively spared language development, enhanced vocabulary, and social use of language compared to visual-spatial perception

Facies

- Medial eyebrow flare
- Short nasal palpebral fissures: epicanthal folds
- Flat nasal bridge\
- Stellate iris
- Long philtrum
- Prominent lips with open mouth

Cardiovascular

- Supravalvular aortic stenosis
- Peripheral pulmonary artery stenosis
- Pulmonic valvular stenosis
- Ventricular/atrial septal defects

Musculoskeletal

- Joint limitations
- Kyphoscoliosis
- Hallux valgus
- Hypoplastic nails

Genitourinary

- Nephrocalcinosis
- Small, solitary, and /or pelvic kidneys
- Vesicouretal reflus

Endocrine

- Transient infantile hypercalcemia

Figure 1. Summary of major WS phenotypic features. *

*From "Genome Structure and Cognitive Map of Williams Syndrome" by Kornberg et al., Journal of Cognitive Neuroscience *12*(90001), p. 90. Copyright 2000 by the MIT. Reproduced with permission.

The prevalence of individuals with WS in the general population was changed from 1:25,000 to 1:50,000 during the early 1980s, and to 1:7,500 in 2007 (Morris, 2006; Semel & Rosner, 2003). Journal articles published in 2007 and 2008 raised questions and provoked discussions about previous articles, sometimes suggesting findings contradictory to previous research. Articles about WS published in the 1990s are now considered out of date, although those from as early as the 1980s are presented here as part of the history of WS research.

Physical Appearances and Medical Issues

The characteristic facial appearances of those with WS have often been described as "pixie-like" or "elfin-like." This is typically characterized by a broad forehead, puffiness around the eyes, full cheeks, a wide mouth, full lips, small chin, a small upturned nose, long philtrum (upper lip length) and large ears across different races (Morris, 2006; Semel & Rosner, 2003). The drawings of young children with WS (see Figure 2) are constructed based on 12 pictures of children with WS and emphasize these characteristics.

Figure 2. Drawing based on characteristics of children with WS.

Illustration by Hyang Eun Lee

The majority of individuals with WS are subject to numerous health problems including cardiovascular abnormality in various degree, hypercalcaemia, hernias, kidney abnormalities, and musculoskeletal abnormalities (Udwin & Yule, 1990). The spectrum of cardiovascular manifestations plays an important role in the recognition of a group of individuals with similar condition and leads physicians to the etiology of WS as a molecular genetic abnormality. Approximately 50 % to 75% of individuals with WS are clinically detected with supravalvular aortic and peripheral pulmonic artery stenosis (Semel & Rosner, 2003).

Children with WS appear younger than they are because of their short stature and infantile facial characters, such as full cheeks. As they age, adults with WS look older than their chronological age because of a lack of subcutaneous tissues, which gives them lax facial skin and a prematurely aged appearance. Their body posture also contributes to this appearance; long necks, sloping shoulders, deformity of the spine (kyphosis and lordosis), and limitations of the joints (Semel & Rosner, 2003). When a group of individuals with WS gathers, they seem to be missing those in their 20s or early 30s. The premature looks and the mean adult height (165.2 ± 10.9 cm/5.41 ± 0.35 feet in males and 152.4 ± 5.7 cm/4.98 ± 0.18 feet in females) contributes to this appearance (Bellugi et al., 2001). There has been some speculation that individuals with WS may have been the inspiration or prototype for elves and pixie in folktales because of these characteristics and because folklore presents elves as energetic, as well as music lovers (Lenhoff et al., 2001; Lenhoff, Wang, Greenberg, & Bellugi, 1997). While there is no way to substantiate such speculation, it does lend itself to an interesting hypothesis.

Several medical conditions are common among individuals with WS. Eighty percent of children with WS have cardiovascular disease, including supravalvular aortic stenosis (SVAS), and/ or high blood pressure (Mervis & Morris, 2007). Fifteen percent of infants were diagnosed with hypercalcaemia, and 40% of infants needed to have surgery for inguinal hernia. Thirty-five percent of individuals with WS have been reported to have structural urinary anomalies by renal ultrasound examination (Mervis & Klein-Tasman, 2000). Hypercalcaemia and hernias improve during childhood, but cardiovascular and kidney abnormalities become more problematic as they age (Bellugi et al., 2001; Semel & Rosner, 2003). Many of these medical difficulties have mild manifestations. However, in some cases they become life threatening, especially with SVAS, which occasionally requires open heart bypass surgery (Bellugi et al., 2001; Mervis & Morris, 2007; Semel & Rosner, 2003).

While young children with WS often have low muscle tone and joint laxity, as they age, contractures (joint stiffness) may develop and physical therapy is recommended to improve muscle tone, strength, and range of motion. When these individuals walk, they raise their shoulders, throw out their chests, and have stiff movement in their arms and legs. As toddlers, their movements are cute and adorable; however, as they grow, the awkwardness in their movements becomes more noticeable. This awkward gait is typical of older children and adults with WS. Hypertonic and hyperactive deep tendon reflexes, kyphosis, and lordosis are typical symptoms in individuals with WS. Combined with the spatial cognition defect, children with WS often have difficulties with fine motor skills. As a result, self-care skills involving fine motor control are affected. Personal grooming, manipulating zippers, snaps, and buttons, tool-use (scissors, knife, utensils), and writing and drawing skills are all limited to some extent. These difficulties become more obvious as they grow and attempt to take care of themselves (Semel & Rosner, 2003).

Language Characteristic

Despite their cognitive challenges, the linguistic ability of many individuals with WS tends toward an appearance of precociousness. While researchers generally agree with this statement, there are different abilities within various language areas, e.g., semantic, syntax, and pragmatic, as well as within different age groups (Bellugi et al., 2001; Mervis & Becerra, 2007; Semel & Rosner, 2003). Some researchers strongly believe that individuals with WS' extraordinary language ability is evidence of the separation of language and cognition (Bellugi et al., 2001; Semel & Rosner, 2003). Meanwhile, others, more recently, claim that even though WS individuals showed better semantic skills, their language ability is affected by cognitive limitations such as difficulties in abstract concepts and the apprehension of spatially related prepositions such as "between," "in," "on"; "above," "below" (Brock, 2007; Mervis & Becerra, 2007; Peregrine, Rowe, & Mervis, 2006).

Adults with WS typically can achieve advanced language development, which is in contrast to the majority of toddlers with WS, who show difficulties in the initial stages of language development (Semel & Rosner, 2003). While typically developing children (TDC) exhibit two-word utterances at age two, children with WS usually exhibit two-word utterances at age three (Semel & Rosner, 2003). While children with Down Syndrome (DS) tend to plateau after the onset of their first words, children with WS improve dramatically in language development as grammar awareness emerges (Dykens

& Rosner, 2006). Vocabulary acquisition and grammatical development of individuals with WS appear to be positively correlated to auditory rote memorization ability (Rice, Warren, & Betz, 2005).

Considering their level of cognitive ability, children with WS seem to have impressive linguistic capabilities, especially with vocabulary. When interacting with individuals with WS, one's initial impression is that the individual with WS has average or greater abilities with spoken language. However, there are peaks and valleys among adolescents and adults with WS with regard to language. Adolescents and adults with WS are usually talkative and have superficial sociability described as "cocktail party speech" (Fidler, Lawson, & Hodapp, 2003). However, when people talk with individuals with WS long enough, it is noticeable that there is something awkward in their speech (Semel & Rosner, 2003). Affected individuals have a difficult time maintaining the topic of the conversation. They float in and out of the topic or jump to other topics often overusing word fillers, clichés, and stereotyped phrases (Reiss et al., 2001; Semel & Rosner, 2003). Little data exists on the pragmatic skills of individuals with WS (Howlin, Davies, & Udwin, 1998; Mervis & Becerra, 2007; Mervis & Klein-Tasman, 2000; Semel & Rosner, 2003). Studies have shown they have various limitations in comprehending semantics, syntax, abstract concepts, spatial relations, and figurative language (Levitin et al., 2003). In general, it can be concluded that individuals with WS are proficient in imitating sounds, such as those used in articulation, storytelling, narration, prosody, rhythm, and lexical stress in speech, but they have difficulties with the semantic relational vocabularies, complex syntax, abstract semantic concepts, and the social, communicative use of language.

Semel and Rosner (2003) suggest that mediational strategies can promote a more balanced language development. Mediational strategies include the subcategories of labeling, rehearsal, demonstration, dramatization, and self-instruction. Mediational strategies may help to develop more adequate language skills by increasing attention span, assisting in the comprehension of abstract concepts, and promoting self-regulation procedures.

Social Characteristics

Individuals with WS are friendly, outgoing, and sensitive to the feelings of others (Semel & Rosner, 2003). Their behavior is often described as "highly sociable," "never going unnoticed in a group," "highly approachable," and "overly friendly, highly empathic" (O'Hearn & Landau, 2007). Therapists and medical personnel commonly describe individuals with WS as overly friendly, which is considered typical WS problematic behavior (Levitin & Bellugi, 2006). A therapist who worked with children with WS reported an anecdote about a boy who was scolded because of his conversation with a stranger. The boy replied to his mother, "*But he is not a stranger, because he said 'Hi' to me.*" Greeting everybody in a hallway at school or other settings is not uncommon in children with WS. However, it can be problematic, especially in public settings. This characteristic increases risks of exploitation, abuse, difficulty initiating and maintaining friendships, and may result in older individuals with WS losing a job. The strong desire to be everyone's friend might lead to poor social judgment and make them vulnerable to abuse. It was reported that over 90% of children with WS showed "no fear of strangers" (Semel & Rosner, 2003) and 100% of employers of adolescents with WS (n=21) mentioned the problem of overfriendliness as a major concern (Davis, Howlin, & Udwin, 1997). When I attended the Williams Syndrome Conference for families in Richmond, Virginia, I knew no one from the association, but I never felt lost, isolated, or out of place because of the warm welcomes, greetings, and open conversations from those with WS. They acted like they knew me and introduced me to their parents, in spite of parents' wishes to keep them out of conversations with strangers. Parents are not likely to be successful with such a request.

Empathy is the other salient social characteristic of individuals with WS. Affected individuals typically tune into others' discomfort or distress making it difficult to conceal our feelings. When they feel the discomfort of others, affected individuals become nervous and uncomfortable. They often want to talk about it. In society, even if we suspect someone's discomfort, unless the person specifically asks help, TDC do not intervene. However, individuals with WS, because of their fearless nature and overfriendliness, often approach persons in distress and ask what is wrong with them. It is not difficult to find an anecdote about their empathy: When a ten year old boy with WS at the William Syndrome Conference found somebody in the lobby at the hotel who looked depressed and agitated, he approached her and asked, "Are you OK? Are you OK?" with full expressions and physical gestures. Individuals with WS' naturally empathetic virtues can be socially appropriate and in many cases need to be praised and reinforced. At the same time, their expressions of empathy need to be shaped to avoid unnecessary or unwanted interference in public settings and limit potential exploitation by others.

The intensity of fear and anxiety in individuals with WS vary from being on edge, uneasy, or worried, to phobias or panic (Scheiber, 2000; Semel & Rosner, 2003). I observed a 21 year old camper at the Williams Syndrome summer music camp in Grand Rapids, Michigan who could not go to sleep by himself in his cabin when other cabin members were not there. Even though there was another cabin a few steps away, a staff member had to stay with him to calm him down. The boy was in and out of his cabin every few minutes looking for signs of his cabin-mates' return. He was unable to calm down and go to sleep. Even though fears and anxieties during childhood are common in the human developmental process, individuals with WS exhibit unusually persistent and intense reactions far beyond their childhood years.

Behavioral Domain

Observations and research reports on the behavioral domain in individuals with WS suggest there are six major problematic areas: fears and anxieties, distractibility and attention problems, impulsiveness, poor adaptability, low frustration tolerance, and atypical activity (Dykens, 2003; Dykens & Rosner, 1999; Dykens & Rosner, 2006; Semel & Rosner, 2003). The results from the studies using the Child Behavior Checklist or similar measures for adults have indicated that a high number of individuals with WS have significantly elevated problematic scores (Mervis & Klein-Tasman, 2000). Comparison research with TDC, children with Prader-Willi Syndrome (PWS), or children with mental retardation of mixed etiology suggest that children with WS exhibit greater activity, intensity, and distractibility (Dykens & Rosner, 2006; Mervis & Klein-Tasman, 2000). Additionally, children with WS display increased negative mood and self-image, and decreased persistence, adaptability, and threshold to arousal.

When compared with other types of mental retardation, severe aggressive behaviors (destroying objects, attacking others, and extreme temper tantrums) are less common in children with WS (Gosch & Pankau 1994; Udwin & Yule, 1990; Dykens & Rosner, 2006). According to Gosch and Pankau (1997), while 19% of adults with WS (twenty-seven adults, aged twenty years and older) were unable to sit still, 62% of children with WS showed restlessness and difficulty sitting still. The frequency and intensity of hyperactivity and aggression decrease as they age. However, distractibility remains the same across ages (90% of informants) (Davies et al. 1998). Einfeld, Tonge, and Rees (2001) conducted a longitudinal study of maladaptive behavior in children with WS and concluded that observation of "overactivity" or "tantrums" indicates reduction in those areas over a five-year period. This is an indication of gradual reduction of aggressive behaviors during the childhood to adolescent years.

Semel and Rosner (2003) concluded that high reactivity and low self-regulation are the two major elements underlying those symptoms. They claimed that high reactivity caused overreaction to various stimuli. As a result, individuals with WS' fears, anxieties, distractibility, and impulsivity were manifested. Low self-regulation tendencies cause individuals with WS to have difficulties handling or overcoming unexpected and challenging situations. Consequently, individuals with WS showed poor adaptability and low frustration tolerance. Atypical activities could be confused with obsessive compulsive disorder. For example, afflicted individuals may have a fixation about cars, an insect, or a TV show, and they need to know everything about it. Every conversation will revolve around that topic. Their atypical activity is the manifestation of a lack of self-regulation that hinders their ability to restrain or withhold unessential forms of activities. In addition, these two elements are interwoven in their impact on individuals with WS' behavior phenotype.

When Big Red, a 20-year old male with Williams Syndrome, did a presentation about WS with his music therapist for an audience of music therapist at the Great Lakes Region Conference of the American Music Therapy Association (AMTA) in Novi, Michigan in 2006, he was supposed to talk about his journey with music and how music helped him overcome his difficulties. Outside of the window, there was a dove that made noise and walked along with the window sill. Big Red could focus his attention on the task. He visually followed the dove and tried to talk at the same time, but could not do both. When the music therapist whispered his name, he told us, "I'm supposed to pay attention to my task." He could keep to his speech for a few seconds but then he started following the dove again. This incident demonstrated how the two elements are connected. High reactivity caused him to focus on the dove, which was an irrelevant and unessential stimulus at that moment. He could not take the necessary steps to control his reactions to the dove because of low self-regulation.

Distractibility and attention issues are persistent throughout life and a major cause of behavioral disturbance in individuals with WS. These characteristics can interfere with the learning process and hinder achievement. Distractibility is speculated to be caused by different perceptual processes such as auditory hypersensitivity, visuospatial difficulties, and tactile defensiveness (Bellugi & George, 2001; Mervis & Morris, 2007; Semel & Rosner, 2003). As illustrated in the aforementioned case, 97% of parents with children with WS report difficulty in their children's ability to pay attention, and 88% of parents report their child pays attention to irrelevant stimuli. However, individuals with WS' abilities to concentrate vary depending on the task. If the task is of special interest , their attention span and concentration level is higher. It is possible that if we can use their abilities in music and combine it with other difficult areas like mathematics; they might be able to focus better. This ability to focus is a major premises of this project.

Semel and Rosner (2003) interpret individuals with WS' impulsivity as, "an outward manifestation of the internal, uncontrolled distractions and the uninhibited, unrestrained patterns of WS behavior" (p.259). In TDC, the ability to engage impulse control usually improves gradually during childhood. However, in individuals with WS, something hinders this process, and their ability to control impulses is seriously delayed or impaired.

Individuals with WS demonstrate great difficulty adjusting to unanticipated changes in various aspects of their lives such as schedules at school, routines at home, cancellations of appointments, and running out of supplies can lead to uncontrollable temper tantrums. As mentioned above, the difficulties seem to stem from high reactivity and low self-regulation. Dykens and Rosner (1999) suggest that reducing environmental stimuli and introducing behavioral modification techniques, such as ignoring and redirecting off-task behaviors, and rewarding on-task behaviors, can be useful interventions. A verbal mediation strategy was found to be very helpful in managing fear and anxiety as well as distractibility. The strategy involves a discussion of the strategies to overcome difficulties by using labels, rehearsal, demonstration, dramatization, and self-instruction (Semel & Rosner, 2003).

Visuospatial Abilities

Weakness in visuospatial ability is repeatedly reported in WS literature (Bellugi & George, 2001; Mervis & Morris, 2007; Semel & Rosner, 2003). Individuals with WS display difficulties in visuospatial construction, which denotes the ability to perceive visual and spatial information of an object or picture and to perform a reproducing task (e.g., a pattern reconstruction based on visual representation, drawing, or completing a jigsaw puzzle). Early research by Bellugi and her colleagues (Bellugi et al., 2001; Bellugi, Marks, Bihrle, & Sabo, 1988; Bellugi, Wang, & Jernigan, 1994) reported that individuals with WS have difficulties drawing an object. Instead of drawing an outline of familiar objects, such as a flower, bicycle, or elephant, they draw a part of the object without particular spatial relationship of the object to the rest of the space.

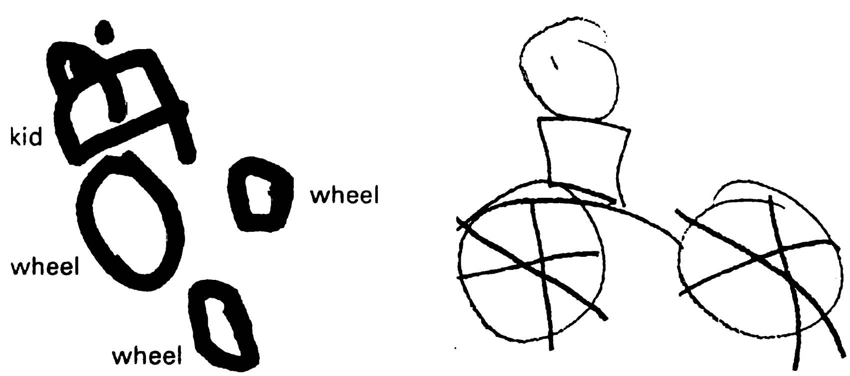


Figure 3. Drawing of two bicycles. *

Two bicycles drawn by the same girl with Williams syndrome, at age 5 years 9 months (left) and 10 years 9 months (right). Both times, the child was given a blank piece of paper and asked to draw the best bicycle she could. The labels on the left drawing were provided spontaneously by the child.

*From "Williams syndrome" by Mervis and Morris (2007) in Mazzocco & Ross (Eds.), Neurogenetic Developmental Disorders: Variation of Manifestation in Childhood. Copyright 2007 by the MIT press. Reproduced with permission.

They concluded that persons with WS are local processors rather than global processors. Recent articles (Bertrand, 1997; Bertrand & Mervis, 1996) now challenge the preceding theory concerning WS's drawing ability. Based on their four-year longitudinal study, while persons with WS are significantly delayed in this area, they obviously follow the same developmental path as children with typical development (TDC) (see Figure 3).

In the DAS pattern test, 88% of the subjects belonged in the first percentile of the T-score, approximately 50% of the subjects stayed in the lowest possible score, and only 10% were in the normal range of the pattern construction (Mervis et al., 1999). With WISC-R subtest, 6 subjects (10-17 year olds) completely failed the test. It was even difficult for them to maintain the overall 2 X 2 arrangement of the blocks (Bellugi et al., 1988). Mervis and Morris (Mervis & Morris, 2007) concluded that the difficulty with block construction appeared to be due to spatial representation difficulties. Construction ability seems to improve over time.

The difficulties in visuospatial ability hinder the performance of everyday activities: using tools, scissors, knives, tying shoelaces, copying simple lines or figures (which is related to hand writing), or plugging a cord into outlet. These activities involve processing visual information, calculating distances, and executing tasks. Sports activities require visually tracking balls or other moving objects and estimating trajectory. According to a Utah Survey (Semel & Rosner, 1991), parents report that 97% of children with WS have difficulties in drawing, 89% in cutting with a knife, 77% with personal grooming, and 77% using scissors. While fine motor skills that are required to perform such task are receptively preserved, visual perceptual problems are responsible for difficulties in completion.

Visuospatial concept difficulties in the WS population are suspected to also be a factor in mathematical abilities (Ansari et al., 2003; Ansari & Karmiloff-Smith, 2002; O'Hearn & Landau, 2007). However, the exact mechanism of interference with mathematics performance is still not fully understood. Visual aids are often suggested for individuals with cognitive impairment, but because of their difficulties in visual information processing, they might not be helpful for individuals with WS.

Affinity to Music

The musical ability of those with WS is often exaggerated words such as *wonderful, amazing, extremely good, fascinating*, and *extraordinary* (Semel & Rosner, 2003). Musicality is defined as the "sensitivity to, knowledge of, or talent for music, and/or the quality or state of being musical" (Merriam-Webster Inc., 2003). Ansdell, a British music therapist, expresses musicality as "a quality which involves both 'musical thinking' (or 'know-how') and 'musical feeling'" (1995, p. 210). The Williams Syndrome Association (WSA) uses the term, "affinity to music" to describe the magnetic attraction individuals with WS have to music: an attraction defined as "a natural attraction, liking, or feeling of kinship" (Jarrold, Baddeley, & Hewes, 1999; Klein & Mervis, 1999). This study will use a description of musicality in individuals with WS, to also include the affective bonds of music.

There is ample evidence of individuals with WS exhibiting a high degree of musical affinity. A 1991 WSA survey of parents reported that 86% of children with WS easily memorized songs, 71 % had a musical talent, and 87% liked to sing (cited in Semel & Rosner, 2003). In a similar study, more than 90 % of children with WS reported that they loved music (cited in Semel & Rosner, 2003). Parents, clinicians, and educators who work with individuals with WS continuously report the latent musical talent of many individuals with WS (Mervis & Klein-Tasman, 2000). The most nationally known musician with WS might be Gloria Lenhoff, born February, 11, 1955 in the book, *the Strangest Song* (Sforza, 2006). She is a lyric soprano and accordionist and has Williams Syndrome. She has a repertoire of over 2,000 pieces in more than 20 languages, but she cannot read music. She has performed with members of the L.A. Opera, the Boston Lyric Opera and numerous other settings around the world.

Several studies confirm that individuals with WS also have great strengths in auditory rote memory (Sforza, 2006, p. 61). This ability is may be a strengthening mechanism for both vocabulary acquisition and grammatical development (Sforza, 2006, p. 61). Another characteristic of WS is a hypersensitivity to sound, sometimes expressed as hyperacusis (Bellugi, Lichtenberger, Jones, Lai, & St. George, 2001; Levitin & Bellugi, 2006; E. Semel & Rosner, 2003). This hypersensitivity is especially problematic in infancy. While it can be ameliorated as children with WS mature, it does not completely disappear. Studies of this issue generally suggest that the cause of hyperacusis is mainly due to the hyperexcitability of cortical regions associated with auditory processing (Levitin & Bellugi, 2006).

Auditory abilities of children with WS are also exceptional as they relate to music. As a music therapist, I was inspired by WS children's ability in music and how they might be used to compensate for othe deficits. A number of examples exist describing the extraordinary abilities of children with WS. Amada was diagnosed with WS at age three. Sandy Miller, Amanda's mother, said, "…from the second she could stand up, [she] would hang on the piano. She wasn't even tall enough to see the keyboard. She'd stick her arms up high over her head until she felt the keys. She would not pound away indiscriminately, as so many toddlers did: instead, she picked out perfect, harmonious notes" (Sforza, 2006, p. 18). Sally Meersman has a similar story about her daughter, Mary, who was diagnosed at age two. "Mary would snap to attention whenever she heard music. She'd listen with the most comically intense look on her face. Mesmerized" (Mills et al., 2000). The musical intensity of Gloria Lendroff during her toddler years was captured by Scheiber (2002):

> "He (Howard: Gloria's father) settled onto the sofa, turning pegs and plucking strings to bring the guitar into tune. A room away, Gloria snapped to attention, as if the sound were a bolt of electricity. She dropped her favorite toy -- a jingle key chain she would shake and shake until Howard wanted to scream – and crawled as fast as she could to her father's feet, hauling herself up and standing almost on the guitar strings, watching, listening, with almost comical intensity. Howard strummed Elizabethan folk songs, classical pieces, sea yarns, and cowboy tunes. Gloria stared wide-eyed at the strings the entire time, hypnotized, mesmerized by their luscious sound."

Individuals with WS show a unique ability to reproduce a melody after only hearing it once, and to remember songs and complicated rhythm patterns. Neurological studies on individuals with WS report relatively well-maintained or slightly-spared areas in the prefrontal cortex, the auditory association cortex, and the neocerebellum, all of which are important in auditory and language processing (Baharloo, Johnston, Service, Gitschier, & Freimer, 1998; Zatorre, 2003). Children with WS tend to eagerly participate in music activities and give music a longer attention span in comparison to other daily activities. In consideration of these facts, researchers recommend using simple percussion instruments such as tambourines, wood blocks, and castanets during the infant and toddler years (Miyazaki & Rakowski, 2002; Peretz & Hyde, 2003).

Absolute pitch (AP), also known as perfect pitch, refers to the ability to accurately identify by name and produce the pitch of musical notes without benefit of a reference note (Levitin & Rogers, 2005). The incidents of AP in WS is higher than the incidents in typically developed individuals (Lenhoff et al., 2001; Semel & Rosner, 2003). AP is a rare ability that is exhibited in approximately 1 in 10,000 people. Even though the definition of, and the manner in which AP is tested is varied and complicated, research suggests that early musical training plays an important role, but is not sufficient for the development of AP (Baharloo et al., 1998).

There are controversial discussions concerning the benefits and disadvantages of AP (Dowker, 2003). Peretz and Hyde (2003) state that there is increasing evidence that individuals with AP have an innate, music-specifically neural network, and that these networks can be selectively compromised by congenital disposition and brain abnormalities including brain damage, abnormal brain structures, and abnormal perceptual processing. Levitin and Rogers (Donnai & Karmiloff-Smith, 2000) point out that even though there is a difference between the processing of color and pitch, it is possible that *categorical perceptions* for pitch can be transferred, and an equivalence of categorical processing might be achieved.

Pitch processing and advantages/disadvantages of AP are still elusive. However, I speculate that there is the possibility that AP can be used to teach abstract concepts to children with WS. There is an anecdotal report on this speculation. During my previous music therapy interactions with children with WS in Korea, color recognition was observed as a problematic domain for toddlers. I tried to teach different colors to a boy named Mike for several weeks with unsuccessful and frustrating results. With knowledge of AP in mind, I used a color-coded instrument. I have a xylophone that has an individual color for each note; red for C, orange for D, yellow for E, etc., forming a rainbow of color. The same concept is supported by other instruments and objects, such as boom whackers, bells, scarves, and color sticks. Music was composed based on the colors on the xylophone with distinctive melodic and rhythmic structures. Mike showed remarkable improvement in color recognition after the first trial, and I observed generalization with other objects (scarves and color sticks) in the following weeks.

Neurobiological Factors

Each expression of WS symptoms has a complex phenotype defined by a specific subset of symptoms and limitations in functional domains. They are caused by abnormal neurological development believed to be the result of the deletion of the ELN gene, and some surrounding genes in chromosome 7 (Reid & Lienemann, 2006). Research on WS is rapidly expanding and adding detailed information, thanks to advancing technology in brain imaging and genetic mapping. Brain imaging methods from positron emission tomography (PET: one dimensional computer scans) to voxel-based morphometry (VBM: three dimensional scans) allow researchers to examine the specific areas of the brain in terms of volume, density, shape, and degree of activation (National Research Council (U.S.), 2000; Ormrod, 2003). Linguistic capability is largely managed by the left brain, and the right brain handles visual and spatial information. Prior to development of the fluorescence in situ hybridization (FISH) test for WS in 1993, WS was suspected, but could not be confirmed as the unifying cause of a range of symptoms that were treated separately with mixed results. Because individuals with WS have spared language capability and visuospatial difficulties, researchers in 1993 expected to find lesions within the brain regions related to WS disabilities. However, once the FISH test verified these subjects as having WS, no indications of lesions or other apparent abnormalities were found in either the left or right hemispheres in the brains of individuals with WS. Recent improvements in technology and newer conceptual models have helped researchers reconsider the relationship of the areas of the brain to atypical behavioral and cognitive profiles. Recent research has confirmed developmental abnormalities of the brain's volume, shape, and neural density.

Research in the neuroanatomy, neurophysiology, and neuroscience of WS is providing a better understanding of WS and helping to establish a better comprehension of brain function in the general human populace. As better evidence has been obtained, a broader consensus has developed. By conducting research using individuals with WS, scientists are now considering stronger relationships between genetic structure and cognitive maps as a more distinctive case of human cognition and genetic expression. Neurologists are investigating the differences in individuals with WS' brain structure to better understand the connections between localized brain function, cognition, and language. They anticipate that a better understanding of the idiosyncratic characteristics of WS's brains will give them more refined insight into typical human neurological development.

Genetic studies of WS focus on identifying the genes that are responsible, the cause of the deletion, and gene mapping within the WS common deletion (Feinstein & Reiss, 2006; Korenberg et al., 2001). The common WS deletion is ~1.6 Mb, including ~20 genes; the elastin gene (ELN) and LIM-kinase 1, and extends to the area from WBSCR20 through GTF2I (Morris, 2006). The ELN encodes the protein elastin, which is a major component of the elastic fibers found in many connective tissues such as heart, skin, and intestines. The elastin gene is responsible for congenital heart disease (supravalvular aortic stenosis) and other vascular stenoses. LIM-kinase 1, is speculated to contribute to the characteristic cognitive profile, in part through the spatial deficit. A growing number of other genes mapped in the region include three major areas of deletion of the chromosome band (see Figure 4). Some genes are responsible for characteristic features of WS cognition and some with the characteristic facial features illustrated in Figure 4.

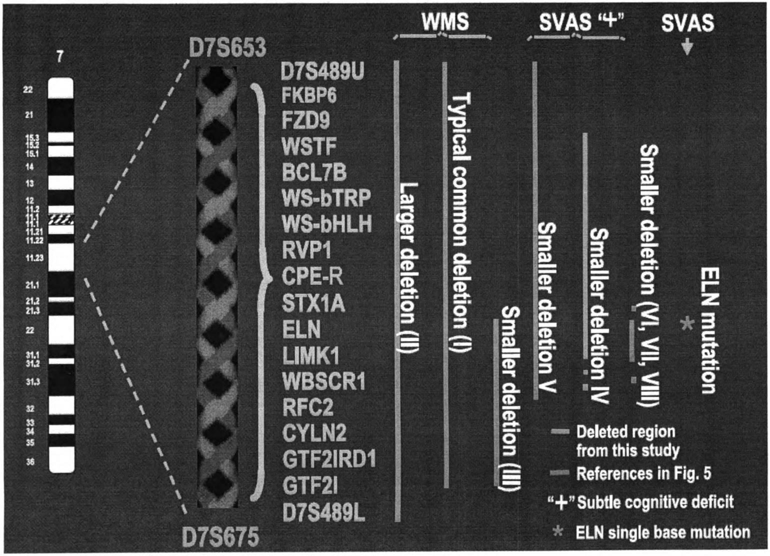
There is a great deal of research about the volume and the shape of the brain of individuals with WS. Reiss et al. (2001) observed that the brains of individuals with WS have smaller total volume (13%) than those of individuals with typical development. They also found, as previous studies suggest (Jernigan & Bellugi, 1990; Jernigan, Bellugi, Sowell, Doherty, & Hesselink, 1993), that reduction in brain volume is proportionately uneven depending on regions. While overall brain tissue volume reduction was at 13%, cerebellar volume was reduced only 7%, and brainstem tissue volumes were reduced 20%.

*Figure 4. Model of phenotype to genotype map of Williams Syndrome.**

Vertical lines on both figures indicate the regions deleted and the number of subjects carrying the common WMS deletion associated with some of the typical facial features, mental retardation, and heart disease. The larger deletions are associated with similar features, or the smaller deletions that include subregions of Synaxin1A through RFC2, are associated with only the typical heart disease Supravalvar Aortic Stenosis (SVAS) and subtle cognitive deficits that fall within the normal range. Gene symbols are noted in the corresponding regions. Subject VIII has a subtle defect in visuospatial processing. * Indicates individuals with deletion or single base pair mutation of elastin, all associated only with SVAS and normal cognition. Small vertical brackets indicate deleted regions that differ among subjects, and therefore provide the potential to assign specific WMS features to single regions or genes. Some brackets indicate regions that, from the current data, are likely to contain a gene or genes that when deleted contribute in some measure to the WMS features denoted. The significance of these data is that deletion of STXIA, ELN, LIMK1, WSCR1, and RFC2 do not appear to be strongly associated with the characteristic facial or cognitive features seen in WMS, although they may contribute. In contrast, deletion of the region telomeric to WSCR1 is associated with characteristic features of WMS cognition.

*From "Genome Structure and Cognitive Map of Williams Syndrome" by Korenberg et al., Journal of Cognitive Neuroscience *12*(90001), p.102.

Figure 4. Model of phenotype to genotype map of Williams Syndrome.* Cont.



Comparing right and left total cerebral tissue volume between the four lobes of the brain, frontal-lobe, parietal-lobe, temporal-lobe, and occipital lobe tissues indicates that the gray matter tissue volume of parietal lobe seemed to be disproportionately increased (Overy, 2000, 2003). In contrast, overall tissue volume in occipital lobe is decreased predominantly in the gray matter in the right hemisphere (Reiss, et al., 2001). The superior temporal region is the only area in the brain to be preserved in size and shape. This area is believed to be the center for perception and processing of music as well as auditory and language processing.

As indicated by their behavioral phenotype, the frontal cortex of individuals with WS is relatively larger than the posterior (visual) cortex. The visual cortex indicates an abnormal clustering of cells (Feinstein & Reiss, 2006). The visuospatial-motor (VSM) difficulties of individuals with WS may be based on this neuroanatomical difference, specifically in the dorsal cortical stream (Meyer-Lindenberg, Mervis, & Berman, 2006). There are two areas involved with transmission of visual information; the dorsal cortical stream and the ventral cortical stream. The dorsal cortical stream sends the visuospatial information (the "where" of the object) to the parietal lobe, and the ventral cortical stream transmits visual identity information (the "what" of the object) to the temporal lobe, reflecting a deficit of frontoparietal processing (Meyer-Lindenberg et al., 2006).

Post-mortem investigations on individuals with WS reveal reduced brain size, Chiari I malformations, more convex shape of the corpus callosum, and altered cell-size and density in primary visual cortex (Mervis & Morris, 2007). Functional Magnetic Resonance Imaging (fMRI) indicates isolated hypo-activation in WS in the parietal portion of the dorsal stream when the participants performed tasks that are related to spatial locations of drawings or block reconstruction assignments (Meyer-Lindenberg et al., 2004; Meyer-Lindenberg et al., 2006).

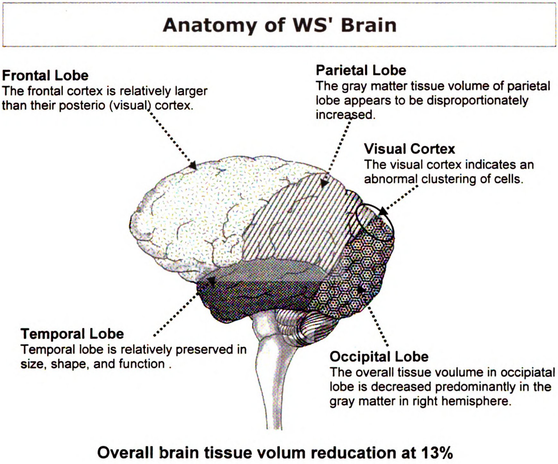


Figure 5. Anatomy of WS' Brain.

Illustration by Hyang Eun Lee

The parietal portion of the dorsal stream, which is immediately adjacent and anterior to the intraparietal sulcus region is identified by the volume of reduced gray matter (Meyer-Lindenberg et al., 2005; Meyer-Lindenberg et al., 2004; Meyer-Lindenberg et al., 2006; Schmitt, Eliez, Bellugi, & Reiss, 2001).

Other aberrant brain morphologies include relatively *spared structures* within the limbic system of the temporal lobes. It is speculated by researchers that the temporal lobes may be associated with memory and emotion. Another difference in the brains of afflicted individuals includes a relatively large cerebellum, especially in the neocerebellum, which may incorporate language function. One last consistency among individuals with WS involves enlarged sections of the temporal lobe and planum temporale, which is involved in the processing of auditory verbal and music stimuli. The volume of the superior temporal gyrus is preserved, providing a basis for their cognitive strengths and musicality.

Different patterns of neural organization in individuals with WS have been discovered by functional magnetic resonance imaging (fMRI) (Levitin et al., 2003). Compared with individuals with typical development, the fMRI of participants with WS indicated decreased activation in the temporal lobes and more variable and diffuse activation throughout the brain, including the right amygdala, cerebellum and brain stem[2]. When the control group processed music stimulus, it showed focused activation in particular areas of the temporal lobe. Between the responses to music listening verses noise listening, two groups showed differences in activation patterns, while the control group mainly activated temporal lobes for music processing. The subject group did not significantly differentiate those two different stimuli. Levitin et al. (2003) concluded that

---

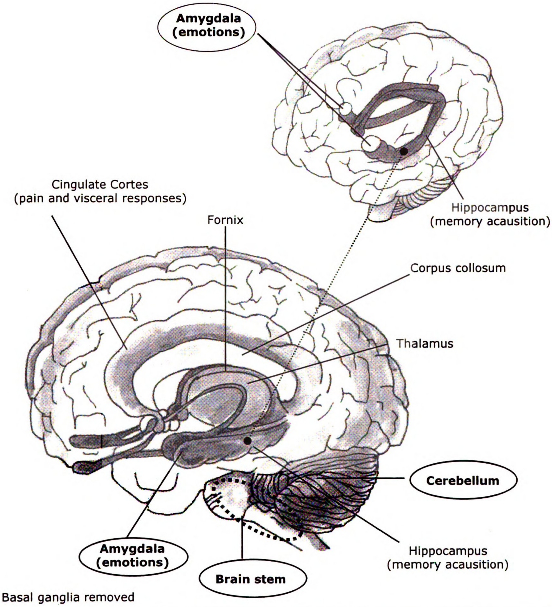
[2] The brain stem (brainstem or corticorubrospinal) is evolutionarily the most primitive part of the brain and is responsible for sustaining the basic functions of life such as maintaining breathing and blood pressure (Adams et al., 1998; Heimer, 1995). In terms of motor control, the brain stem provides maintenance of axial body tone which is necessary for erect posture and continuously modifies the body posture to maintain equilibrium. (Adams et al., 1998; Love, 1992). Voluntary movement is controlled by many different part of brain. The cerebrum initiates selective voluntary movement by normal volition. The basal ganglia and cerebellum help to control complex patterns of muscle movement by controlling the intensity and direction, timing, and selection of the appropriate muscle group in order to achieve smooth movement. The brain stem maintains the axial body tone which is necessary for erect posture and modifies the body posture in order to maintain equilibrium.

significantly differentiate those two different stimuli. Levitin et al. (2003) concluded that these findings are congruent with behavioral patterns in individuals with WS toward music and auditory stimulation, and their neural organization seems to be different from typically developed individuals.

When WS was confirmed as a genetic disorder, scientists wanted to compare WS with Down Syndrome (DS) because of the common characteristics; a genetic disorder and cognitive impairment. Scientists believed that by comparing the two disorders they could generate a better understanding of WS based on the existing body of literature in DS. They found a number of similarities, but at the same time many differences. Studies about WS and DS reported that, although the full-scale IQ scores in both groups were similar, the pattern of cognitive strengths and weaknesses were different.

In addition, based on neurological research (Feinstein & Reiss, 2006; Reiss et al., 2001) and high-resolution MRI studies (2003), scientists suspect that the difference in the brain structures of those who have DS and WS, as well as the specific degrees to which their respective syndromes are activated, demonstrate fundamental differences in the processing of stimuli. This helps differentiate the distinctive phenotypes of DS and WS and provides explanations for preservation of language skills in individuals with WS, and significantly better spatial and motor abilities of individuals with DS. Therefore, even though people with both disorders are categorized as cognitively challenged, interventions for each syndrome should be differentiated based on its specific expression and underlying cause. While the neuropathology of WS remains elusive, it is important to refine the understanding of specific causes and characteristics of WS difficulties and to use this knowledge to develop music therapy strategies that address them.

Limbic System



While the control group mainly activate temporal lobes for music processing, individuals with WS activate amygdala, cerebellum and brain stem as well.

The subject group did not significantly differentiate music and noise process.

Figure 6. Limbic System in WS' Brain.

Illustration by Hyang Eun Lee

Bellugi, George, and Galaburda (Ansari & Karmiloff-Smith, 2002; Mervis & Becerra, 2007) state that their research with children and adolescents with WS suggests that neural systems in WS differ in typical paths from those seen in TDC. Fisher and Als (2004), neurologists specializing in neonatal development, state that neurological wiring is *different*, not *delayed*. The theory of *different*, not *delayed* is extremely useful because it sheds light on the differences in genetic disorders and suggests that different approaches for each disorder are required.

Mathematical Development

Anecdotal reports by parents and related personnel, and the results of various cognitive tests indicate a significant deficit in numerical cognition in individuals with WS. Mathematical development has remained relatively neglected and has not yet been systematically investigated other than through limited references in articles by O'Hearn and Landau in 2007 (Ansari et al., 2003; Karmiloff-Smith, Ansari, Campbell, Scerif, & Thomas, 2006; O'Shea, O'shea, & Algozzine, 1998).

Mathematical development, especially during early childhood (ages 0 to 7), is generally overlooked because young children typically gain an understanding of basic mathematical concepts without requiring much intervention by adults. Young children learn by playing with toys and manipulating objects, and by interacting with parents, siblings, and friends. In addition, there are other issues with children with WS that require more immediate attention such as medical needs, early language issues, toilet training, and self-help skills. However, some individuals with WS do not seem to develop mathematical concepts in their early years. When they enter school, mathematical problems such as addition and subtraction, are introduced. WS children's lack of understanding quickly becomes apparent to teachers and parents. The underlying problem appears to be rooted in their lack of foundational mathematical development.

Developmental guidelines in mathematics for children ages 2 to 7 years give insight concerning individuals with WS and the missing developmental milestones (Clements & Sarama, 2004). Clements and his colleague established developmental guidelines for numerical operations, algebra, geometry, measurement, data analysis, and probability (see Appendix H). According to their guidelines within numerical operations, individuals need a range of concepts and a knowledge base in order to perform simple operations.

Dowker (2003) stated that there may be as much as a seven-year gap in the typical 11-year old's highest and lowest mathematical performance. However, for children with WS, the gap widens to 10, 11, or 12 years. Research on numeral discrimination in infants suggests that, while infants with DS showed a significant impairment, infants with WS showed a similar response to both their chronological and mental age control group (Paterson et al., 2006). However, as adults, individuals with WS show a more serious deficit on a wide variety of number tasks than individuals with DS. These findings suggest that mathematical cognition development in individuals with WS is disturbed, to some degree, after infant- and toddler-hood and that several levels of components in the numerical system need to be taken into account. The exact pathway and means of mathematically cognitive development, and which level of cognition hinders mathematical development in WS, remain elusive. However, Donnai & Karmiloff-Smith (2000) suggest that low-level cognitive processes, such as the ability to count and to use counting to determine exact quantities, are affected by deleted genes. As a result, while general development proceeds, different levels of cognition are uniquely affected (Donnai & Karmiloff-Smith, 2000). Mathematical difficulties are directly related to basic living activities involving numbers, such as money, telling time, and finding pages in a book.

Elementary mathematics as logic (solving a problem by logical thinking) rather than abstract thinking can be taught with strategic instruction, i.e., a step-by-step approach. The literature in academic learning of WS, emphasizes the importance of using auditory and verbal modes and the order in which to teach new concepts (Carpenter, Fennema, Franke, Levi, & Empson, 1999, p. xiii). A strategy of instruction was developed and its effectiveness documented by researchers in special education (Dehaene, Bossini, & Giraux, 1993). In practical terms, the strategy is defined as "a series of ordered steps that will allow a student to perform a task" (Reid & Lienemann, 2006, P.18). Therefore, when teaching mathematics, it is important to analyze mathematical tasks and know which mathematical concepts the student does not understand. For example, the mother of a 10-year old child with WS reported that her son could not understand the meaning of "carry over" in two-digit addition. Songs to illustrate or teach how to carry-over could be composed and implemented providing students with step-by-step instructions and self-guidance as a possible music therapy intervention.

The following table gives examples of problem solving logic in mathematics.

*Table 1. Example of task breakdown for two-digit by two-digit multiplication**

Steps	Skills required
Multiply 1's column.	Knowledge of place value Knowledge of multiplication facts
Bring down the 1's digit part of the answer.	Knowledge of place value Where to write answers to vertically written math problems
Carry the 10's digit part of the answer.	Knowledge of place value How to carry numbers
Multiply across, the bottom 1's digit to the top 10's digit.	Knowledge of place value Knowledge of multiplication facts
To that answer, add the number that you carried and write that down.	Knowledge of place value Where to write answers to vertically written math problems
Under that answer write a 0 in the 1's column.	Knowledge of place value
Multiply the bottom 10's digit to the top 1's digit.	Knowledge of place value Knowledge of multiplication facts
Bring down the 1's digit part of the answer put it in the 10's column.	Knowledge of place value Where to write answers to vertically written math problems
Carry the 10's digit part of the answer.	Knowledge of place value How to carry numbers
Multiply the 10's digit column.	Knowledge of place value Knowledge of multiplication facts
To that answer add the number that you carried and write that down.	Knowledge of addition facts Where to write answers to vertically written math problems
Add your two answers; the number that you get is the answer.	Knowledge of addition facts
Write it down.	Where to write answers to vertically written math problems

*Note. From Strategy Instruction for Students with Learning Disabilities by R. Reid and Torri Ortiz Lienemann, 2006, New York, NY: The Guilford Press. Copyright 2006 by the Guilford Press. Reprinted with permission.

From simple acknowledgement of the symbolic presentation of Arabic numbers to division, there are more than 50 steps to complete a mathematical computation. Table 2 illustrates the basic building blocks in mathematics.

Table 2. Major building blocks on the way to division

Building Blocks
Know Arabic number system.
Write down the numbers.
Add one digit up to 10
Understand carrying-over concept
Add one digit up to 18
Add two digits
Subtract one digit less than 10
Understand borrowing concept
Subtract two digit concepts
Memorize all 9 multiple tables
Multiply one digit
Multiply two digits
Divide one digit
Divide two digits

Another consideration for this project is the mathematic developmental level of each individual informant. This study is intended to teach addition, subtraction, multiplication, and division, which are basic to mathematic development appropriate levels of mathematic development. However, if an informant does not have basic mathematic comprehension such as understanding the Arabic number symbol system, the quantity represented by each number, or the meaning of sequencing numbers, there is a need to focus on lower-level cognitive processes.

Mathematical development is complicated. While language acquisition can continue despite *missing pieces* in language development, mathematic development is sequential and built on prerequisite mathematical acquisitions. As with gross motor development in the first year of life, infants advance from laying down, to developing the muscle in the neck to controlling the movement of the head and trunk , learning to sit, crawl, stand, and finally walk. Walking is not possible without head and trunk control. In much the same fashion, mathematical development is a sequentially developmental process that is more similar to physical development than language development.

The visuospatial aspect of mathematics is neither clearly defined nor thoroughly studied because the process of manipulating and calculating numbers within the brain is still elusive and controversial (Bachot, Gevers, Fias, & Roeyers, 2005; O'Hearn & Landau, 2007). The visuospatial difficulties in the WS population might manifest in the form of an abnormal perception of the mental number line (Dehaene, Dupoux, & Mehler, 1990; Zorzi, Priftis, & Umilt, 2002), which refers to the spatial perception and representation of a number along a left-right orientation in a continuous analogical format, such as that of a ruler (Dehaene et al., 1993; Zorzi et al., 2002). Research on the mental number line suggests that this concept might be an inherited psychological aspect rather than a learned behavioral. Even those in right-left-oriented written documentation cultures, there is evidence that they possess left-right orientation with the mental number line (Davis, 1999; Peters, 2000). There is no specific research on the perception or recognition of a mental number line in individuals with WS.

Music as a Therapeutic Medium

Music provides experience and stimulation in various developmental domains for individuals with special needs (National Research Council (U.S.), 2000). A preliminary study in Korea of three young children with WS ranging in age from 40 to 51-months reported that during 10 weeks of musical intervention, subjects showed distinguishable improvement in word acquisition, including the names of body parts, animals, fruit, and instruments. However, when comparing abstract concepts, subjects continued to show difficulties distinguishing a large drum from a small drum (Song, 2003). The study suggested the possibility of using various aspects of music such as rhythm, melody, pitch, harmony, and dynamics to give toddlers with WS opportunities to develop expression as well as receptive language skills. I think it is possible that the same concept could be extended to the development of mathematical skills. The concept of music therapy provides a theoretical framework for the use of music as a therapeutic medium with regard to mathematical functions. Music can be beneficial for a particular cognitive domain, learning process, memory process, dyslexia, and as a therapeutic medium in memory and attention.

The Learning Process

Human learning, the recognition and absorption of concepts and processes, involves multi-level and multi-dimensional processes. The nature of childhood and the nurturing received during childhood are interwoven and impact an individual's learning process. The learning process is sophisticated so any learning difficulties further complicate an already complicated process. Learning is not the mere memorization of simple facts, but includes knowledge, comprehension, application, analysis, synthesis, and the ability to apply it to multiple situations (Reid & Lienemann, 2006). Therefore, if the structure or characteristics of musical activities can aid in any of these processes, then specific training using music can facilitate and promote the over-all learning processes.

Research conducted in developmental psychology, cognitive psychology, and neuroscience advocates the findings that, "learning changes the physical structure of the brain, these structural changes alter the functional organization of the brain; in other words, learning organizes and reorganizes the brain, and different parts of the brain may be ready to learn at different times" (National Research Council (U.S.), 2000, p. 115). Music can be used to create a structure that integrates activities with learning to help the formation of brain structures. Based on an animal learning process experiment, "learning adds synapses; exercise does not" (National Research Council (U.S.), 2000, p. 120). In other words, mere physical movement (such as treadmill exercise) does not generate new neuron synaptic connections, but the exercise combined with cognitive processing does generate connections (such as occurs with acrobats). Based on those findings, learning through musical activities can add new pathways for performing tasks.

Memory Process

Despite differing perspectives from various fields in human memory processes, the prevailing theory is a dual-store memory model (Ormrod, 2003). The term *dual-store* comes from the two distinctive memory types; short-term and long-term memory. Figure 7 depicts a simplified dual-store model (Ormrod, 2003, p. 187).

Sensory input is registered for a short time period of a few seconds at most. Depending on sensory modality, the remaining information is changed and remembered for a fraction of a second longer than visual information and for two to four seconds longer than auditory information (Ormrod, 2003). In order to process input at the next level (i.e., short-term/working memory), the receiver needs to pay attention to the stimuli.

Since only registered information moves into working memory, attention is the important factor in memory. Human beings consistently need to choose the most salient stimuli because of their limited human capacity. Ormrod (2003) identified six factors that influence attention: size, intensity, novelty, incongruity, emotion, and personal significance (National Research Council (U.S.), 2000; Ormrod, 2003). The interesting factor in these six factors is *personal significance.* Aside from the factors, *personal significance* can change the direction of attention, which explains why different individuals in the same situation perceive things differently.

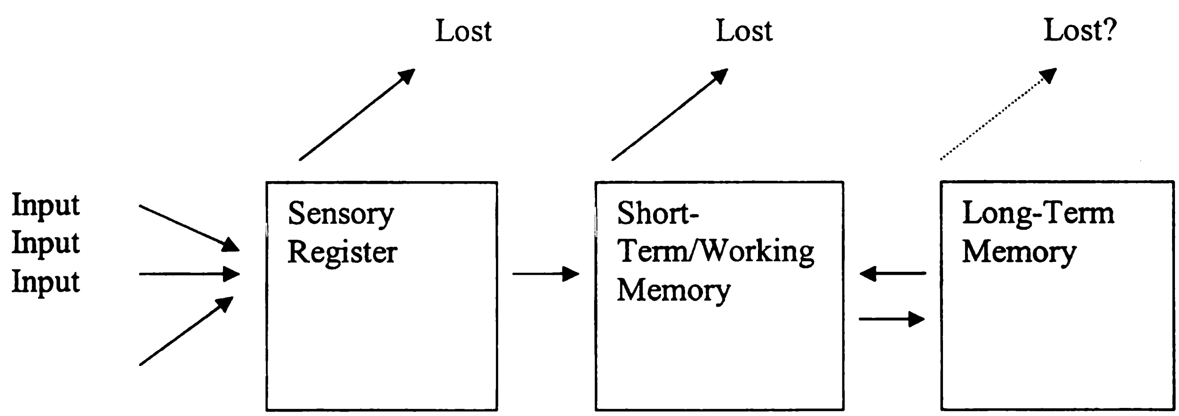


*Figure 7. A simplified dual-store model of memory.**

*From "Human Learning (4th Ed)" by Ormrod, p.187. Copyright 2003 by the Pearson Merrill Prentice Hall Reproduced with permission

When information is moved into the working memory stage, individuals start to *think* or manipulate the information they receive in order to process it into the long-term memory. The strategies used to incorporate information into the long-term memory include organization (chunking), retrieval (scanning process of all the information), and maintenance rehearsal (connecting new information with old information). Storage and retrieval are two main control processes in long-term memory. Storage happens when the learner understands, organizes, and integrates new information with pre-existing information.

The retrieval of information from long-tem memory involves a considerably more sophisticated process than when retrieving information from working memory. Since human beings retain huge amounts of information, it is important to focus on the correct memories. All three steps in the storage process (understanding, organizing, and integrating) are directly related to successful information mapping and retrieval. Fully understood concepts that are organized and richly detailed have a better chance of being retrieved successfully. The more connections that are made with previously memorized information, the better the chance to retrieve it in the future. A comprehensive understanding of the memory process is important to gain an understanding into how music can influence the memory process for individuals with cognitive challenges.

Dyslexia and Music

Research on the relationship between language and timing skills suggests that the difficulties rising from language-learning impairments may result from a fundamental deficit in the ability to process rapidly changing sensory input. Tallal and colleagues (1996) designed a training procedure using prolonged speech patterns that preserved spectral content and the natural quality of speech. They reported that after 3 to 4 weeks of intensive temporal processing (3 hours a day, 5 days a week at the laboratory for 1 to 2 hours a day, with 7 days a week as homework) seven participants (with a mean chronological age of 7.3 years) dramatically improved their receptive language skills. A small amount of similar research has echoed these findings. Results from several other studies support the conclusion that there is a correlation between dyslexia and the temporal encoding of sensory information that can be improved by temporal processing training. The relationship between dyslexia and the temporal aspect of music (rhythm) has been reported in two directions. Dyslexic musicians reported difficulties with rhythm, and dyslexic children have problems keeping a steady beat (Granschow et al., 1994; Miles et al., 2001; Oglethorpe, 1996(Overy, 2003)). Overy (2000) applied the concept of applying temporal processing training with dyslexic individuals to dyslexia and music. Overy (2003) and Overy, Nicolson, Fawcett, and Clarke (2003) used music, which has an intrinsic temporal organization, for remediation of temporal processing deficits and conducted research to identify a particular area of music on which to focus in order to improve timing processes. The results indicated that music activities that place a strong emphasis on rhythm improve both phonologic and spelling skills, but not reading skills.

Overy (2003) also pointed out that the participants exhibited no sign of difficulty with the use and recognition of pitch. This provides additional insight into the relatively preserved language ability of individuals with WS, despite their cognitive impairment. Individuals with WS do not show any signs of difficulties in phonological or spelling skills, and their auditory sensitivity and musical abilities (pitch and rhythm) are part of a well-known phenotype. For other children with cognitive challenges, using visual or whole word teaching strategies is often suggested to teach them to read a word, whereas the phonic system or auditory modality to break words into components is generally suggested for individuals with WS (Mervis & Morris, 2007; Semel & Rosner, 2003). Processing speech involves developing the ability to make fine discriminations between sounds rapidly. Music therapy interventions that require the child to distinguish between high and low pitches, loud and soft tones, and the sounds of various instruments can train the child for auditory perception in time with clear self-evaluation tools (i.e., the students understand the expectations of therapists and whether or not they successfully meet them).

Mnemonic and Strategic songs

Music has been used as a mnemonic device or memory aid, and has been particularly useful for children with memory issues including mental retardation, cognitive impairment, and learning disabilities. Gfeller (1999) suggests using short and simple melodies to recall information such as multiplication tables. Songs for multiplication tables have been used by the general public. Some children in the U.S. learn their multiplication tables with changing lyrics of the melodies from familiar songs such as 'Jingle bells," "Row Row Your Boat," and "Yankee Doodle."

The guidelines for composing a song memory aid, called a *jingle,* can be found in the analysis of the composition of songs used in commercial advertising. Commercials use melodies that are catchy and made to be easily remembered. Based on their empirical experience, Zager(2003) suggests four basic guidelines to make a song memorable:

1. Melodies have to be simple: more conjunct (stepwise) motion than disjunct (skips) motion in the melodic structure, but interesting.
2. The harmony should be simple.
3. Songs should be easy to remember after the first hearing.

4. The song should be easy for the average person to sing along with (Zager, 2003, pp. 94-98).

Phrasing in music through musical elements helps *chunk* verbal information and is the most crucial informational organization strategy for composing music for mnemonic purposes. Thaut (1999) explains the role of phrasing by musical elements for memory processes. *Chunking* refers to the memory organization strategy of grouping single, small pieces of information into larger units that are easily remembered as a whole. For example, seven digit telephone numbers are chunked into two units of 3 and 4 digits. Rhythm, melody, and harmonic elements are all excellent structures that enhance the organization, sequence, and recall of verbal information. A short melodic phrase can trigger the recall of a long series of words and sentences. One of the best known examples might be the ABC song. While it is a considerable challenge to remember 26 separate bits of information, the ABC song is organized in 4/4 meter, and uses musical phrasing to create four, easily manageable phrases of information (Thaut, 1999). Therefore, songs, chants, rhymes, and such can be used efficiently by music therapists to facilitate memory process.

Strategic instructions, such as providing strategies to solve academic problems,are strongly encouraged for students with learning disabilities (Karmiloff-Smith, Ansari, Campbell, Scerif, & Thomas, 2006; Semel & Rosner, 2003). New concepts can be learned and internalized through a series of necessary steps: repetition, comprehension, and application. Most songs for young children use simple rhythmic structures and straightforward melodies that repeat lyrics. When children listen and interact with others, they learn either the actions along with music, or some portion of the lyrics, usually the chorus as it is the most repeated section of a song. Repetition is the important part of the learning process and songs can be repeated many times without making children bored.

The multi-sensory aspects of music are often additional benefits to the memorization process (Gfeller, 1999; Thaut, 2005). Using multi-sensory stimulation as much as possible gives individuals more opportunities to retain and retrieve new concepts (more connections) and provides more chances to apply new concepts in general situations. Music as a multi-sensory activity gives children with learning disabilities a chance to overcome their difficulties using a favored sensory modality (Overy, Nicolson, Fawcett, & Clarke, 2003; Peters, 2000).

Issues in Attention and Motivation

Lack of motivation and attention deficits are often reported as salient characteristics in learning disability. Lack of motivation and failure in academic pursuits can lead to a learned helplessness, which in turn feeds back into a negative cycle that reinforces itself. Attention deficits do not mean that children with learning disabilities cannot pay attention, but that they often pay attention to unnecessary or unimportant stimuli, or can be easily distracted by insignificant stimuli (Ormrod, 2003). Aldridge (1996) claims that four elements are required to achieve sensory integration: arousal, attention, affection, and action. These four concepts are essential to the learning process. In order to learn, the learner should maintain alertness (arousal), pay attention to the subject (attention), enjoy the subject (affection), and demonstrate an understanding of the subject (action). Music activities require synthesizing auditory stimulation (music listening) and appropriate response (playing, singing, or acting), which can be easily observed and redirected if the action is inappropriate.

Based on this theory, it can be hypothesized that, within a rhythmic structure, variation in musical elements could create an attention-gripping moments in the music. Attention can be focused on and manipulated using music from the perspective of the following six factors; size, intensity, novelty, incongruity, emotion, and personal significance (Ormrod, 2003). In other words, while the rhythmic structure of song (meter) gives the listener familiarity, changes in pitch (which comprise melody and eventually phrases), loudness, and timbre, will catch and maintain attention. For those who have an affinity to music, especially individuals with WS who also have hyperacusis and transfixion to different sounds, music interventions can also provide significant emotional and personal connections that increase attention. Music is processed in the brain. Knowledge about the function and role of each element in music as it is processed in the brain provides potential frameworks to use to promote specific goals and objectives in the learning process.

Wish List from Parents and Music Therapists

Before this study, I conducted a preliminary pilot project for developing a rationale for music therapy programs for individuals with WS. After reviewing the literature about WS, interviewing a parent with a child with WS, and music therapy colleagues, it was possible to define at least a partial wish list for those who work with individuals with WS. Nancy, who is the mother of Jessica, a three-year old with WS stated that she is concerned about Jessica's cognitive function. Since Jessica has good language ability and relatively acceptable cognitive skills for her age, and considering her diagnosis, she hopes that Jessica can reach a relatively normal range of cognitive functioning.

Nancy is an actively involved parent; she studies WS and seeks interventions for her daughter's condition. Since Nancy found the information about using songs to teach individuals with WS, she has taught Jessica how to spell her name, her telephone number, and her address using songs. Diane, a music therapist who has two clients with WS, expressed that she wishes to have more information about WS. She feels that the current information about WS is "purely neurological and medical." She thinks there is enough information regarding difficulties, abnormalities, characteristics, or extreme anecdotes about idiopathic examples of some individuals with WS, but there is not enough information about what kinds of interventions are useful to compensate for cognitive differences, and how to use their special abilities in their daily lives. For example, because individuals with WS have good musical skills, many of them could successfully perform in public. However, from a music therapist's standpoint, it is equally important to know how one can use their special music abilities to help improve non-musical skills. There is not enough information and research about these areas.

There may be music therapists who encounter individuals with WS, but have limited resources and time to investigate and develop individualized music therapy interventions. Vicky, a music therapist at the WS summer music camp, suggested that music therapists should provide appropriate and accurate information about the role of music therapy for individuals with WS. Then, administrators, physicians, and parents would have a better understanding of the use of music therapy with individuals with WS, an important first step into school systems and toward being included as regular therapy for individuals with WS in their individual education plan (IEP). The fact sheet about WS, which is compiled by the American Music Therapy Association, could be the official document presented for music therapy service. However, the fact sheet does not currently give enough information to explain the benefits of music therapy for individuals with WS.

Singing activities suggest the need for further investigation because of current successes and limitations. My pilot study reported that Diane (a music therapist with two children with WS clients) mentioned that Jessica and Tom do not like to sing during sessions. Diane speculated that Tom might not like his singing voice. This may be due to the deletion of the gene for elastin, the vocal chord connective tissue in persons with WS. As a result, individuals with WS typically have "hoarse" voices. The reported incidence of this characteristic varies dramatically from 20% to 100%, depending on the study (Semel & Rosner, 2003). Unlike Tom, Jessica seems to be shy and also does not sing during sessions, but she does sing the songs from her sessions in the car with her mother during the trip home afterwards.

Fidler, Lawson, and Hodapp's work (2003supports the need for further investigation of the use of songs. They discuss parents' desire for modifications to their children's current educational programming for children with three different genetic syndromes (Down Syndrome (DS), Prader-Willi Sindrome(PWS), and WS). They concluded that the parents of children with DS need speech therapy and reading services, parents of children with PWS desire increases in adaptive physical education, and parents of individuals with WS need adaptive music instruction and musical aides in the classroom. One parent expressed that a special educator underestimated her child's musical capabilities, and another parent believed music needed to be incorporated into regular classroom instruction. They also cite that parents wish to have available "… [a] class with individualized learning strategies, such as visual learning with music" (Fidler, Lawson, & Hodapp, 2003, p. 201). In accordance with the needs expressed by parents, early music therapy interventions for children with WS should begin as soon as the diagnosis is made, and should be continued for each stage of the child's life to help them overcome and compensate for difficulties and limitations.

Reason for Study, Initial Theory, and Research Questions

This study attempts to develop effective music therapy interventions in mathematical learning for individuals with WS by utilizing music therapy tools as instructional aids based on existing theories of music therapy. Responses of three participants to these techniques were observed and analyzed in relation to the expected effectiveness of the interventions.

Information exists regarding strengths and weaknesses in the characteristics of individuals with WS, as well as the use of music therapy for individuals with special needs. However, the use of music therapy to remediate cognitive difficulties in WS and music therapy has not been tested and evaluated to determine its role for specific academic needs of individuals with WS. A cyclic process of research, redefined theory, and practice are needed to maximize the effectiveness of music therapy interventions in such a context.

Individuals with WS require alternative strategies and tools to address mathematical development because of their unique neurological issues affecting development. Traditional methods used to teach mathematics are ineffective for individuals with WS. Speculative causes for these difficulties in mathematics include cognitive limitations, visuospatial deficits, and attention deficits. If the identification of these causes is accurate, music therapy theory suggests that music may, to some extent, counteract cognitive limitations and lack of attention.

Existing theories of music therapy for individuals with special needs suggest that music can be used to promote cognitive development through the singing of songs that contain the content of academic learning concepts such as the alphabet and numbers (Adler, 2006). Music also functions as focus and reinforcement for attention and as a structure that may promote mathematical development as discussed in the previous section on music as a therapeutic medium. In addition to these therapeutic benefits, individuals with WS' affinity for music can be an additional asset to amplify the benefits of music. The basic premise for the effectiveness of music therapy intervention for individuals with WS is drawn from the individual's known musical affinity and specific neurological responses to music. Individuals with WS have a certain type of musical nature: they are drawn to music and share idiosyncratic musical abilities, such as extraordinary melody memorization, distinctive rhythmic ability, and absolute pitch. Even in the most severe cases of WS, this characteristic affinity for music is not lost. By combining arithmetic with musical activity, individuals with WS might be motivated to participate in activities and their attention can be drawn and held for longer periods that would likely enhance their ability to learn and retain the lessons.

Interventions developed for the individuals in this study are based on theories of neurology, child development, and music therapy. Individuals with WS often have difficulties memorizing some mathematical concepts, such as the value of coins or multiplication tables. The lack of strategies to work on mathematical tasks has been suggested as an integral part of their difficulties in mathematics (Karmiloff-Smith et al., 2006; Semel & Rosner, 2003). Therefore, by providing them with efficient strategies and self-instruction routines through songs, these difficulties may be reduced. Songs can be composed to reinforce mathematical concepts, as well as provide strategic steps or routines to complete mathematical tasks. In this way, music therapy might offer these individuals an opportunity to use their musical strengths to overcome other difficulties. Music addresses the emotional and psychological needs of individuals with WS and promotes a more effective learning environment as illustrated in the following diagram of a cognitive map supporting this study.

This study used observation, video analysis, and interpretation to develop an understanding of the underlying reasons for the mathematical difficulties of those with WS, to improve the understanding of music as a therapeutic medium in this particular population, and to develop music therapy strategies to support mathematical reasoning ability. This study applied a qualitative research approach based on a collective case study foundation, offering the opportunity to collect the information needed for this initial examination of the issue.

Research Questions

The research questions that prompted this study are listed below:

1. What are the obstacles in the mathematical development of individuals with WS? What can they do and what can they not do mathematically?

2. Based on existing music therapy theories for individuals with special needs, as described in the section on music as a therapeutic medium, are there music therapy interventions that can serve as strategies to support learning in mathematics?
3. How do individuals with WS respond to music therapy interventions to overcome their challenges? How are these interventions useful or effective in meeting their needs?

Figure 8 illustrates how these three questions are interrelated to one another in this study.

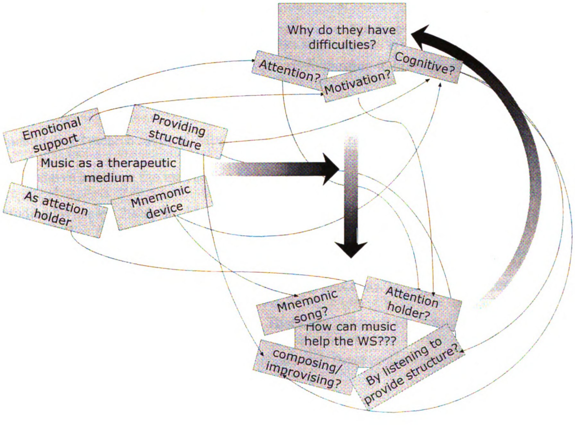


Figure 8. The initial cognitive map linking mathematics and music.

CHAPTER III

METHOD

Research methods provide a framework for the collection, analysis, and interpretation of data. While there is a great deal of research available concerning individuals with Williams Syndrome, including neurological perspectives on their musicality and their abilities involving rhythm and absolute pitch, little work has been directed toward designing music therapy interventions for them. Aldridge (1996) states that qualitative and quantitative research methods have unique and valuable contributions to understanding phenomena in music therapy. According to bibliographic research by Brooks (2003), music therapy, especially within the United States, tends to favor the quantitative research method. Meanwhile, qualitative research is often used to develop a perspective based on the interaction between the researcher and the participants being studied (Wheeler, 2005, pp. 13-15). For this study, qualitative inquiry offers a useful research method because of the lack of foundational knowledge needed to determine the relationship between WS and music therapy. The processes behind the therapeutic effect of music on clients with WS are elusive. Therefore, research incorporating individualized sessions with participants may provide insight into these mechanisms and the development of music therapy for those with WS.

Methodological Framework

A *collective case study* (Stake, 1995) was chosen as the methodological framework for this study. A qualitative case study is "an exploration of a 'bounded system' of a case (or multiple cases) over time through detailed, in-depth data collection involving multiple sources of information rich in context" (Creswell, 1998, p. 61). The goal of a qualitative case study is to develop a thorough analysis of a single case or multiple cases in order to generate a hypothesis based on ontological and epistemological paradigms (Smeijsters & Aasgaard, 2005). Different qualitative case study methods, such as intrinsic case study, instrumental case study, and collective case study, have different benefits and limitations, especially when applied to the previously undocumented use of music to reinforce mathematical concepts for children with WS. While an intrinsic case study focuses on a particular case for its own sake, and an instrumental case study means that *the case* is used as an instrument to understand *the phenomena.* The central tenet of a collective case study is to study *particular cases* as instruments to gain insight and understanding of research questions, or *phenomena* (Stake, 1995). The collective case study method was selected as the best approach to serve the purpose of this study

The collective case study approach provided an overarching picture of the phenomena in this study and aided in establishing the relationship between music therapy interventions that attempt to improve mathematical operations for people with WS, and the possible role of music in clarifying their mathematical difficulties. This approach provided freedom and flexibility to explore different aspects of these phenomena. Observations and interpretations from this study will provide a foundation for more extended research into music therapy interventions for mathematical development in individuals with WS.

Researcher's Lens

My undergraduate training in mathematics led me to work for several years as a computer programmer. The logic and structure of algorithms and code drew me to programming in much the same way that the structure of musical notation and sequences underlies my love of music. Eventually I found that music blended with my tendency to want to help others, and I began to pursue an education in the field of music therapy.

Before I learned the details associated with WS, I was already falling in love with these individuals because of their affection for music. I was amazed by their fascination with sounds and music and the way I could use music to communicate with them. During the earliest sessions with my first WS client, I felt like a music teacher who had stumbled upon a musical prodigy. This client only had to listen to a song or selection a couple of times before he could repeat it back exactly. He could imitate complicated rhythms and patterns, and maintain a musical dialogue with me, something of which few adult musicians are capable—and he was only 5 years old.

Several other clients of mine with WS have demonstrated similar talents in varying degrees. They seemed entranced by new sounds and instruments such as finger cymbals, a gong, a rain stick, and the thumb piano. My limited piano playing ability was enough to enthrall them. I felt like a world-famous, concert pianist engaging my audiences. Music makes these individuals happy. In fact, when music is involved in therapy sessions, their behavior significantly improves. When music therapists and individuals with WS focus on musical experiences, and the clients are engulfed by the music, clients seldom show their frustrations and limitations such as uncontrollable tamper-tantrums, emotional roller-coasters, and obsessive-compulsive. Those moments do not typically emerge while individuals are happy and content. When I became more deeply involved with individuals with WS and spent more time with them outside sessions, such as working at the music camp for individuals with WS, and attending their conferences and gatherings, I witnessed the desperation, frustration, and agony that are also part of their daily lives.

"They are smart enough to know that they are different," said Dr. Barbara Pober, director of the Williams Syndrome Clinic at Massachusetts General Hospital in a TV documentary (CBS, 1997). Another statement from the documentary was that persons with WS did not feel that they "fit in." When they are with other individuals with WS, they feel a sense of belonging, and can relate to, and understand each other. The sense of hopelessness—'there is nothing I can do to improve this condition,' 'I tried this and that, and nothing has been working'—is a devastating feeling. If the love of music by individuals with WS can be used to augment mathematical ability, it could be a significant breakthrough that could make their lives, and their parents' lives, a little easier.

Today's materialistic and product-oriented society does not readily understand individuals with WS' inabilities in certain areas. In some ways I empathize with the day-to-day interactions and prejudices someone with WS might experience. English is not my mother tongue and I have found over the past ten years in the United States that this can cause a range of negative responses. I am not perceived as *foreign*, necessarily, but as *language-impaired* and this sometimes translates into being treated as ignorant, or less than competent, something a person with WS experiences intimately and often. The fact that I am normal in my native Korean society does not help me feel better. Shifting from my linguistic challenges to individuals with WS' mathematic obstacles, I might claim that I have experienced something similar because of the perceived lack of ability. This allows me to relate to how WS individuals might feel in their daily lives.

Participant Selection

The participants in my study were three individuals diagnosed with WS as confirmed by fluorescence in situ hybridization (FISH) testing. The participants' ages from 10 to 25 years of age and were selected to provide a broad spectrum of mathematical development. Gender was not a basis for selection. Individuals who were non-verbal and non-ambulatory were excluded because of out-of-normal distribution of functions in Williams Syndrome[3] (Bellugi et al., 2001).

In order to understand mathematical function in different age groups, three participants were recruited; one from the 10 to 15 year age group, one from the 16 to 20 year age group, and one from the 21 to 25 year age group. I met my three participants at WS conferences, music camps for individuals with WS, and through my work with parents in the WSA. Detailed information about the participants will be shared in each case study.

---

[3] Bellugie, et al (2001), cited 47 studies on cognitive function of individuals with WS using standardized intelligence tests, mainly the Wechsler Intelligence Scale for Children-Revised (WISC-R), and Differential Ability Scales (DAS) (Martens et al., 2008). The mean IQ of individuals with WS was between 50 and 60 with a range of 40 to100. Another source for the *average* or *typical* performance is the Williams Syndrome Cognitive Profile(WSCP) (Frangiskakis et al., 1996; Mervis, et al., 2000).

Sessions Procedures

Music therapy sessions took place over a ten week period, once per week, for 40 to 60 minutes, and in each participant's home environment. Session duration varied according to the participant's needs. The participant's home was used instead of a clinical setting to maximize the effectiveness of music therapy. The study encompassed ten weeks, which may not have been enough time for the participants to fully learn and internalize the concepts and strategies. The effectiveness and sustainability of the interventions and their residual effects were also concerns, even after the project was ended. Therefore, providing the sessions at home was meant to increase the residual effects without having to be as concerned about generalization of learning outside of a music therapy clinic. In addition, the parents and siblings had opportunities to observe and participate in music therapy sessions and to learn songs to support the mathematical development for future use.

The initial intervention designs were based on literature and individual stories drawn from anecdotal experiences that included the WSA, Parents List Servers, third person narratives, and empirical/personal experiences with various WS gatherings. These experiences suggested likely difficulties that might be encountered during music therapy sessions and helped formulate plans for music therapy. As the project unfolded, the interventions evolved, and were modified and then adapted to each participant's functional level, in order to address their individual needs and difficulties. Video recordings of each session were reviewed and transcribed prior to the next session in order to revise preparations based on a growing awareness of each participant's needs. Concurrent investigations into the mathematical development of the participants were an important part of this study. They shed light on the underlying difficulties in each participant's mathematical development and revealed specific impediments of their ability to process mathematics.

Data Collection

Video Recording. All thirty individual sessions with the three participants in this study were digitally recorded and converted to mp4and DVD file formats using the Macintosh iMovie software program. Each video recording focused primarily on the face and hands of each participant, and the materials with which they worked. Each session was reviewed and transcribed within two days to preserve nuances and other elements that may or may not have been directly related to the sessions.

Parent Interviews. Before beginning the study, the mother of each participant was interviewed using open-ended questions to establish her attitudes and frustrations as the parent of a child with WS, her expectations for the study, and her desires for her child's future. After the sessions were completed, each parent was asked to share observations, both positive and negative, and suggest improvements for future music therapy interventions. These conversations provided a secondary data source for triangulation.

Worksheets (Artifacts). Worksheets of math problems were periodically provided to each participant. The worksheets were individualized for each participant's specific skill level. Each worksheet was analyzed and adapted for future sessions. A comparison of all completed worksheets was used to identify common mistakes among participants, and to analyze the benefits or disadvantages of particular songs used in the sessions.

Personal Journals and Field Notes. A personal journal of each session and field notes taken during sessions were maintained. The journal recorded observations, difficulties during the various processes, questions about behaviors and responses, and speculations regarding changes in the subjects' use of mathematics. The field notes served as a reminder of particular events in the sessions that may, or may not, have been captured by video tape.

Peer Debriefing. To assure trustworthiness, peer debriefing took place on a weekly basis during the study. Peer debriefing was done with a music therapy faculty member at Michigan State University (MSU), who reviewed the personal journals, field notes, and video recordings. Afterwards, the tentative themes and interpretations were reviewed and discussed with other professors and music therapy graduate students at MSU. Music therapists at the WS music camp and an occupational therapist, who had experience working with WS populations in a music therapy camp for individuals with WS discussed recurring themes and possible interpretations.

Data Analysis

Data analysis began with transcription of the video recordings. These transcriptions were reviewed before the next session and any repetitive behaviors or patterns were given a code and added to a cumulative data set (see Appendix B for the final list of codes and themes). Each code had either its own font color or highlight color. Red highlights were used for mathematical difficulties, yellow highlights for distractibility, blue font for musical responses, and interesting moments without a corresponding code were highlighted in gray (see Appendix B). After all thirty sessions were transcribed, all uncoded items (gray highlighted items) were reviewed to aggregate any similarities and reinforce comparisons. A couple of new codes emerged from the review and the videos were reviewed again, and the new codes were applied.

Session progress charts (see Appendix G) were used to outline the main events of each session and provide changes across sessions in either developmental progress or regression during sessions. The mathematical mistakes made by each participant were gathered in a video format for each participant as well as compiled in written format (see Appendix J). This process was used to provide easy access to the mistakes and illuminate any themes and relationships in the foundational difficulties of the participants' individual mathematical development. The three compiled video files were reviewed multiple times by participant, intervention, and side-by-side by using two or three monitors to uncover the similarities and differences. Each code was cumulatively reviewed by searching for patterns, consistencies, and outliers for emergent themes and trends.

Trustworthiness

Thick descriptions, analytical memos, repeated analyses, auditing, peer debriefing, and triangulation using different types of data (video tape, worksheet, parents' interview, and personal journal) were employed to establish the trustworthiness of the data. Each research step was carefully and rigorously implemented as suggested by Smeijsters and Aasgaard (2005) and Stake (1995) with "standards of integrity for qualitative music therapy research" in mind as suggested by Bruscia (1998). Authors of qualitative research methods demand that qualitative researchers be fully dedicated to their study while conducting research. They must hold to rigorous standards, not merely for personal academic achievement, but also to maintain a self-motivated and intrinsic curiosity about the relationships among a phenomenon, the client, and the music. I was mindful of theses requirements during the research process.

CHAPTER IV

DESCRIPTION OF MATHEMATICAL INTERVENTIONS, SONGS, AND PROPS

In this chapter, the principal mathematical interventions, songs, and props that were used for this study are introduced. They are introduced before the case studies are described in order to more clearly understand the descriptions and purposes of interventions, songs, and props. The literature review identified key themes and theories in the cognitive development of WS as well as the principle difficulties involved with fine motor control and visuospatial difficulty. The interventions in this study were designed to capitalize on the musical ability of WS in a way that might help to compensate for their difficulties in understanding mathematical concepts. There are seminal interventions that were developed based on literature reviews of WS, music therapy theory, and prior experiences of individuals with WS, as well as others with cognitive challenges. Also included are adapted and modified interventions from seminal interventions. In addition, I developed new interventions that were necessary as new difficulties emerged. Interventions, new song compositions, and appropriate props to teach mathematical concepts were also imperative to this project. The descriptions of the songs and props, the way to design and develop them, and their purpose are included in this chapter.

Mathematical Interventions

According to the *Principles and Standards for School Mathematics* by the National Council of Teachers of Mathematics (NCTM), mathematics has five categories: numbers and operations, algebra, geometry, measurement, and data analysis/ probabilities (Clements, 2004). The area of number and operations is most directly related to tasks such as manipulating money and the most frequently discussed topic in mathematics. Three mathematical tasks in number and operations were selected for this project because of their relationship to everyday life and other difficulties as cited in the body of literature on WS. Tasks included an intervention focused on coin use, written addition, and reading an analog clock.

Coin Related Intervention

Coin usage is one of the most necessary mathematical skills in everyday life and was the starting point of this project. As illustrated in the prologue, many individuals with WS have difficulties manipulating coins. I performed informal testing related to the concept of coins with individuals with WS at the WS music camp and the WSA convention. In my test 1 quarter and 2 pennies were often identified by WS individuals as '3' without specifying the total amount. A couple of campers and attendees said '75' also without the unit i.e., coins or cents. I concluded their answer was probably was the memorization of the number sequence of 25's—25, 50, 75—based on quarters. Only about one-third of campers were able to correctly answer '27' cents.

In a task analysis of coin usage, several steps have been identified: coin discrimination, coin knowledge, coin calculation, coin combinations for commercial transactions, and value subtraction for receiving change. The first step in calculating monetary values and in manipulating coins is to understand the differences between coins. The next step is to discriminate the value of each coin. Then individuals are ready to process the amount and give and take reciprocally. All of these processes are necessary to be able to function in daily life; therefore, interventions related to coin usage began with coin discrimination, calculating the amount of values, and then practicing the exchanging of coins. None of the participants in this study was able to move on to calculating subtraction for receiving change.

Written Addition

Single digit addition is often considered the first *real* mathematical skill. Addition, subtraction, multiplication, and then division is typically the order of teaching operations in a general education setting. There are many anecdotal examples in the body of WS literature and documentaries of the inability of individuals with WS to add two single digit during observations in various settings. Since written addition is the most used form in the educational system, and the ability to perform mathematical tasks is tested by written addition, written addition was included in this project. There was a pre-test worksheet in order to determine the current mathematical skill level of each participant. The worksheet indicated that the participants had not yet developed a reliable understanding of addition. I developed a couple of individualized worksheets based on each participant's needs. Single digit addition was used as the starting point. Initially, the plan was for them to move on two digit addition, but this did not take place, because of the limited ability of the participants.

Clock Related Interventions

Reading an analog clock is also a basic life skill. Although digital clocks are readily available and can be used as an alternative, analog clocks are still considered important and included in elementary school curricula. Reading a clock is a comprehensive activity that requires accumulated knowledge and understanding and is a challenging task for any young child. Difficulties in telling time from an analog clock were reported in the literature on WS. There are a number of related concepts that form the foundation for understanding the use of time; the comparison of words such as the *big* and *little* hands, the directionality of their sweep around the clock, or *clockwise*, and the different values for hours and minutes. The concept of fractions is also involved in reading an analog clock. For example, half an hour, a quarter after 2, or 5 minutes to 10 are concepts that must be mastered in order to read a clock face. If any of these competences are not overcome, the task can not be successfully accomplished. Understanding comparison words such as *big* and *little,* visual perception difficulties, and problems understanding changing values based on units are common for in individuals with WS. Interventions using a clock were designed to help identify the degree and intensity of these difficulties in the participants and to help find a way to intervene.

Lexicon of Mathematical Terms and Concepts

Many mathematical terms will be used to describe the mathematical functions used by each participant. The detailed description and implication of each term will be discussed for each case study. The following table serves as a reference for further reading.

*Table 3. Lexicon of mathematical terms and concepts**

Math Terms and Concepts	Description
Cardinality	The number of elements in a set
Carrying	A digit that is moved from a given place value, or column, to another column of greater place value.
Commutative property of addition	The sum is not changed by the order of addends in addition
Complements of ten	If number X and Y are added and equals 10, then X is Y's complement of 10 and vice versa
Composing and decomposing number	The operation of combining and separating the numbers. For example, children recognize 6 (wholes) as the number 1 (part) and 5 (part), or 2 and 4, or 3 and 3.
Fact extensions	Calculations with larger numbers using knowledge of basic facts. Knowing 2 + 1 = 3 can be used to solve problems 20 + 10 = 30
Flexibility of starting	Counting not only from 1, but being able to start from any number
Identity property of zero	The sum of zero and any number is that number (2 + 0 = 2)
Magnitude	The ability to recognize which numbers, quantities, or amounts are larger than the other
Mental calculation	The mathematical operation done by the human brain without help from other tools
Mental number line	A number in the brain which is spatially represented, possibly with a left-right orientation, in a continuous analogical format like in a ruler
Subitizing	An action which refers to quickly glance at the small number of objects and to be able to make judgments of number.
"Teens" concept	Knowing fourteen to nineteen is same sequence as four to nine with the suffix "teen"

* This list is based on *Adding It Up: Helping Children Learn Mathematics* by Kilpatrick, Swafford, and Findell (2001), *Children's Mathematics* by Carpenter, Fennema, Franke, Levi, & Empson (1999), *Engaging young children in mathematics* by Clements and Sarama (2004), and *Glossary of Math Terms* by Benson (2003).

Songs and Props

Music functions in many capacities and influences various domains such as the psychological, emotional, cognitive, and physical. Using an appropriate intervention to each target area at the right moment is the key to success. Therapeutic interventions often include purposefully composed songs for children with cognitive impairment. However, not enough specific interventions for individuals with WS have been developed. Further, interventions to facilitate the mathematical development of individuals with WS are not available. Therefore, as a part of this study, songs and props were developed that focused on mathematics, and the responses of participants were carefully observed to improve the quality of further sessions. In the next section, the most frequently used songs and props for all three participants are explained. The particular songs and props for individual participants will be explained in each case study.

Songs

A series of songs were used with all three participants. These included "How Many Pennies in a Quarter?" "Nickel, Dime, and Quarter;" "Give Me a Quarter!" "Finding the Bigger Number;" "Nobody's Perfect," and "You Can Do It." Songs are from various sources; some are pre-composed songs by third parties, some were composed by the participants and the therapist, and others are motives from other songs. There were also a couple of songs and interventions spontaneously improvised either by the participants or the therapist. Sometimes, modifications of the improvised songs were necessary for later sessions. Songs used only for specific participants are listed in their individual case studies or in Appendix A.

How Many Pennies in a Quarter? The song, "How Many Pennies in a Quarter?" (Figure 9) was composed by Big Red and used to learn the value of each coin. The lyrics were prepared prior to the session and given to Big Red at his first session. Because of previous experience with Big Red, I knew of his improvisational ability and acknowledged it. I asked him to compose a song and to rhythmically chant the lyrics and add rhythms with his drum set. Based on his melodic line, I provided an accompaniment chord progression and transcribed the song as follows (see Figure 9).

How Many Pennies Are in a Quarter?

Big Red

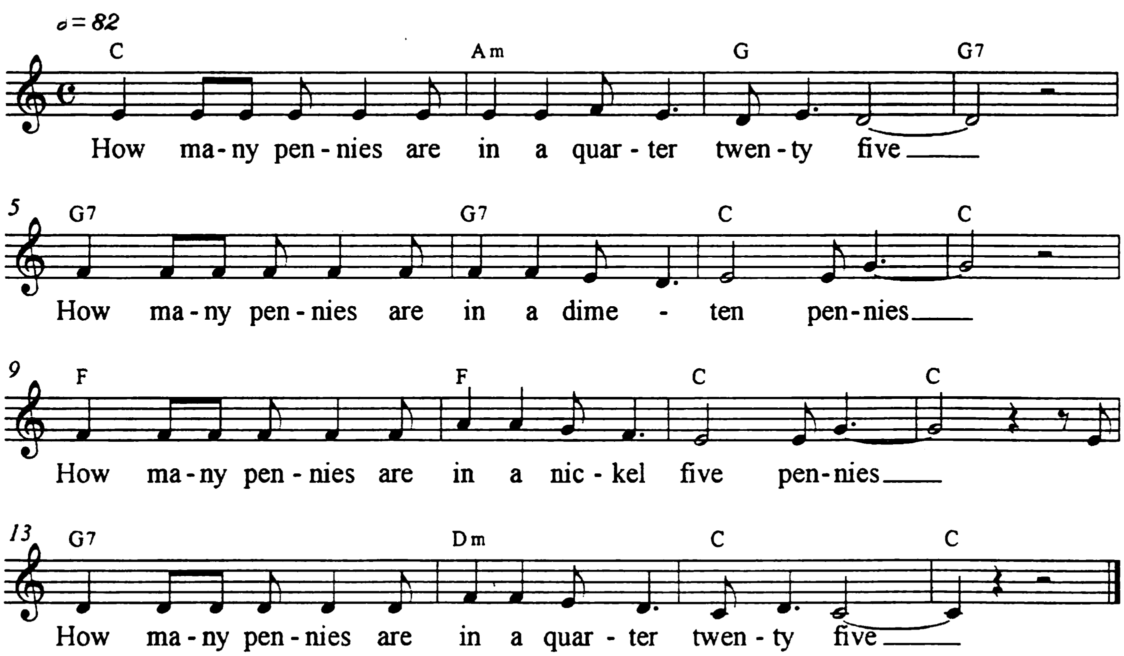


Figure 9. How Many Pennies in a Quarter?

While the song was interesting and catchy, I noticed that it did not serve as a mnemonic device. The structure of the song was useful for questioning and confirming acquired knowledge of coin concepts, but was not functional as a mnemonic device. There was no immediate connection between each coin and its value, and the melodic pattern used for each coin was too similar to the others and did not make distinct differences between the coins. In other words, any combination of the name of coin and value was possible; quarter – ten pennies, nickel –twenty five. While the song was pleasant and musically successful, it was not itself useful for the purpose of facilitating memorization.

Nickel, dime, and quarter. I composed the song, "Nickel, Dime, and Quarter" (see Figure 10) and used it to assist in making direct connections between the name of a coin and its value after, "How Many Pennies in a Quarter?" failed as a mnemonic device. I tied a rain stick to the dime to reinforce the mnemonic purpose of the song by providing additional auditory stimulation. The initial thought was to use a triangle for the nickel and a woodblock for the quarter. However, it became too difficult to switch between three instruments within a short period of time. Because it is concise and succinct with few distractions, this song serves as a mnemonic device, but is a less aesthetically pleasing piece of music than, "How Many Pennies in a Quarter?"

Nickel, Dime, and Quarter

Eunmi Emily Kwak

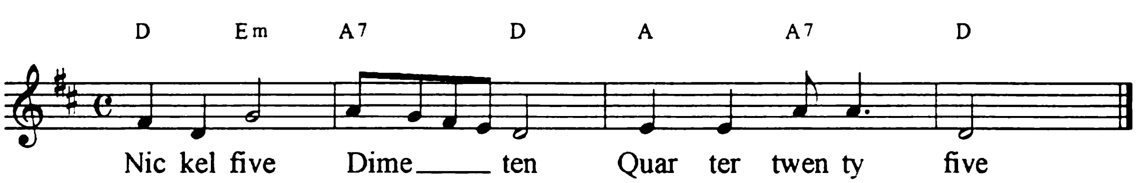


Figure 10. Nickel, Dime, and Quarter.

Give Me a Quarter! The song, "Give Me a Quarter!"[4] was based on the motive of "The Money Song" by Robert Lopez and Jeff Marx from the musical *Avenue Q* (Lopez & Marx, 2004). This song includes rest measures that provide time to process the meaning of each request and to accomplish each task. This song was designed and used to ask questions and prompt answers that would help with the discrimination of coins.

Finding the bigger number. The song "Finding the Bigger Number" (see Figure 11) was improvised with Big Red as a strategic song to help reinforce the process used to solve mathematical problems. It was a truly spontaneous song. While participants worked with the addition worksheet, their lack of understanding of the associative property became apparent. Accordingly, the concept of the associative property was explained and reinforced at the beginning of the tasks using single digit addition. Repetitive verbal instructions were used in an attempt to guide them, as has been suggested for individuals with WS (Semel & Rosner, 2003). The idea to improvise a song based on these verbal instructions came about while working through the worksheet with Big Red. He asked to make a song using the verbal instructions. Although he preferred to compose using duple meter, he was asked to try using triple meter instead. He created the following song.

[4] Due to a copyright issue, the modified score of "Give me a quarter" cannot be included in this dissertation.

Finding the Bigger Number

Big Red

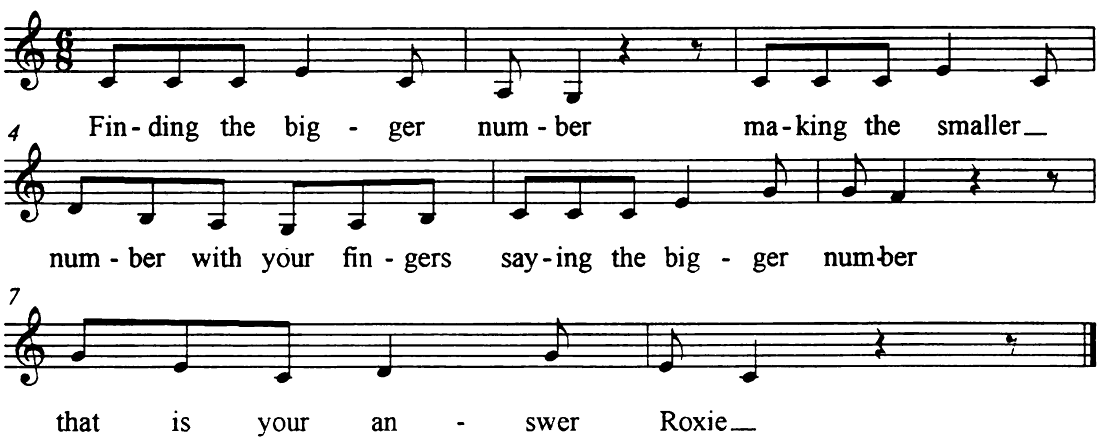


Figure 11. Finding the Bigger Number.

These lyrics indicate the steps that the participants needed to use in order to solve a problem, with rest sections to provide opportunities to answer, and time for the participants to work on each task. The participants were asked to circle the bigger numbers when this song was introduced to them. After a couple of questions, the participants showed that they could skip this process and complete the task without mistakes. When the song was sung by me or together with a participant, the participants pointed to or said the bigger number on their papers. The next part of the song is, "Make the smaller number with your fingers." The participants were asked to represent the smaller number with their fingers. They were taught to count upwards from the larger number. For example, the problem was 5 + 3. They began counting at 5 and speak each step: "six, seven, eight."

Nobody's perfect by Hanna Montana and You can do it. Because of their cognitive limitations, the participants already had difficulty with academic achievement, and they showed signs of disappointment and distress when faced with obstacles. They were expected to fail. While their individual characteristics influenced their attitude toward experiencing failure and the emotional responses of hopelessness, individuals with WS can also be expected to have some level of learned hopelessness. This was observed in differing degrees with each participant. Two main songs were used for emotional support. The first was "Nobody's Perfect" sung by Hanna Montana. Roxie and Angela both knew the song and were fans of the artist. The chorus section of the song is:

> Nobody's perfect…I gotta work it
> Again and again till I get it right
> Nobody's perfect…ya live and ya learn it
> And if I mess it up sometimes…hey
> Nobody's perfect
> (Gerrard & Nevil, 2006)

The lyrics focus on keeping a positive attitude and emphasize that effort alone can and should be respected. While the participants already knew the song, they seemed to have overlooked the meaning. The message of this song and its resonance for participants can be magnified and internalized by participants if the song is used in a suitable context. For this reason, participants were given the lyrics on a sheet of paper to help them classify the words. After the meaning of the song was discussed, when the participants made mistakes and showed obvious distress during activities and interventions, the song was played on the piano or a recording was played and the participants were encouraged to sing along.

"You Can Do It" (the composer is anonymous) was also used for emotional support. The lyrics emphasize effort, not results, and encourage one to continue to try and not focus on the product. The lyrics "if you try (4th and 8th measure)" were changed in various versions, such as "if you want" and "if you really work hard." These two songs were used to redirect the participants' focus from the actual accomplishment to the attempt itself.

You Can Do It!

Anonymus

Figure 12. You Can Do It.

Props

Props for use with each intervention were carefully designed to provide more tactile than visual information because individuals with WS are known to have difficulties with visuospatial perception. Even with training as a therapist, it is difficult to plan and use alternate strategies that do not incorporate visual information. Age-appropriateness was also considered, and childish illustrations and toy-like materials were avoided. There were props that were selected and designed before the study, and props that were designed during the study depending on participants' needs. The props that were developed because of individual needs had more immediacy and practical use than the ones that were developed without interactions and observations with the participants.

Coins. Real coins instead of imitations (toy coins or educational coins) were used in this project to assist in the generalization process as well as to increase age-appropriateness. Participants had their own jar in their homes, each containing approximately 40 quarters, 40 dimes, 40 nickels, and 50 pennies. The coins were sanitized prior to use and left with each participant in their home to provide them with greater opportunities to work with the coins during the week.

Coin hand props. The coin hand props were to help performance and reinforce the comprehension of different coin denominations and values. While I worked with Big Red using my hands and his hands to make the nickels and dimes distinct, the idea of using drawings of hands to explain the concepts of different coin values emerged. Coin hand props were prepared for later sessions. A nickel was represented through the illustration of a hand with five fingers to show the equivalent of 5 cents (see Figure 13).

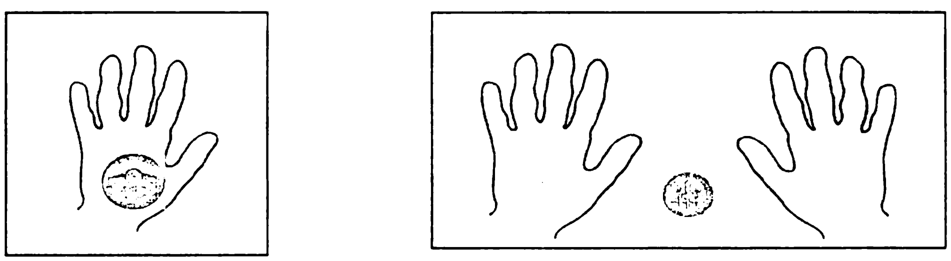


Figure 13. Nickel-hand-prop and Dime-hand-prop. *

*This is not an actual size. The actual size example is in Appendix I, Figure I-3 & I-4.

A dime was represented with two hands (see Figure 13), and a quarter was represented with five hands. There were two types of quarter-hand-props (see Figure 14) to put the pattern 1 and 2 together makes 50 cents presentation. For the later sessions, the actual coin was added to hand props as shown in the figures.

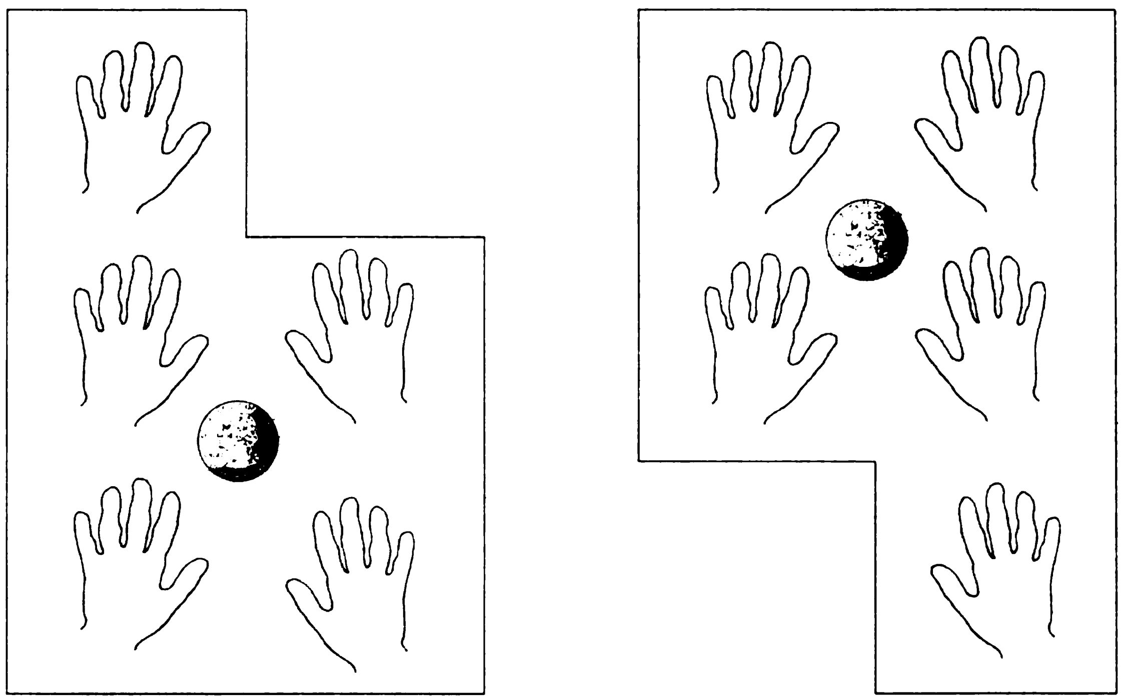


*Figure 14. Quarter-hand-prop Pattern 1 & 2.**

*This is not an actual size. The actual size example is in Appendix I, Figure I-5 & I-6.

American coins are based on multiples of 5, except pennies. Therefore, using a method to count by increments of 5 is a useful tool in making money and using mathematical functions. It also became a good tool for promoting the comprehension of using different units, such as hands or fingers, in place of actual nickels, dimes and pennies as a way to instill the abstract concept of value.

The coin-classification-chart. During sessions with participants, I observed that they did not have strategies for adding coins and do not know how to arrive at the designated amount. Participants attempted to calculate the aggregate values of various coins by adding lower value coins first, then the values of larger denominations. For example, when the participants had a quarter and a nickel, they began with 5 cents and attempted to add 25 cents instead of adding 5 cents to 25 cents. Participants had a limited ability to perform addition, but it was a far simpler process to add 5 to 25 by using the finger counting method. Unfortunately this was impossible to perform when 25 was added to 5; when the larger denomination is added to the smaller. Knowing the names and values of coins is not beneficial unless it also takes the form of functional knowledge. People with WS need a strategy or procedure to efficiently calculate the sum and value of an arbitrary selection of coins. Figure 15 shows the coin-classification-chart was utilized to facilitate their calculations. Participants were asked to place coins in order from largest to smallest and to add from left to right. Strategies for each coin were introduced. The value of a dollar was used to provide a consistent scale and the number of quarters used to reach 100 cents was memorized using songs developed for each denomination, i.e., 25, 50, 75, and 100.Participants were instructed to tap twice when saying the numbers in 5's for dimes (the first tap with 5, the second tap with 10); nickels were a tapping when saying the numbers in 5's'; and pennies were a tapping with saying the numbers in 1's.

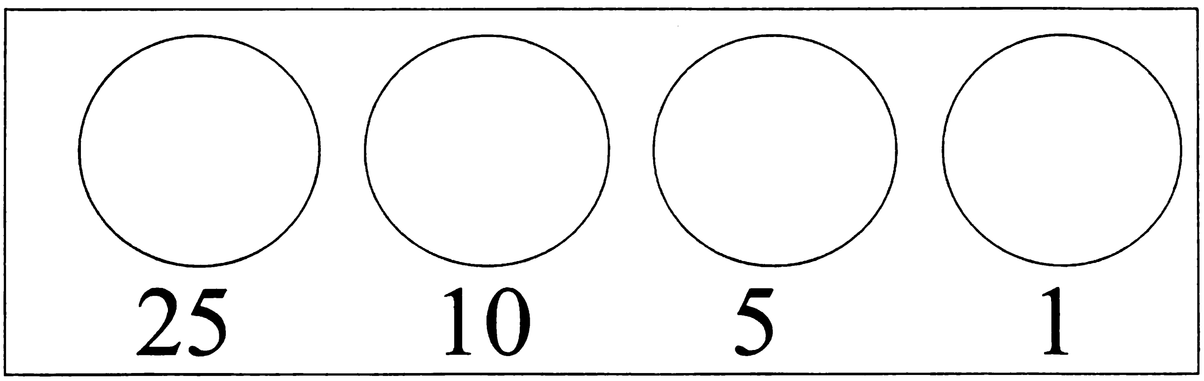


Figure 15. Coin-classification-chart. *

*The chart is not actual size. The actual size chart is in Appendix I, Figure I-2. The circle did not represent the size of coin but the placement for the quarters, dimes, nickels, and pennies.

Number flashcard. The article by O'Hearn and Landau (2007) regarding mathematical skills in individuals with WS was newly published while this study was in progress. The article indicates that individuals with WS appear to have difficulty with the magnitude of numbers. Number flashcards with diagrams (dots, stars, squares, or triangles etc.,) or objects (stamps, seals, or smiley faces etc.,), and with and without Arabic number were used to evaluate the participants' abilities to distinguish orders of magnitude. Commercially manufactured number flashcards were avoided because of their child-oriented illustrations. The range of numbers of objects used was from 1 to 10 and 20. A card with 20 dots was included to confirm their ability to differentiate 20 dots from other cards. The objects were organized in two line formations; the top line has 5 objects and the second line has from 1 to 5 objects.

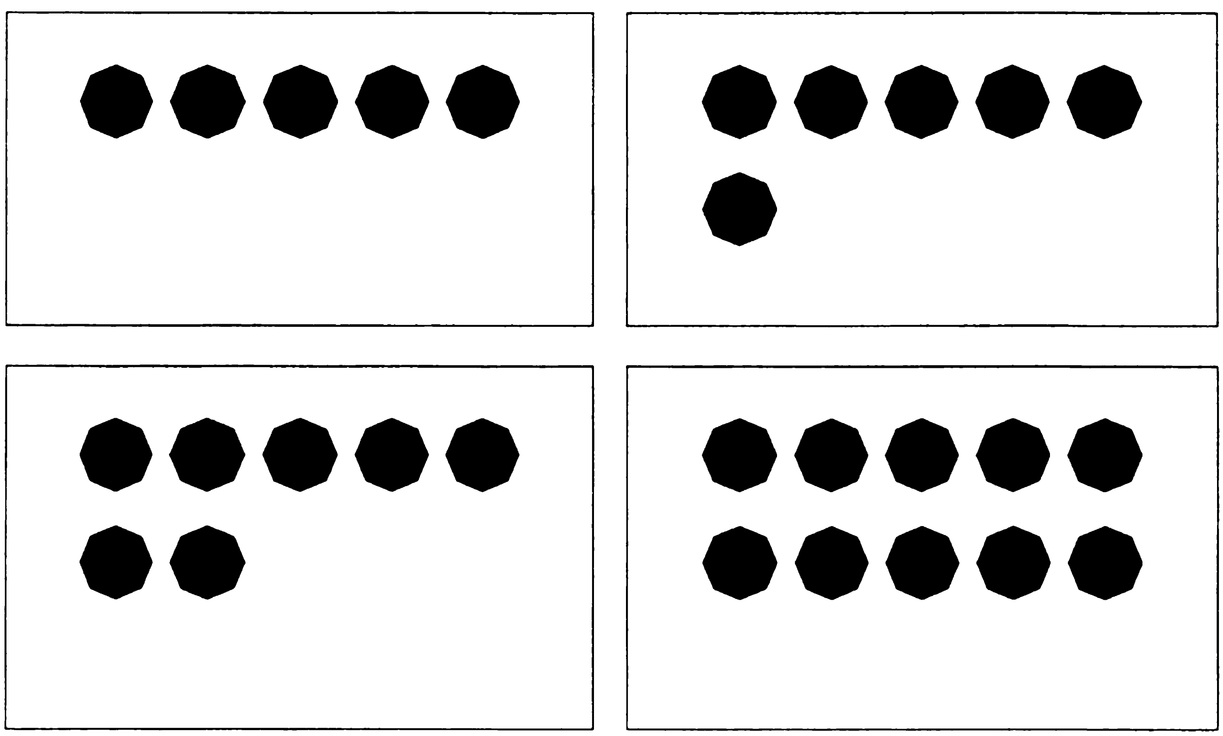


Figure 16. Example of number flashcard. *

* This is not the actual size of the cards. The actual size of these cards was a 4 by 6 inch index card.

Analog clock. An actual analog clock that included marked and numbered increments for minutes (i.e., 5 for 1 o'clock, 10 for 2 o'clock, 15 for 3 o'clock and so on; see Figure 17), was used in this project. An actual analog clock was chosen rather than an educational practice clock or toy clock, to provide age-appropriate materials as much as possible. The plastic cover over the face of the clock was removed in order to allow participants touch the big and little hands for additional tactile stimulation. The minute increment of this analog clock was based on units of five, echoing the function and value of a nickel. The relationship of clock increment and the use of a nickel could be naturally reinforcing and strengthen the concept of multiples of 5.

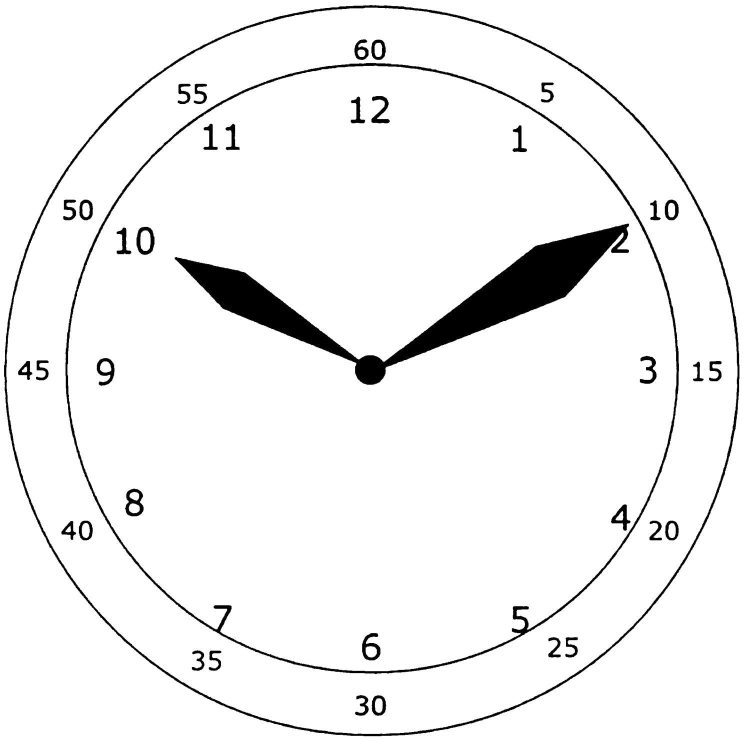


Figure 17. *Example of analog clock.*

Address numbers for address plaque. Brass address numbers typically used for number plaques for homes were used in addition to written numbers as part of the continuing effort to provide more kinesthetic and tactile stimulation.

Figure 18. *Example of address numbers.*

Summary

In this chapter, the principle interventions and the major foundational materials for the therapeutic interventions were introduced and explained. The songs and props were developed prior to, and in the course of the project. There were some unexpected responses to the songs and props. Detailed information about interventions, songs, and props were provided here in order to more clearly understand the case studies and to help music therapists and others to use them for other individuals with WS.

CHAPTER V

THREE CASE STUDIES

The three participants in this study told their stories to me over 10 weeks. I have attempted to convey their stories without my own analysis, but in some cases, it was not possible to solely narrate the *facts*. The rich information about themselves, their difficulties, frustrations, and enjoyment was astonishing. In this chapter, I will introduce them as separate cases so as to understand the participants as unique and authentic individuals. The participants' responses to mathematical exercises are rather difficult to understand with typical *logic*. Their way of thinking was different; they did not think and process the mathematical tasks the ways that most people do. Accordingly, the participants' exact wording and mistakes and the contexts in which these happened are illustrated in order to follow their patterns of thinking and thought processes. When I believe it may be difficult to understand the participant's rationale, answers will be provided in the analysis and interpretation sections.

Big Red Clown

> When Big Red was asked to select a pseudonym for this project, he proudly announced, "My name is Big Red Clown" without a moment's hesitation. Besides being a drummer, being a clown is his secondary passion. He was dignified when he handed me his business card with a picture himself in a clown costume.

Big Red Clown was 21 years old and has Williams Syndrome. He is involved in a local band whose members are typically developed individuals (TDI), individuals with WS, and individuals with special needs. I first met him at the 2006 Great Lakes Region of the American Music Therapy Association Conference. Big Red was a speaker for the presentation along with his music therapist. He started his portion of the presentation with an opening comment, "Williams Syndrome is the best thing that ever happened to me," and stated, "Music is my life." His speech was impressive, touching, and moving. He talked about his journey with music and how it helped him to overcome his difficulties. During that extraordinary and thought-provoking presentation, the 'dove' incident that I described earlier occurred. Big Red could not pay attention to his presentation and kept looking at the dove. The contrast between his outstanding speech and his difficulty in focusing his attention were marked.

Big Red is an outstanding musician. The day after his presentation at the conference, I noticed he was the drummer in a band that had performed music for the music therapy conference during breaks and lunch periods. When he played with his peers, he blended into the group; he was simply the drummer. However, knowing that he is diagnosed with WS changed my appreciation for his talent. There are a few WS musical celebrities, but I have never encountered them personally. This conference was my first time actually observing someone with WS who had fully developed his musical potential and played as a professional musician.

Big Red has several mantras that he often recites: "Music is my life," "Practice makes perfect," and "I need to focus." He has picked up many sayings and verbal mannerisms from various teachers, tutors, and other significant individuals, but there did not appear to be much application of these messages in his behavior. "Music is my life" was the statement that initially caught my attention, but after a while, it became bothersome to listen him say it over and over. The first time I spoke with him and heard repeat the phrase I was impressed, but the more I heard him say it the more irritated I became because of the inconsistency between his quotes and behavior. His inability to execute what he had memorized indicated that either he did not actually comprehend the meaning, or there were great difficulties in self-regulation and executive functions.

During my sessions with Big Red, my main focus was interaction with him, but, from time to time, I needed to take care of other things for the session, such as changing camera angles and preparing for next intervention. While I was transcribing his sessions, I noticed that he looked sad and dejected when I was not interacting with him. His facial expression radically altered according to the level of my attention to him. The more I evaluated and scrutinized the videos, the more I felt uneasy about his mood swings. Why did he not appear content when by himself? Were his smiles real or fake? He only looked happy when I interacted with him and gave him my full attention. While many people have a tendency to use a different persona depending on with whom they are interacting, the extremes Big Red demonstrated were atypical. The happiest moments were when we played or sang together. He seemed to be confident in what he was doing. He knew how to lead the musical experience and that made him happy as he could be.

Big Red was interested in my country of origin and he wanted to learn how to say some words in my language such as hi, good-bye, bravo, and funny. He memorized these words and used them often. Big Red is a born actor; he knows what actions go with which song and makes appropriate gestures and facial expressions for each song. He has a big Muppet for his clown job and made several different voice patterns for his it depending on the situation and fluidly used them for his act. He seemed happiest and most fulfilled when he performed for young children as a clown.

When he knew he had performed well, or *hit it,* as he called it, he laughed proudly and announced, "I am impressed with myself!" When he realized that someone was uncomfortable, it seemed as though he could physically feel it and he wanted to ease their pain. When he was stressed because of his inability to solve basic mathematical questions, such as finding the sum of coins or the number on a card, he became distraught. I often found myself asking, "*Does he have to know this concept*?", or, "*Is this a necessary skill*?" Big Red really made me doubt the necessity of mathematics in his life and to reconsider the importance of the role of mathematical interventions in his therapy setting.

Language

Talking with Big Red was an interesting experience. I had spoken with him outside this project at the music therapy conference, as well as in other WS conference settings and outings in the Michigan area, and at the 2007 WS Christmas party. I also interacted with him at music camps in which I was a music therapist and he participated as a camper, and as a counselor who worked as a helper for my music therapy sessions at the camp. My initial conversations with him were polite, elegant, and pleasant. He always greeted people with appropriate small talk or questions concerning the weather, or travel. In my case, since he knew I drove about an hour and half to get to his home and it was wintertime in Michigan, he was often concerned with whether or not I had eaten and what the driving conditions had been. He is a gentle man with good manners and cares about how others feel. He uses polite speech, such as "Can I ask…?", "Would you mind…?", and "May I…?" When we unexpectedly met at the National AMTA conference in Kansas City, Missouri, in 2006, he expressed joy to see me there and asked me why I was attending. There were no awkward moments during these initial conversations, but after these formal greetings, the conversation did not progress until we talked about music, his favorite band, the Beach Boys, or the album *Smile* by Brian Wilson who was the lead singer of the Beach Boys. Conversations then became awkward and choppy and he always began to look for someone with whom to start a new one.

Big Red sometimes articulated well how he perceived situations. I often wished for a pen and a paper to write down his delightful words. When I asked him to compose the song, "How Many Pennies in a Quarter?" I let him know that I would be using the song for other participants. To that he replied,

> "Sometimes it is hard for people to learn it a different way. Because they are so confused and they don't know. When they teach them the right way and they got it. So it helps me. I can sing the song everyday to learn (Big Red 1-27:08)."

Even without my explanation, he understood the benefit of using music for his mathematical skills and was able to express it in his own terms. Later in the same session, he said, "It really gives me the ability to work with math in easier ways (Big Red 1-33:32)."

Finger Dexterity

Big Red's fingers looked as if he had advanced arthritis; his joints were stiff and the bones were twisted. When he picked up small objects like coins and pencils from a flat surface, he was not well coordinated and it took him a long time to do so. When he held up fingers or curled them down, it did not look natural; it looked like it took a great amount of effort and appeared to create pain. The way he held up three fingers was similar to that of a one-year old who is trying to move a single finger for the first time. When I asked him to do complete tasks that required finger dexterity, I felt as though I was giving him a challenging task that caused him extreme discomfort. I wanted him to use his fingers to help with adding numbers, but difficulty in finger dexterity slowed down the process could not be used effectively. His limited understanding about numbers and operations required him to have a concrete object as a reference. Hands and fingers as concrete props would have been useful because he carried them everywhere. However, because of his difficulty with finger dexterity, his hands and fingers could not be used efficiently (Big Red 8-45:13).

Attention

Big Red had significant difficulties in maintaining attention. His attention span was short and his self-regulation ability was limited. He knew what he was supposed to do, but distractions, especially auditory distractions, quickly diverted his attention.

	(A phone is ringing and he tries to not look away)
Big Red:	We ignore the phone.

	(Emily does not hear the cell phone ringing during the session during the video clip analysis)
Big Red:	1, 2, 3, 4, 5, 6, 7, Oh! No! 8, 9, 10 That's my cell phone going off.

Big Red:	That's 5, right?
Emily:	No
Big Red:	Think before you answer. (A bird screeches in background; he looks away)
Big Red:	Oh! My!!!

	(A bird is singing and a phone is ringing, and he looks away)
Big Red:	Uh-Oh! ...(calls out to father) Who is that?

Big Red:	6, (A bird screeches and he looks away) It's 7.
Emily:	Yeah! Focus
Big Red:	It's 7.

Big Red had a pet bird with an open-door cage. When the bird flew around and made noise, he looked at her. He also had a big grandfather clock that chimed on the quarter hour that he looked at each time it chimed. When his father came back from work, Big Red needed to greet him immediately, and this also distracted him from tasks. He could sometimes hear things I did not and that also distracted him. Some of these auditory distractions included: Each time he looked away from the task, he tended to lose his train of thought. He often had to restart tasks. Even if he could keep working on the task after the distraction occurred, he usually did not get the correct answer.

Music, as an auditory stimulation, was also a distraction for him. I could use songs to ask him questions, but while he worked on the task, I needed to sit still and be quiet. At the beginning of this project, instead of providing complete silence, I provided a short musical phrase. However, while music played, he could not focus on tasks. Instead, he would start harmonizing with the song, finish the musical phrase, or tap his knee and then losing track of what he was doing. Several times during these events, he would cover his ears and say, "I have to concentrate." It was difficult for me to sit and wait for him to complete his tasks because, as a therapist I had a tendency to want to help, and doing nothing seemed to be waste of session time. However, it quickly became clear that he needed to have absolute silence to work.

All sessions were recorded using a digital video camera. Each time it was set up, Big Red wanted, and needed, to greet the camera. In most cases, distraction caused by a camera wears off after 3 or 4 sessions. However, Big Red needed to be reminded to ignore the camera every session. During the second half of the project, he incorporated a comment that reminded him to disregard the camera, but he continued to greet the camera through the final session.

Big Red was interested in many personal things about me such as marriage status, family, age etc. "How old are you?" "Are you married?" "What did you eat for lunch?" (Big Red 3-41:24) These unrelated questions were randomly asked while he worked on his task. Later on during the project I asked him if his questions were related to the task. He typically answered, "No, it is not related." Then I observed that he asked unrelated questions and instructed himself saying, "Do not ask a girl's age. That is not appropriate," "Do not ask personal things" (Big Red 2-43:18).

Big Red:	22 dollars (sings the song, *Don't forget the change.* Right after he finishes song)
Big Red:	How do you say bravo in Korean, when someone…?
Emily:	I cannot think about Bravo, Bravo, Bravo.
Big Red:	How do you say good?
Emily:	좋았어.
Big Red:	That's was so 좋았어. Yeah!!!

(Big Red 8-40:16)

Big Red often said "focus" with the hand gesture of touching both sides of his temples with his hands, but he was only able to focus for a few seconds (Big Red 3-6:00). His sayings, body gestures, and behaviors suggested that he was aware of his difficulty. He had been redirected many times by other authority figures. However, he did not develop self-regulation skills and had limited ability to redirect himself to focus on a task.

Mathematics Exercise

Big Red was clearly aware of his inability in mathematics. He had a math tutor prior to this project. His mother decided it would be better to have one person assist him in mathematics than two people working on the same subject but in different ways. Big Red had many roadblocks that prevented him from improving his mathematical skills. I needed to readjust his interventions every session because he did not understand the prerequisite concepts required to solve the math problems.

Coin discrimination. My first session with Big Red began with identifying different coins using the song, "Give Me a Quarter!" He did not have problem with pennies, but the other three coins were too complicated for him. While he could discriminate between the four different coins in his hand, he had a difficult time finding different coins when they were disorganized in a pile. When he was asked to find each coin, he often said "nickel normal," "quarter big," and "dime tiny (Big Red 2-11:15, 3-14:10)." However, this appeared to not help him find each designated coin because he lacked the understanding of the meanings of *normal, big, and tiny*. Occasionally he asked, "A nickel … is a nickel smaller or bigger?," this suggests that he had not completely understood the connections between the names and sizes of coins. Rather, he had worked on this task previously and somebody had explained how to find different coins using a different method than I wanted. This also indicated that his strategy to find different coins was to use verbal instructions to guide him.

Big Red could not process information fast enough to keep up with the tempo of the song "Quarter, Dime, Nickel, Penny". In addition, his fine motor skills were not fluent and hindered his performance, causing him to take a long time retrieving a coin from the table. I sang the type of coin in two musical beats and gave him six beats to work, which helped him to find the coins. However, when he only had two beats to complete the task, he became agitated and anxiously rubbed his hands together or nervously shook his two hands in front of his chest like some individuals with autism.

He said, "Nickel normal; dime, tiny; quarter bigger" to guide him to find the designated coin. However, because he often confused the size of the coins, the mnemonic song, "Normal, Tiny, Big" was composed to help his performance. The simple rhythmic pattern helped him distinguish different coins and was introduced based on his own understanding that a nickel is the normal size, a dime is a tiny, and a quarter is big (see Figure 19).

Normal, Tiny, Big

Eunmi Emily Kwak

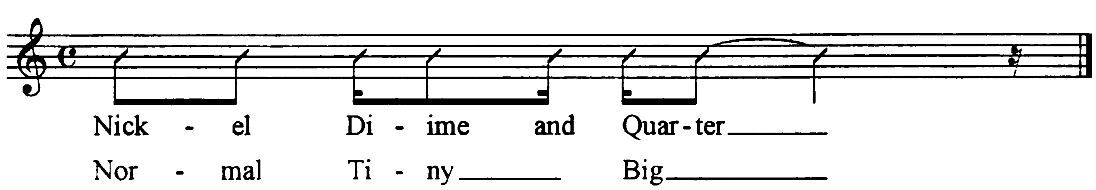


Figure 19. Normal, Tiny, Big.

Although he had no difficulty singing the mnemonic song, he did not appear to comprehend the meaning of sizes such as normal, tiny, and bigger, because he had difficulty understanding comparison vocabularies. He also used my facial expressions to confirm that he had given the correct answer (Big Red 2-11:00). If he felt agitated or that the pace of the question and answer was too fast, he randomly picked the coins. Occasionally, he did not even look at the coins, but fixated his eyes on me and picked up the coins. He tried hard to answer correctly without knowing what else he could do and kept asking, "How am I doing so far?" His performance in discriminating different coins was inconsistent.

Coin calculation. The concept of different values for each coin was introduced in introduced in the second session. Big Red was confused by different coin values and kept asking about it. "Dime is worth 5 cents? Dime is worth 25 cents? 10?" His questions demonstrated that he knew that there are three values for the three different coins, but that he could not make a clear connection between the name and the value of the coins. I provided the lyrics for "How Many Pennies in a Quarter?" and Big Red composed the song. The song itself was delightful and enjoyable, but it failed to help him understand the concepts (the details of this song were discussed in the songs and props section. p. 74). After the song "Nickel, Dime, and Quarter" was introduced, instead of asking questions about the value, he started singing the song and made a better connection between the coins and their values. At the end of the third session, he was able to recite that "a nickel is 5, a dime is 10, and a quarter is 25" However, I continued to doubt that he truly comprehended the distinction. The lyrics for the song "Five Pennies Make a Nickel" were provided and the song was composed by Big Red to help him understand the concept. I used a visual prop to go along with the lyrics in order to help reinforce the concept as illustrated in Figure 20.

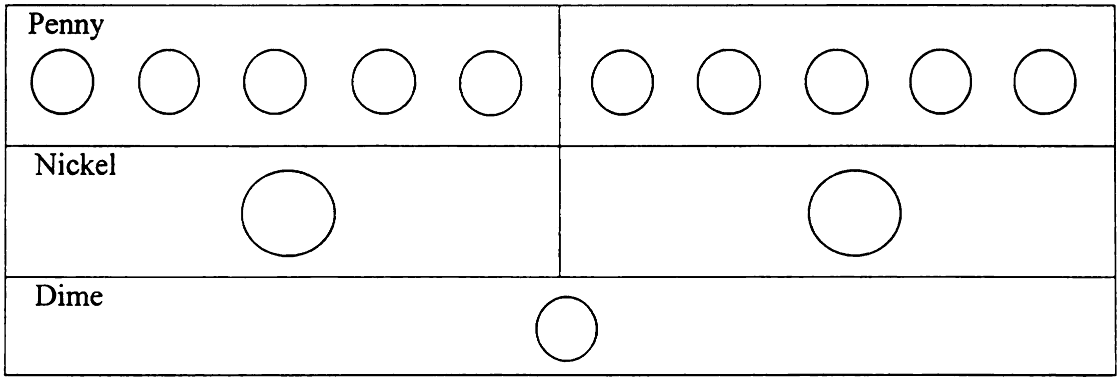


Figure 20. Visual prop for five pennies make a nickel.

*This is not an actual size of the prop. The circle in the actual prop is the actual size of the coins and the participants can place different coins in each spot.

Big Red and I made errors by changing the names of coins in the song "Five Pennies Make a Nickel." For example, instead of singing "two dimes and a nickel make a quarter every time," he sang "two dimes and a quarter make a quarter every time," or instead of dimes, we used nickels or quarters or whatever unit came to mind. On paper, it was a clear and easy concept to grasp, but when we sang the song, he needed to think about the name and value of the coins with rapidity. "How Many Pennies in a Quarter?" was not effective for learning because the melodic lines of the various phrases were too similar to each other, making the lines interchangeable. The song could not promote the comprehension of coin combinations unless a solid understanding of the value or sum of each coin was already in place. Therefore, the song failed to serve its primary purpose.

Five Pennies Make a Nickel

Big Red

Figure 21. Five Pennies Make a Nickel.

Beginning with the second session, the relationship between the value of coins and the numbers of fingers on hands was established to connect the idea that a nickel is a hand, and a dime is two hands (10 fingers). He could add two sets of five fingers as 10 fingers when using actual fingers. He could add up to “four hands” to 20 fingers by counting by 5 (i.e., 5, 10, 15, and 20). However, immediately after he finished this addition using four hands, I changed the method by asking the same question in a slightly different format (from my point of view); then he completely lost track of his process.

Emily: You have ten fingers and my ten makes
Big Red: 5, 15
Emily: No, No. Think about it your hands have 10 fingers. My fingers are 10. All together?
Big Red: 10, 15, 20, 25 (counts my first hand as a 10)

He appeared to be able to recite numbers in five's, but, since I used 10 to describe the10 fingers of a person, he thought that he needed to start from 10, which led him to the wrong answer. In addition, while we worked on the dime hand-props and nickel hand-props, he demonstrated that he could not add up the dime hand-props for 10 plus 10. This indicated that he did not comprehend the operation and solution of 10 + 10 = 20.

Emily: (shows a dime-hand-prop)
Big Red: 10, right?
Emily: (nods her head "yes" and shows the second dime-hand-prop)
Big Red: 25 (examines Emily's facial expression)
Emily: (shows non-approval expression)
Big Red: 10, 20. There we go.
Emily: (shows the third dime-hand-prop)
Big Red: 25 (examines Emily's facial expression)
Emily: (shows non-approval expression)
Big Red: 30, there we go.
Emily: (put down a dime-hand-prop and a nickel hand prop)
Big Red: 10. Just 10 (points to a dime-hand-prop).
Emily: Ah-ha, this is 10. (points a nickel-hand-prop) and this
Big Red: 25

Between hands and fingers, he had a hard time understanding that, depending on the unit, the answer needed to be changed. One hand has five fingers is the same concept as a nickel is five cents. When given four nickels and asked to figure out the sum, he made similar mistakes: instead of 5, 10, 15, 20, he counted 1, 2, 3, 4 and answered "4" without specifying the unit i.e., 4 hands or 4 fingers. For Big Red, changing the value to a different unit was an abstract concept. His difficulties in converting between the units could be understood in light of the fact that typically developed individuals have difficulties when converting from inches to centimeters or from pounds to kilograms.

The reason he kept saying 25 was unclear, but indicated that he did not comprehend the pattern of using increments of 10. In order to show him the differences between a dime and a nickel, a dime hand-prop was placed on the table as a constant, and the other props were switched back and forth between a dime hand-prop and a nickel hand-prop. In other words, if I held up the dime hand-prop, he needed to add 10 and the answer would be 20, and if I held up the nickel hand-prop, he needed to add 5 and the answer would be 15. We practiced together. However, while he could sing "Nickel, Dime, and Quarter," he could not figure out whether the dime hand-prop or the nickel hand-prop was 5 or 10. The best example of his confusion was when I presented three dime hand-props. He declared the first line of the dime hand-prop as 5, the second line as 10, 15, and the third line as 30 (see Figure 22; Big Red 3-48:57, 3-49:51, 3-51:07).

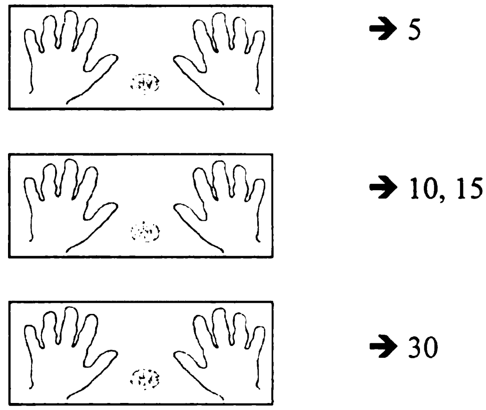


Figure 22. Three dime-hand-props and Big Red's answers.

The majority of TDI understand that 5 plus 5 equals 10, therefore, a nickel (5) and a nickel (5) equals a dime (10). This is not an abstract concept. TDI are able to transfer the understanding of '5 + 5=10' to 'a nickel + a nickel = a dime'. Big Red's facial expression suggested that this was an abstract concept that he did not comprehend. This was difficult to explain, because the concept was so fundamental. It was difficult for me to think of other ways to introduce the connection or explain it. While it could have been my language limitations or my different cultural background, even when my limitations are considered, his capacity for understanding a basic mathematical skill seemed to be limited.

During the fourth session, a quarter-hand-prop was introduced and he was asked to figure out how many hands and how many fingers were there. Instead of counting all the fingers together, he counted the fingers on the prop as1, 2, 3, 4, 5; and started from 1 again for each hand. Since we worked on dime and nickel-hand-prop in the previous session, I expected him to count by 5 and come up with 25. However, when I asked him how many fingers in the prop, he kept saying "5" and he counted the fingers on one hand. When I covered up the other 3 hands and showed him 2 hands like a dime hand-prop, he was able to say 10 fingers. The slight change from showing only one hand (a nickel) or two hands (a dime) to five hands (a quarter) confused him, and he was unable to identify the similarities between the three different props. During the first attempt, I tried to teach him a quarter hand-prop with 10 for the first line, 20 for the second line, and 25 for the third line. After he practiced, when he was asked to count fingers in a quarter hand-prop, he counted 10, 20, 30, 35, 40, as shown in Figure 23. Immediately after his mistake, and without correcting it, I asked him to do it again as seen in Figure 24.

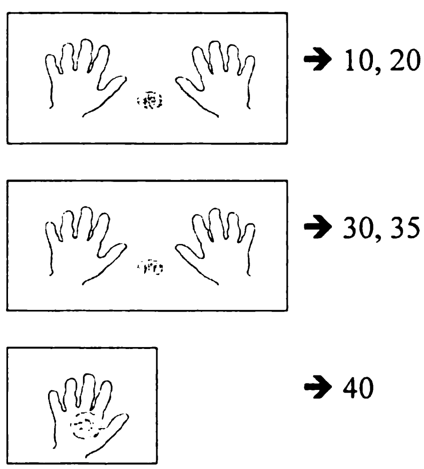


Figure 23. Two dime-hand-props and one nickel-hand-prop, and Big Red's answers.

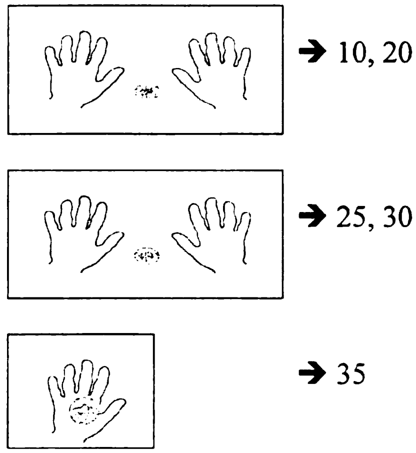


Figure 24. Two dime-hand-props and one nickel-hand-prop, and Big Red's answers.

During the session with the combinations of nickel, dime, and quarter hand-props, it was clear that Big Red did not understand the relationship between 1 hand and 5 fingers. Because of his inability to understand this concept, as well as his confusion with different coins, he was not able to keep working on coin calculation.

Written addition. Big Red was able to do some single digit addition. The following worksheet (Figure 25) is an example of how he performed on an addition worksheet without help. He picked the equations he knew he could handle. He appeared to memorize the answers for the questions with two same number addition problems, such as "5 + 5" or "2 + 2." The interesting thing was his response to questions # 7 and # 9. While he scanned these questions, he skipped # 7, but worked on # 9 and correctly answered it. This incident indicates lack of understanding of an associative strategy to switch the order of the variables.

He correctly answered "3 + 6." The process by which he arrived at his first answer was pointing to imaginary dots on the paper. This was not successful. The second attempt was by holding up 3 fingers with one hand, and making 6 with the other hand by putting his thumb up (his way of indicating 6), and air-fingering for 6 and counting 3 fingers by speaking "7, 8, and 9," He reached the correct answer, but when he counted 3 fingers on his hand, then pointed to his ring finger once, pointed to his index finger twice, and skipped the middle finger. It was difficult to decide whether it was a simple mistake or because of the camera angle that it looked like he pointed at the same finger twice and missed another.

The song "Finding the Bigger Number" was composed by Big Red to help with the associative strategy used for written addition problems. He had a difficult time holding up the correct number of fingers, especially with 6, 7, 8, and 9, because of his lack of understanding of composing and decomposing—the concepts of "parts" and "wholes" that is 6 as 5 + 1, 4 + 2, and 3 + 3—and his fine motor skills difficulty. When those digits appeared in the questions, he often asked, "How do I do that?" or randomly held up fingers and waited for me to confirm whether the answer was correct. While we worked on this task, it became clear that he needed to master the skill of holding up designated fingers before he could master it.

BIG RED !!!!!!!!!!!!!!

1. 9 + 2 = 11

2. 5 + 5 = 10

3. 8 + 2 = 10

4. 3 + 2 = 5

5. 6 + 5 =

6. 2 + 2 = 4

7. 2 + 7 =

8. 3 + 9 =

9. 7 + 2 = 9

10. 3 + 6 = 9

Figure 25. Big Red's worksheet. *

* Hand written

Magnitude. While contemplating Big Red's inability to perform calculations, it became clear that he was missing a much deeper foundational mathematical concept. A clue was provided in the *Development Guidelines for Number and Operations* by Clement and his colleagues (see Appendix H) and the newly published article about WS's mathematical abilities (O'Hearn & Landau, 2007); difficulties in magnitude and cardinality. Magnitude refers the understanding that if there are more than two sets of objects, which set has more objects. Cardinality means understanding that the Arabic number represents a certain number of objects (Nickson, 2004; O'Hearn & Landau, 2007).

Big Red's ability to subitize—to glance at the object and label it with a number—was tested and practiced with a set of flashcards numbered from 1 to 10 objects and 20 objects (see Props, Number flashcard. p. 86.) He easily mastered the cards up to 5 objects, and the card with 20 objects. However, he was not able to find cards with 6, 7, 8, 9, and 10 objects. The cards with 5, 6, 7, 8, 9, and 10 objects were randomly placed in front of him and then the placement was not changed for each card. For the cards with 5, 6, 7, 8, 9, and 10 objects, Big Red was instructed to count from 5 and then by using an increment of 1 instead of counting from 1. Each card was counted together to help him to learn the flexibility of starting from any number. The objects on the cards were organized in 2 lines as shown in Figure 16 The first line always has 5 objects so it could be processed as one unit that has five objects. Therefore, the first line did not need to be counted one by one. This fact was explained every time he counted the first line during our practice.

After we counted the cards together, and practiced finding the cards without changing the placement for about 25 minutes, he was still not able to find the cards with 6, 7, 8, 9, and 10 objects. He kept trying to count from 1; he could not start from 5. In his logic, it did not make sense, as numbers have to start from 1. In addition, he often counted the same objects twice or skipped an object. When it happened the first or second time, I overlooked it. However, after the project had been completed, and after repeated viewings of his video clips, those incidents appeared to not be a *simple mistake*. It raised doubt that he would ever develop the concept of one-to-one correlation with an increment of 1. He frantically moved his hand over the cards one after the other. He looked so desperate. He gazed back and forth between the cards and me with a "silent scream for help." He could not find the designated number of object cards. Out of 6 different cards (from 5 objects to 10 objects) with the same placements and 25 minutes of practice on the same task, he was not able to find the designated card.

Address numbers for address plaque. Brass address numbers typically used on houses were used for some exercises. While the design of the font represented the numbers well, Big Red wanted to know, "Why this is cut off here (points number 8 in Figure 26)?" His other concern was between number 1 and 7; while the difference between 1 and 7 is obvious, when they are presented separately, The numbers1 and 7 have similar shapes except the longer front line for 7. Big Red was confused by those two and made same mistakes several times.

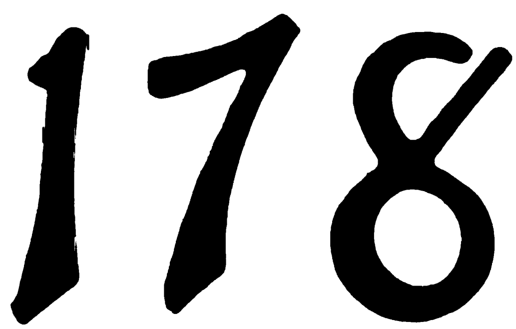


Figure 26. Address numbers.

Clock. Big Red had a difficult time distinguishing between the big and little hands of the clock. However, he understood clockwise direction, and could correctly apply the concept when reading an analog clock. To make it easier for him to identify the big and little hand, I asked him to put his left index and middle fingers at the end of the little (hour) hand. The instructions for the reading the clock were used with much the same wording, the same tactile cues, and the following sequence with a tactile cue as illustrated in figure 27:

i. Find the big hand
ii. Clock goes this way
iii. It passes ___ but does not pass ____.
iv. _______ o'clock.
v. OK, Find the little hand
vi. Clock goes which way?
vii. sing *5 number song* and _________ minutes
viii. use the number

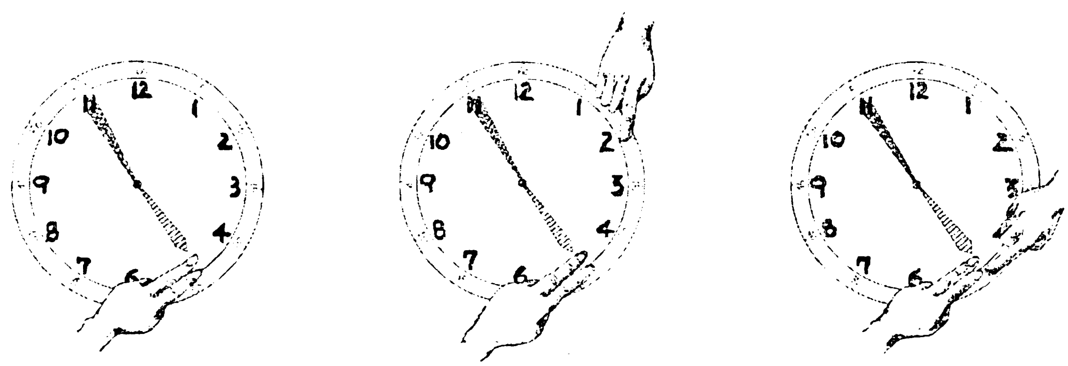


Figure 27. Clock with tactile cues.

Illustration by Hyung Eun Lee

Big Red could follow these step-by-step instructions and read a clock with my guidance. However, he was not able to perform the process by himself. Even with the tactile cues of the big and little hands, he often asked me to confirm his answer. To use either of the increments of 1 or 5 depends on context—the big or the little hand—and this confused him. When the minute hand pointed to the 11 (55 minutes), the hour hand seemed to be closer to the next hour than the actual hour. The visual and spatial information offered by an analog clock was too complicated and confused Big Red.

Reading such a clock requires a number of small steps that themselves require different strategies. After all our sessions, I came to the unfortunate conclusion that reading an analog clock was not learnable at this point in his level of function.

Music

Big Red is an accomplished musician. He is a drummer who can play many different rhythmic patterns on the drum and perfectly support either a single musician or an ensemble with his meticulous playing. He also learned how to play piano with another music therapist. He plays with both hands, the right hand for the melody line and the left for the accompaniment. His accompaniment pattern is two notes chords, typically the bass and 5th note of each chord instead of a complete triad. He effortlessly played and seemed to easily *find* the two notes that went along with the melody line instead of playing by reading chord symbols or other instructions. When he did not 'like' the 'sounds,' he tried different combinations of notes with the melody line and decided what he liked most. He appeared to learn the music by ear, not by reading the notation. He could also play the djembe (African hand drum), as well as sing and dance.

Big Red improvises well. The first time I asked him to create a song based on some lyrics, he started to rhythmically chant, picked the rhythmic pattern, added a little melody, and started singing, creating the song, "How Many Pennies in a Quarter?" While giving presentations at the national AMTA conference and workshops, Big Red's video clips of improvising the song "How Many Pennies in a Quarter?," which depicts the process of his improvising a song based on the lyrics, impressed audiences with his ability. A music therapy student approached me after one of the presentations and said that she was not sure she could keep up with his musical talent. His musical ability made me feel the same way. He made me doubt my capacity to fully support his musical potential.

Whenever I asked him to make a new song out of lyrics, he usually had no difficulty. He simply read through the words a couple of times, picked a rhythmic pattern, and began tapping, drumming, or singing. He preferred to improvise with his drum set. One exception was during the Christmas season when we sang several Christmas songs before the session began. He kept singing the lyrics with different Christmas tunes. I asked him to compose a song in 3/4. When I pointed out that he sang it with a Christmas tune, he started with a new melody, but he kept going back to the Christmas tune. At that particular moment, Big Red's pet bird was especially noisy, and he seemed to be agitated by the bird. He touched and rubbed his forehead, which is his sign of distress, told himself "focus," and regained his composure. After he reorganized his thinking, he was finally able to improvise "Finding the Bigger Number."

His songs are catchy, repetitive, and easy to follow (see Figures 9 and 11). The melody lines reflect the characteristics of the words such as intonation and long and short vowels. Big Red continues to have drum lessons and other music-related tutoring sessions. However, although he has not had formal composition lessons, he seems to compose intuitively. He created five major songs during our 10 sessions along with other short musical phrases. When I asked him to make a different drumming pattern to describe the words *normal, tiny,* and *bigger*, the rhythmic patterns sounded the same. I kept asking him make it different, but it appeared he could not. However, when I brought the video home and listened again, there was subtle difference, that I had not detected earlier.

Another song he composed was "Five Pennies Make a Nickel" (see Figure 21). Almost immediately after I gave him lyrics and asked him to rhythmically chant them, he said that he wanted to use a Calypso rhythmic pattern, and the song was coming out of his mouth. Then he added a drum beat accompaniment, as if he knew the song from the bottom of his heart, and just needed an opportunity to sing it. While he improvised and composed a stunning song with the lyrics, Big Red and I kept changing the quantities and names of coins.

Before this study, I myself did not know which coin was labeled as a nickel, dime, or quarter. I did grasp that the big one was the quarter, but the others I knew as 5 cents and 10 cents. I am from another country, and my own second language difficulty was my own obstacle. Not knowing the names of coins did not bother me living in an American culture until this study. When I first wrote the lyrics, I had time to think about them: "OK, a nickel is 5 cents and a penny is 1 cent; therefore, 5 pennies makes a nickel"; 2 nickels are 10 cents and 10 cents equals a dime... etc. However, when I needed to sing along with Big Red, I did not have time to consider the value of, the name of, and the sum of the coins. The lyrics were too complicated and the tempo of the song was too fast. We both made mistakes with nickel, dime, and quarter, and his mother could not stop laughing at us. The song failed as a mnemonic device, because I had inserted too many concepts into the song.

If the provided lyrics did not fit into a standard measure format, Big Red spontaneously added a line or two lines to make lyrics into an 8 or 12 measure format..

The original lyrics I prepared for "How Many Pennies in a Quarter?" were:

> How many pennies in a quarter? 25
> How many pennies in a dime? 10
> How many pennies in a nickel? 5

However, he added pennies after 10, and 5 to fit the melodic contour, and added one more line "how many pennies in a quarter? 25" to make a song with 8 measure format as followed:

> How many pennies in a quarter? 25
> How many pennies in a dime? 10 pennies
> How many pennies in a nickel? 5 pennies
> How many pennies in a quarter? 25

Another similar incident happened later in the project during session 7 when we worked on composing a song for addition. The initial lyrics were:

> Finding the bigger number
> Making the smaller number with your fingers
> Saying the bigger number

This strategic song was composed to remind him of the process of addition and the steps necessary to complete the task. When he started to improvise this song, he added "putting it all together" as a forth line to finish up the song.

A third case was with "Five Pennies Make a Nickel." Big Red added two measures, "Five pennies make a nickel, Make a dollar every time" to make a song with 12 measures. The second part of the added lyric was not logically correct, but melodically it matched perfectly with the song. Sometimes I did not notice his additions until I reviewed the video, because they were so smoothly blended into the song. He did not stop improvising or hesitate. I was astonished to observe him create music so naturally and effortlessly.

During music camp, about a year before I began the study, I improvised songs based on themes from the musical *Beauty and the Beast*. Big Red appeared from nowhere and began playing the drums, and we played together for about 30 minutes. That was the first time I noticed his ability to improvise and I really enjoyed that time with him. While we communicated musically, he seemed to be so gratified and contentment radiated in the air. Looking back at the sessions, when Big Red is *musicing*[5], he knows he is good and needs no additional encouragement or external esteem boosters. He is neither arrogant nor conceited but accepts his ability as a given. He could lead our music experiences, articulate what he wanted musically, and clearly express his musical preference for that moment. We were two individuals drawn to the music who shared our joy together. When he composed or improvised the songs, he did so effortlessly, unlike his difficulty on mathematical tasks. It was like he had a jukebox in his head, and as soon as I pushed the button, music came out of his brain. The more I worked with him, the more musical moments we shared that were precious and treasured. We were no longer defined as a therapist and client, but as two people who wanted to share our musical passion and could understand each other without words.

The project ended just before Christmas. After we sang several Christmas songs, I sang for him "We Wish You a Merry Christmas." When I finished, he started singing:

---

[5] The term used by D. J. Elliot (1995) means 'music making.'

I am gonna miss you this year.
I hope see you next year
So we all have fun again.
See you in 2008.

The wording matched with the melodic contour of the song perfectly, and the content of the song was appropriate for that session. The song was a nice conclusion to our 10 week journey (Big Red 10-50:53).

Emotional Rollercoaster

How am I doing so far?
Is that working?
Is that right?
This is the one, right?
15. right?
How do you like it?

Big Red knew that he had limitations and difficulties and when not musicing he was concerned about his non-music performance. He often asked the questions above. When he knew that he had done a good job, he commented on his performance as follows:

So, why do I have good memory?
Why am I learning so fast?
We make good progress today. Wow!!!

During the fourth session, he asked me, "How am I doing so far?" Previously, when he had asked similar questions, he was reminded to think about his performance and answer himself rather than asking the same questions. Immediately after he asked me about his performance, he stated, "You (Emily) don't have to answer that question. Because I (Big Red) know I'm doing good." When he did a good job, he was proud of himself. He laughed as though he could not believe that he had gotten the correct answer. When he made a beautiful and interesting song for the lyrics to *10 +3*, he said, "I am impressed myself."

When he could not answer a question or follow the steps as instructed, he became desperate and agitated—nervously rubbing his chin, flipping his hands in front of his chest, and anxiously pressing against both of his temples. When he was frustrated and confused, he often touched his forehead and had a desperate look on his face. Nonetheless, he swayed between positive and negative comments like a pendulum. When I tried to minimize the emotional effect of his mistakes by comforting him, he realized that I was trying to cover up his mistake and felt my distress. He admitted his mistakes and was discouraged by his inability to do what I asked. He told me that he knew he did not do good job that day and that I did not need to lie about it. I am relatively good at not showing how I feel and think because of my training as a therapist and my personality. As a result, not many people notice how I really feel. However, Big Red accurately read what I was feeling and immediately perceived my disappointment and discomfort. In front of him, I felt like I was an open book. Since he was keenly aware that my discomfort was caused by his inability, he was frustrated and wanted to me make me happy. However, he often did not know what he could do. Perhaps because he had difficulties in so many areas, he was negative toward himself. There were so many mundane things that he could not do by himself. Big Red had reasons to get frustrated, and he was sensitive to other people's feelings. His ability to notice my discomfort showed me that individuals with WS are acutely sensitive to the feelings and emotions of others.

In contrast, his posture, facial expressions, and speech all changed when Big Red worked on a music-related activity. Instead of being passively involved and checking my facial expression every minute, he expressed himself easily with music; the tempo, the style, and the choice of instrument. He was confident and ready to share his joy of music with others. He had two extremely different attitudes toward mathematics-related activities and music-related activities. When math and music were combined, he was confident and happy, until he realized that he needed to perform some math related manipulations in order to finish the song. Because of his limited math ability, strategic songs were often interrupted to give him more time or to help him to finish that part of the task. When he would get frustrated because of some concept or procedure, I would suggest that he play or sing a musical phrase with me to divert his attention from his hopelessness toward his strength. Musicing could change his mood almost instantaneously so that he did not require verbal redirection.

In summary, Big Red is a great musician who plays drum set and loves to play music with others. He is a gentle man who cares about others, and a clown who loves to work with children. Despite his wonderful personality and characteristics, his daily life is full of obstacles. It was not pleasant for me to observe his struggles and difficulties in simple mathematical tasks. It made me wonder whether starting interventions when he was much younger would have made it possible or easier to overcome his difficulties.

Roxie Montana

> It was early in the morning on Saturday the first time Roxie and I met each other at her home. When she was asked what her favorite music was, she proudly announced Hannah Montana, brought her CD player and CD and played *Nobody's Perfect*. She got up and then started dancing in her pajamas. She moved with music and felt the music with her body. She was in the zone with the sunshine coming through the window and illuminating her, it was a moment of perfection as she listened and danced to her favorite song.

Roxie was a lively and cheerful 16 years old girl with dreams, wishes, boyfriend issues, clothing issues, make-up issues, and rebellious teenager behaviors. Roxie is the oldest child in the family, with two brothers, one 11 and one 10 years old. Her parents are supportive and caring. The brothers want to help her in any way they can. Her parents moved Roxie's schedule around to make sure a weekly meeting with me was possible. The family members were lively, energetic, and dynamic. The extended family, grandparents, aunt, and uncle live within a walking distance and many family gathering and activities were going on. Kelly Montana, her mother, described that she treats Roxie the same as the other two children, and Roxie was not given any leeway for having WS diagnosis. Mrs. Montana brings her to many concerts; the concert setting mesmerizes Roxie, and Roxie is so happy to be there.

Roxie is mainstreamed in the public school system. She struggles with handwriting and spelling. Her parents have considered purchasing a dictation software program to help compensate for her spelling difficulties and to give her another tool to connect with other people through letters, e-mails, and communal websites such as Facebook. Her parents had emphasized the importance of reading a clock since she was a child, but she had not developed the ability to do so. Roxie's mathematical development lagged behind her peers, and she clearly acknowledges her inability in the area of math. She witnessed her younger brothers' math skills surpass hers. When her brothers teased her when she had difficulties, she said, "You know I don't get it." She gave up and did not put any more effort into developing her mathematical skills.

Roxie did not enunciate every word. She seemed to lack the minute motor skills necessary to clearly form each word, and she seemed to not be fully present. Her lack of enunciation had the charm of childhood speech. The emotions she seemed to feel were the extreme highs and lows of a rollercoaster ride; when she was happy, she was extremely happy, when she was sad, she was devastated. When I told her that she was doing great, she nodded, smiled, looked at me, and said, "I know" with a tone of pride. When she easily accomplished a task, she proudly announced, "I'm so good at this," and then the very next minute, when she was disappointed, she threw her head into her arm saying "I messed up," and "I am not good at math." In WS circles, "Drama Queen" is an unofficial term used to describe these emotional ups and downs. I heard the terms and was finally able to clearly understand and feel what is meant by the "Drama Queen" title when I was with Roxie. Her emotions did not appear to occupy middle ground.

Roxie was mesmerized by piano playing, saxophone, and the iPod; everything related to music. The first time I played for her in a "show-off" piano style, she exclaimed, "It is so cool. Bravo!!! Excellenté!!!" (in Italian pronunciation). She made me feel very special as a musician and fed my ego. She was attracted to the iPod and wished to have one of her own. She was amazed how many songs could be stored and accessed on a tiny iPod, and she was so happy to find the songs by Hanna Montana. She especially liked the glockenspiel, keyboard, saxophone, and rain stick.

From the initial interview, Roxie was open and friendly. She did not hesitate to talk with me and to ask some questions about my gadgets and instruments. She did not display any sign of discomfort because of my presence in her home. She clearly expressed what she liked, and what she wanted to do. It was difficult to believe that this was our first meeting. Coin discrimination was her first task using music in the mathematical interventions.

Finger Dexterity

Roxie appeared to have relatively good finger dexterity compared with Angela and Big Red. While there was room for improvement in her fine motor skills, she handled coins and other small objects almost as well as typically developed individuals. She could easily display different hand gestures; however holding up different numbers of fingers took longer, not due to physical limitation but due cognitive limitation. She needed to count each finger one by one.

Attention

Roxie was easily distracted: the dog, her cousin, siblings, or father—whoever passed by our session room which was the formal dining room of her home, distracted her. The living room had two openings; one was toward a dinning room and the other one was toward the foyer. The third side was the window. Whenever someone passed by, she felt the necessity to communicate with them—saying hello, petting the dog, telling them what she had done. While her distraction could be understood as a normal response to the stimuli, the degree of distractibility was more severe than it would be with TDI. There were two questions to which I wanted answers: How much attention is appropriate at her age, and if the environment is changed, could her behavior be changed?

At the beginning of the project, she talked to the video camera a lot. "Hello! Camera!," "I love people and Lansing[6]. See you soon." However her interest in the camera diminished around the third session, and she no longer needed to greet the camera. Her attention span changed depending on the day's event. When she expected Travis, her friend from Grand Rapids, Michigan, to come just after the session, she did not able to pay attention to the task. The day she had a basketball practice after the session, she was distracted and checked the time almost every 5 minutes.

Musical cues, interestingly, were more effective than verbal redirections for her distractive behaviors. When I verbally redirected her to focus on her task, she rolled her eyes or talked back like "I'm doing it," or "I'm working on it." She displayed typical adolescent behaviors; however, when musical cues were given, she usually smiled and gave me the signs of understanding the meaning of a musical phrase by a wink or a hand gesture pointing at her worksheet or the materials, and focused back on her task.

Mathematical Exercises

Coin discrimination. Roxie could easily distinguish between different coins. She already knew the names of each coin and could order them from the most valuable to the least valuable. I used song "Give me a Quarter!" to evaluate her ability to discriminate

[6] Roxie knows I live in Lansing, Michigan and the particular day she was supposed to go Lansing, Michigan for a football game after the session.

be4tween different coins. She successfully handed in the designated coins. In order to challenge her to speed up her processing speed, I asked her to find each coin along with the improvised song, "Quarter, Dime, Nickel, Penny." She had difficulty keeping to this tempo (two beats with a tempo of approximately 100 beats per minute tempo). It seemed to be too fast a pace to process as well as too challenging for her fine motor skills. Picking up flat objects from the table was not easy for her. Even though the task was too difficult, she thought it was funny and threw her head in her arm laughing. After we enjoyed the moments, the song slowed down and gave her 6 more beats to complete the task. She effortlessly completed it. Next, I gave her two beats to name the type of coin and two beats for processing; she easily accomplished that task as well.

Coin calculation. Roxie demonstrated that she understood the concept that different coins has different values; a nickel is 5 cents, a dime is 10 cents, and a quarter is 25 cents. She could also recite the incremental sequence of each coin: 5, 10, 15, 20, 25 for nickels, 10, 20, 30, 40, for dimes, and 25, 50, 75, 100 for quarters, each all up to one hundred. Nevertheless, Roxie was not able to apply these concepts to calculating the amount of change in her hand. When I presented to her a nickel or nickel-hand-props (see Figure 13), she answered in increments of 5s, and she could do the same for the dime and the quarter as well. However, when the coins were mixed, she had no strategy to calculate the sum. For example, when I presented four nickel-hand-props one by one, she answered 5, 10, 15, 20. Then I separately presented a dime-hand-prop, and I expected that she would answer either 10 (just for the prop) or 30. Instead she answered "25," which was the next number in the 5 sequence (see Figure 28).

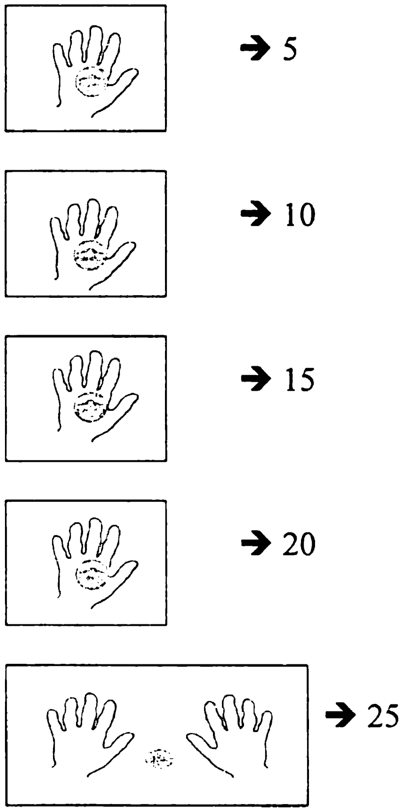


Figure 28. Four nickel-hand-props and one dime-hand-props and Roxie's answer.

This suggested that she did not grasp the concept, but based her response on rote memorization. When I pointed out a dime-hand-prop and asked her again to give me just the amount of the dime-hand-prop, she was able to answer 10. A nickel-hand-prop was added after a dime-hand-prop, and she correctly answered 15. Then another nickel-hand-prop was added, and she incorrectly answered 16 (see Figure 29). After a couple more questions, the same question in same sequence was tried the second time, and she made the exact same mistake. The precise reason for her incorrect answers and how she processed the information were elusive but indicated that she did not comprehend the process.

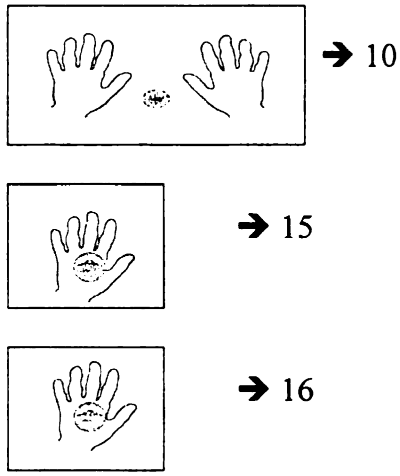


Figure 29. One dime-hand-props and two nickel-hand-prop, and Roxie's answer.

During the third session, I asked Roxie to calculate amounts by putting coins in a coin-classification-chart (see Figure 15) and then adding the amount from right to left. To teach adding a dime to a quarter, I initially used the concept of the identity property of zero (the sum of zero and any number is that number i.e., 2 + 0 = 2) and fact extensions (Calculations with larger numbers using knowledge of basic facts. For example, knowing 2 + 1 = 3 can be used to solve problems 20 + 10 = 30). In other words, a quarter (25) plus a dime (10) equals 5 + 0 = 5 (identity property of zero), and then 2 + 1 =3 make 35. However, Roxie comprehended neither the concept of identity property of zero nor fact extensions. After the initial teaching method had failed, I developed and explained the tapping strategy to Roxie.[7] The tapping strategy is that a dime is ten cents, and that a dime is also two fives, just as two nickels equal 10 cents; therefore she can calculate the sum of different coins by tapping twice on a dime, and say the numbers in 5's and tapping once on a nickel. A quarter plus a dime, tapping a dime twice and a nickel once with saying 5's (i.e., a quarter plus a dimes is 25, 30, 35 or two quarters plus a nickel 25, 50,

[7] The tapping strategy was developed after all three participants had same difficulty as Roxie had. They did not comprehend the identity property of zero and fact extensions.

55) method was introduced. This strategy appeared to simplify her thinking process. She was able to use the tapping method and could figure out the amount of cents for different combinations with the song "How Much Is It?" However, in practicing the tapping method with various other combinations of coins, she had difficulty.

While she was able to calculate combinations with quarters and other coins by using increments of 25 and then the tapping method for nickels and dimes, and then using increment of 1 for pennies, she had a hard time finding how to start without a quarter. With 2 dimes and 1 nickel, she calculated the amount of coins by saying 10, 20 for dimes; and then she did not know what to do with the nickel. She answered 45, without providing a reasonable rationale. In the same session, she tapped the dime twice saying 10. She ended up answering 2 dimes (10, 20, 30, 40) and 1 nickel (50) equals 50. These mistakes could be explained by confusion between *old* knowledge and *new* knowledge. Roxie knew that dimes are numbers in 10's (the *old* knowledge) and then she learned that she could count a dime with tapping (the *new* knowledge). However, she did not understand the sameness in the two methods or that both methods arrived at *10*. When she needed to decide which method to use, she could not decide which method was the correct one.

The task of giving change requires more steps than calculating the amount for given coins. While understanding the different types and values of coins and the process of adding the coins based on using 5's, giving change the concept of bigger and smaller numbers, and then choosing the best way to arrive at the same total amount. Roxie could make different combinations of the same monetary amount; however, she tended to use the easy combinations, such as using 3 dimes to make 30 cents, 7 pennies for 7 cents instead of a nickel and two pennies, 2 dimes and 7 pennies for 27 cents. Difficulties often came when the using quarters and nickels. When Roxie was asked to give 40 cents, she selected 4 dimes. When challenged to use quarters, she said "(pointed 2 quarters) 25, 50" and added a nickel "55,"and then looked at me. I prompted her to figure out which number was bigger, 40 or 50. She answered 40. After I told that two quarters are more than 40, I asked her to use nickels or dimes. Her choice was 3 nickels, and she was able to give me 40 cents. It was difficult for her to come up with different combinations for the same amount. In real life situations, every coin would not be available for making change in a transaction.

Written addition. Roxie was relatively good with tasks requiring single digit addition. However, her pattern of mistakes revealed that she did not understand the commutative property (also known as the order property—the sum is not changed by the order of addends (Kilpatrick, Swafford, & Findell, 2001). As shown in the Figure 30, Roxie correctly answered 9 + 2, but she did not correctly answer: '6 + 5 (question # 5),' '2 +7 (question # 7),' '3 + 9 (question # 8),' or '3+6 (question # 10).' The common factor in these questions is that the second addend is larger than 5. While she was able to handle questions that had a smaller second addend, she could not correctly answer with the larger second addend. That indicates that she did not have a strategy to switch the first and second addend.

After the song "Finding the Bigger Number" was introduced, she was able to switch the first and second addends and could arrive at the correct answers. She enjoyed the song; she swung side to side along with the song and eagerly displayed her fingers for the smaller number, and enthusiastically counted the fingers. She proudly wrote down the answers on the paper and looked at me to start all over again for the next question.

Roxy !!!!!!!!!!!!!

1. 9 + 2 = 11

2. 5 + 5 = 10

3. 8 + 2 = 10

4. 3 + 2 = 5

5. 6 + 5 = 10

6. 2 + 2 = 4

7. 2 + 7 = 7

8. 3 + 9 = 10

9. 7 + 2 = 10

*Figure 30. Roxie's worksheet.**

* Hand written

One incident particularly stood out interesting. Roxie worked alone on a single-digit addition worksheet, while I prepared for the next intervention. She counted all of the questions on the worksheet correctly. I praised her for doing this by herself and moved on to the next intervention. However, when the video clip was transcribed, I noticed an interesting detail was revealed. For the question "9 + 6," the correct way to calculate, according to the song, was to hold up the smaller number using her fingers (6 fingers), and air-counting the bigger number (9), and count holding up fingers from 10. Instead she said the smaller number 6, but held up her 7 fingers. Instead of air-counting for 9, she said 9 with her pointing finger, and counted each finger one-by-one; she got the right answer "15." The two mistakes made her final answer correct, but the process of arriving at the answer was not right. This incident should inform teachers in special education settings or any educational setting. When one leaves a student alone to work on a task, the answer is checked for success or failure; however, the process of the solving the problems is not necessarily checked by this procedure. Individuals with WS illustrate that they think and process problems differently from TDI. Unless the teachers or therapist knows how the students approached a problem, it is not possible to intervene with their way of thinking.

Sense of numbers. Roxie showed that she was missing a couple of key elements in her sense of numbers. First of all, the ability to subitize, which typically develops around 6 years of age (Clements & Sarama, 2004), was difficult for her. She had difficulty when she was asked to glance at a number of objects and identify the number beyond 4 or more objects. Even, when I showed less than 5 objects, she felt the necessity to count them individually. It was unclear whether she could perceive smaller units, or if she just preferred to count as confirmation. Roxie knew that one hand represents 5 fingers and two hands—5 fingers plus 5 fingers—equals 10; however, when she encountered 5 pennies in a row, and added another 5 pennies in a second row, she counted from 1 and to 10. Even after she was specifically asked to count from 5 with verbal explanations of the sameness between 5 fingers in a hand and the *hidden* 5 cents in a nickel and practiced counting objects from 5, she had to start from "1" to count 10 pennies. Her facial expressions suggested that she was wondering why she needs to use the new method when she has a method in her hand that walked perfectly well. She made me feel as if I had intentionally given her a difficult time over an unimportant thing.

Similar patterns were observed in her finger counting. When I held up seven fingers, she could not identify it as the quantity of 7 without counting. The pattern was the same as when counting objects. When I held up eight fingers or nine fingers, she counted from 1. This indicates she did not build concepts of composing and decomposing, which means a whole can be the sum of parts (decomposed) and the parts can be brought together and became a whole (composed). This occurs when 5 is a partner number that where children comprehend 6 as 5 + 1, 7 as 5 + 2, 8 as 5+3 up to 10. Typically developed children are reported to develop this skill by the age of 6 years (Clements & Sarama, 2004).

When we did the finger counting interventions—presenting 6, 7, 8, 9 fingers, and she needed to figure out the number of fingers in less than two seconds—her inability to identify the sum at a glance became more obvious. After I asked her not to count from 1, because she already knew one hand had 5 fingers and had practiced counting from 5, she was finally able to do the computation. However, she still needed to count fingers; that is

"5, 6" for 6 fingers, "5, 6, 7" for 7, "5, 6, 7, 8," for 8 fingers and so on. This indicated she did not have a concept of 6 as 5 and 1, 7 as 5 and 2, and so on—composing and decomposing.

When she moved on to identifying the number of fingers from 11 to 20, she revealed she did not have the concept of "teen" (knowing fourteen to nineteen is the same sequence as four to nine with a suffix "teen"). While she easily grasped that she did not need to count 10 fingers from 2 hands like 5 from 1 hand, she needed to count 11, 12, 13, 14, 15, 16, 17, 18, and 19 instead of seeing 5 fingers and saying fifteen or 6 fingers and saying sixteen. Roxie was missing two key elements: teen concepts and the ability to subitize the number of objects. These two missing concepts prohibited her from figuring the total number of fingers on 4 hands.

Even though she grasped the concept of counting from 5, or 10, her mouthing "1, 2, 3, 4, 5" was often observed. Counting from 1 seems to be the only solid technique Roxie seems to understand absolutely, and she utilized that technique for counting the quantity of objects. She could not count by 2's, 3's or 4's, but she could count by 5's. She knew a quarter is 25 cents, a dime is 10 cents, and a nickel is 5 cents, but she did not know a quarter and a dime together equals 35 cents. Roxie grasped some the *facts* of mathematics; but not the *process* of mathematics. Her mathematical skills make me think of a 1000 piece puzzle; she has only a couple of pieces out of 1000 pieces, but she did not know where the pieces fit into the big picture.

2 fingers in right and 5 fingers in left for 25. Roxie held up 2 fingers on her right hand and five fingers on her left hand and proudly announced "25." It was understandable and acceptable; even charm and cute; I assumed she used the 2 fingers to represent two groups of ten, and the five fingers to represent 5; so I did not intervene. However, a problem emerged when I presented 5 + 2. I used my right (her left) for 5 and my left (her right) for 2, she yelled, "25!" It was clear that while most typically developed children will understand the differences between the two settings, it might be not the best way to present 25 with 2 in one hand, and 5 in another hand for individuals with WS. Since she did not grasp the concept of abstract representation, it was a confusing abstract concept. The best way might be to hold up 10 fingers themselves, 10 fingers from a second person, and 5 fingers from a third person. Since individuals with WS have difficulties with quantity, it will be better let them feel and see the large quantity of 25.

Clock. Roxie was not very comfortable reading the clock. During the pre-interview, Kelly, her mom, expressed in five different questions in the pre-test (see Appendix J. Roxie) that Roxie most likely figures out the clock questions, because Kelly had really emphasized reading the clock since Roxie was in school. Unlike Kelly's expectation, Roxie did not get the right answer. She selected 7:15 as an answer out of four choices for 3:30. When I asked her to read the clock during the session (it was 10:10), she said, "Let's me guess." That word choice indicated her insecurity with her clock reading skills. She read 10:10 as 9:20. There was no pattern or consistency in the mistakes. This told me that she did "guess" in her answers.

Music

Emily: Does she enjoy listening to music?
Mom: 100%

Kelly, Roxie's mother, answered the questions without a moment of hesitation. After school, Roxie comes home and plays her favorite music and dances hours and hours like she did it when we met for the first time. Roxie takes pleasure in listening to *High School Musical, Hair Spray*, and *Chicago* (it is not a mystery to speculate from where she selected her pseudonym). When music is played, she has a hard time not dancing to it. At that point, her favorite singer was Hannah Montana.

Roxie has a strong memory for melody. She could remember a song after hearing it only a few times. The week before the first session, when I had a pre-interview with her mother present, I played *The Money Song* from the musical *Avenue Q* as background music. Because I expected to use the song for the sessions, I let her hear it a couple of times along with other prospective songs while I interviewed her mother. When we settled down to begin the first session, she spontaneously sung the melody from *The Money Song*, and expressed that she wanted to listen to the song. It was very impressive that she could memorize the melody and sing it back a week later. Throughout the project, she relatively easily learned new songs; she usually memorized the songs after a few repetitions we sang them together. She has a tendency to sing when she counts the numbers and reaches 100 or at the end of counting and makes rather exaggerated endings.

Roxie has an eerie musical sense. When we improvise together; she predicted the next note and we could sing in unison; as when two individuals say an exactly same word at the exact moment in dialog. A case in point happened 5 minutes after the very first session. While she worked on coin discrimination, I improvised based on the word quarter, dime, nickel, penny with the following pattern:

Part A

Part B

Part A & B

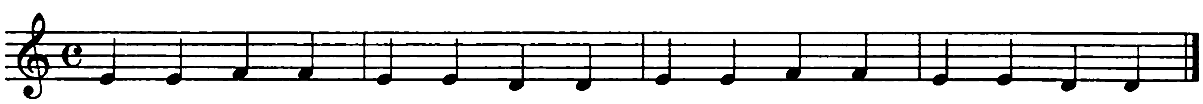


Figure 31. Quarter, dime, nickel, and penny improvisation.

She jumped into the song at the 5^{th} note and sang along with me. It was not certain whether the part B section of improvising was her idea or my idea. It appeared as though we had practiced it previously. After the first two measures of the improvisation, she was able to continue the melody by herself with my basic chord accompaniment without my paying the melodic line. Since she did not have any formal music training, this incident provided an insight that she is aware of a basic chord progression, not theoretically, but as a second nature. Another similar episode happened when I rhythmically chanted based on the word "done." It seemed to remind her of a similar tune with hand gestures. She danced with her improvised singing and beamed with joy. Her gesture and movement reminded me of the scene *Born to Hand Jive* in the movie *Grease.*

Roxie has a piano and a drum set at home, she also said that she wanted to play the flute; however, she does not actually know how to play any of these instruments. Roxie was instructed to play a rain stick when we sang that the *Dime* part in *Nickel,* *Dime, Quarter*. She smiled when she played the rain stick and was fascinated with the sounds. She especially liked to play a rain stick with improvisations on the piano. She enjoyed musicing and described our playing together as "very relaxing."

Roxie likes to play the glockenspiel. Roxie played an unidentifiable melody on the glockenspiel and claimed that she had played *Mary had a Little Lamb*. I asked her to play it again, and I was able to identify the song. She played the song in D dorian mode with an introduction as shown in Figure 32.

Figure 32. Roxie's version Mary had a little lamb.

While she sang the song correctly, she played it in a modified version. When I attempted to determine how she ended up playing with an incorrect version, it was noticed that if she had started the song using the C note instead of the D, she would have had the correct version (see Figure 33).

Figure 33. Correct version in the key of C, Mary had a little lamb.

The reason for her inability to recognize the differences between the tune when sung and when played was not clear. One possible explanation is that she may have learned how to play the tune on piano or keyboard instrument from someone, but did not accurately remember the starting note on the keyboard. This speculation comes from my observation with other individuals with WS; once an individual with WS could audiate a song, they were going up and down a keyboard and finding the next pitch based on their melodic memory. Even when a person started with a wrong pitch, the person will find the next pitch based on the relation with the previous note. If she learned by herself, she might do the same thing, but she played the white keys on the keyboard by sequencing—up, up, up, and down—as she plays in the key of C.

Another speculation is possible based on theories of child development and musical ability. Typically developed children learn melodic contour of the music before they can reproduce the precise interval and pitch for each note in a melody (Dowling, 1991, 1993). Contour is defined as "the sequence of ups and downs in a melody, regardless of interval size" (Dowling, 1991; Dowling & Fujitani, 1971, p. 524).The contour of two figures is matched at earlier stage of musical development and that gives another way of explaining her "mistake."

"Nobody's Perfect" and "You Can Do It" worked well for Roxie as an encourager. These two songs were sung during the first session and we discussed the meaning of the songs. During the second session, she was so frustrated because of her inability to calculate with dimes and nickels. She growled, thrust her hands downward, and proclaimed "I always messed up." I said, "No" and started singing "You Can Do It" and I stopped after "If you," she appeared to be momentarily lost, but she came up with "try." She laughed after she answered and she was able to get back on task. During the project, she liked to substitute the 'If you try" part of the song "You Can Do It" with "nothing to it."

During the 3rd session, when she commented about her poor performance in math:

> "I am not good at math. I keep forgetting."

I started improvising on her intonation as follows;

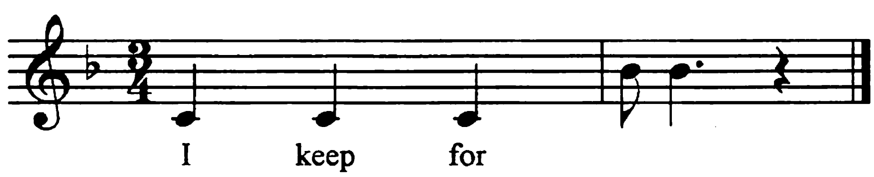


Figure 34. Intonation of Roxie's "I keep for getting."

I sang for her with that motive and Roxie started improvising the melody with my basic chord progression accompaniment between I and V in the key of F major. The lyrics were as follows;

> I don't want to give up on counting penny, dime,
> nickel, and quarter: dime, penny, and nickel.
> I don't want to mess up on counting quarters and
> dimes but if I can I will do well, so let's do it all over.

She pointed out her difficulties, and expressed her frustration, and described her next action plan. The melodic line fit well with the lyrics and was quite an impressive piece of work.

There was an incident that illustrated the power of music in her behavior. When Travis, her best friend who lives about two hours away was supposed to visit, she was very distracting. She looked at the clock almost every five minutes and had a big smile on her face. When the phone rang, she got up to answer it, because it might be Travis. When her mother redirected her to pay attention to the task, Roxie became very angry, growled and sat down in her chair. Since she had just finished her worksheet for the day, I wanted to play Roxie's congratulation song for her. When I started playing the song, her emotions switched from angry to happy as though she had an on-off switch activated by the music. Roxie immediately shouted "1, 2, 3, 4," and clapped with the song.

Music and musicing can change Roxie behaviors and attitude toward mathematical tasks. She has a reason to be frustrated in mathematical tasks, however when the mathematical tasks presented in musical context, she takes it as *music* activity than *math* activity. Even if she cannot play any instrument, her desires to learn how to play an instrument exist, but she appears to not meet the right person to teach her yet.

Emotional Support

Roxie consistently made mistakes during the 2nd session when asked to sum the value of the coins. She was so troubled that she exclaimed

> "I always messed up"
> "Messed up every time."
> "I always messed up on those one with the dime and nickel."

I also was so frustrated and worried about the whole project. However, the expression of 'always' and 'every time' raised concerns. This particular incident, the song "You Can Do It" did not do the trick. I took time to talk about why she needed to keep trying, and sang "Nobody's Perfect" and "You Can Do It" again. As I mentioned in Roxie's music section, she improvised songs about how she want to handle situations. She also added a line "nothing to it" for the song "You Can Do It." Her performance in mathematics is not very strong, so perhaps she had a reason to be agitated and frustrated; however, her responses to music for emotional support suggest that she "self-medicated" using music to ease her distress.

In summary, Roxie is a cute and adorable 16 year old girl. She is energetic and lively and is ready to laugh at any given moment. She wanted to teach me how to dress and to put on make up. She was really easily distressed by her simple mistakes in mathematical tasks and was ready to give up. She was mesmerized by music and different sounds from various instruments. When I called her and wanted to get her full attention, I chanted her name with a descending major 3rd (G to E), she would answer with "Yes, MA'AM." It became our ritual and she and I enjoyed our tradition. Her mother started using the same tone, and Roxie and her mother also enjoyed these moments. When I met their family, the year after the project at the music camp, Roxie's mother told about "Roxie-Yes, Mme," that she still used that tune to get Roxie's full attention and it worked so well. She is an adorable teen age girl. I cannot wait to see her again as a grown up woman.

Angela Hill

> At the beginning of 6th session, Angela told me she had just watched a documentary of the Beach Boys that morning and loved *Surfin' USA*. I told her I had *Surfin' USA* in my iPod. She begged me to play the song. When the music started, so did Angela. She wiggled and danced and grooved! Never did the smile leave her face. She danced with such joy and delight, adding lip syncing to complete the performance. She was keenly aware of her mom, me, and the video camera. When she made very cute and adorable movements, she looked at the camera as if she wished that the video camera had caught her joyful moment. It did. Her mother and I had never seen her act like that before; we looked at each other and laughed. The gentle, calm, and quiet Angela had gone wild with *Surfin' USA*.

Angela Hill is a very calm, gentle, cute, adorable, and happy 10 year old girl. Like other children with WS, she loves music; she has her own CD collection and brings her CD case everywhere she goes. The music she likes ranges from Hanna Montana to the Beach Boys to children's Gospel music, but she does not like loud noise and wears ear plugs in noise environments.

Angela's communication abilities seem to be the same as a typical 10-year-old; we had no communication difficulties during our sessions. She does have a rather reserved personality, as WS literature often suggests, and is generally quiet. She tends to be very calm and well-mannered and does not offer a broad range of emotions in her interactions.

When we had spoken on the phone prior to the interview, Angela's mother, Lee Hill had expressed some reservations regarding my accent and pronunciation, and was concerned about my ability to communicate with Angela. I stressed that face-to-face interaction would demonstrate my ability to work with Angela and we agreed that after we met, Angela would decide whether to participate in the study. During this initial interview in their home, Angela was curious and inquisitive as I spoke with her mother. When her mother asked Angela if she could understand me, she eagerly declared that she could understand me perfectly. While it was not clear exactly how much of my actual speech she understood, it was clear that she enjoyed meeting a new person and wanted to please me. It was also apparent that she wanted to spend some time with my attractive gadgets: a bag of instruments including, a keyboard, a set of sticks, a glockenspiel, an iPod, and a file box. She was especially interested in the contents of the file box.

Mrs. Hill advised me that Angela has difficulty with reading comprehension, handwriting, and spelling. According to her mother, she is doing well relative to the others in her special needs class regarding her mathematical development. In general, her attention span is quite good—as opposed to what the body of literature on WS suggests, and in comparison with other children with WS that I have observed. Angela's home environment was calm, quiet, and very well-organized, which may have helped her to maintain her focus and attention. Of all the study participants, Angela was the most prepared for our sessions. Mrs. Hill's interaction with her daughter is pleasant and very gentle. She was very interested in Angela's performance and ready to help her with her tasks. She is also deeply involved with Angela's schoolwork, after school activities, and in the use of additional education programs to improve her reading and comprehension. Mrs. Hill is very reserved and modest, and has a more formal, even old-fashioned speaking style that is quieter and focuses on enunciation and pacing. To a great extent, Angela imitates her mother's speech patterns. She usually speaks very softly, and often nods her head rather than vocalizing. When she wanted to do something other than what I asked her to do, she tended to give a wide-eyed response that could be called "puppy-dog eyes," as a form of emotional appeal or manipulation, rather than a provocative or violent response.

As Angela became more comfortable with me and with the process, we began to build a rapport and a form of mutual understanding. She more clearly indicated what she wanted to do, and also what she could and could not do in terms of mathematical tasks. As the sessions continued she began to talk about subjects outside our exercises, and she started sharing some of her wishes, desires, and concerns. During our sixth session, she announced that she wanted to get her ears pierced. The way she presented this was exaggerated and overly dramatic, a type of response I had not observed from her before. However, this scene was very familiar; similar scenes are frequent during conversations with many individuals with WS. For Angela, this level of exuberance also manifested when I used musical reinforcement after she was successful with math problems during our sessions.

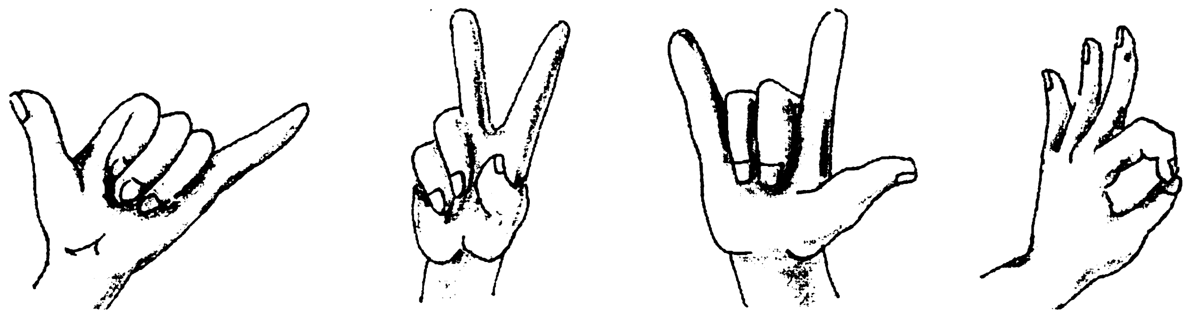
Language

While Angela does not have predominant difficulties in spoken language, she has difficulties with written language: reading, comprehension, handwriting, and spelling. She and her mother had used the "*Hooked on Phonics*" academic program in an attempt to improve her reading skills with limited results. When I asked her to select a pseudonym for this study, I also asked her to spell it out; her facial expression in reaction to the request was one of distress. Her tone of voice changed and took on a hint of sadness. She seldom appeared as distressed during our later sessions, even when making mistakes while working with mathematics, as she did following my initial request to spell her name. Although she finds spelling, reading, writing, and math all equally challenging, her spelling ability troubled her the most.

Finger Dexterity

Angela has difficulties with her finger dexterity. Her pinky is approximately one-third shorter than it is in most people; her pinky does not reach the first joint of her ring fingers. She is right-handed and has more difficulties with her left hand. When she was asked to hold up 3 fingers, she worked laboriously to hold up just three fingers, especially with her left hand. When I helped her during her attempt it took some time to succeed; I physically banded her pinky and brought her thumb down to hold the pinky down. Her pinky did not want to stay in position; she needed to use her other hand to hold down her thumb. She even has a difficult time holding up just two fingers with her left hand; she had to use her right hand to hold down the other fingers. When her fingers resisted this positioning, she said, "You stay there! I am serious," but in a very cheerful manner. In order to provide opportunities to practice finger dexterity, the song "Thumb and Pinky Meet Each Other" (see Appendix A. Figure A-3) was improvised and used during later sessions. A Hawaiian greeting hand gesture of greeting, called the "shaka" sign[8], "V" for victory sign, and "I love you" from American Sign Language were demonstrated and practiced to encourage her to exercise using different formations with her fingers (see Figure 35).

[8] This gesture requires a person to extend the thumb and pinky finger as other three middle fingers bended toward to palm of the hand.



Shaka sign V sign I Love you sign OK sign

Figure 35. Hand gestures.

Illustration by Hyang Eun Lee

Attention

Angela is usually relatively good at focusing on her tasks, with one notable exception. When the window of the session room was covered with sheer blinds, she thought the windows were fogged up, and became distracted.

Emily: Dime 10 (plays rain stick together)
Angela: Wow! Wow! What happened?
Emily: What happened?
Angela: I think the windows are fogged up. Wow!

Lee noticed her distraction and asked her whether it bothered her or not. Angela asked Lee to draw up the blind. After the blinds were adjusted, she was able to focus more on the tasks.

Angela was also distracted by the video camera. In order to verify the visibility and appropriateness of the camera angle, the display window of camera was faced toward Angela could watch herself through the camera lens and enjoyed doing so. She became discouraged when she was instructed to ignore the camera during the initial sessions. Her tendency to look at the camera was expected to lessen after a couple of sessions; however the video analysis revealed that she had stopped her extensive waving to the camera and making faces, yet she would momentarily look at the camera on occasion, or quickly raise her hands, and/or momentarily make faces when she thought I did not observe her. This implied that she could not resist the temptation from the camera and indicated some degree of weakness in self-regulation.

Mathematical Exercises

Coin discrimination. The first step to calculate and manipulate coins and paper money is to recognize the differences between coins and paper money. When we began our sessions, Angela was not able to discriminate among different coins, but she quickly learned and began to enjoy doing so. Initially she had a difficult time distinguishing between a nickel, a dime, and a quarter. She did not confuse these other coins with the penny. However, coins of the same color but with different size confused her. It was also hard for her to remember the specific names and values of each of the coins. The songs, "Give Me a Quarter!," "How Many Pennies in a Quarter?," and "Nickel, Dime, and Quarter," were used to help her learn these concepts. The tactile differences between a quarter and a dime, with their rough edges, and a nickel, with its smooth edge, were emphasized to enhance her ability to categorize these coins. On several occasions she ran the edge of a coin along the back of her hand, just as she had when the coins were first introduced to her, in order to determine their texture. When the coin hand props (see Figure 13 & 14) were first brought into the sessions, Angela was asked how many "fingers" were in the quarter-hand-prop. While she had been told there are five "hands," each with five "fingers," in the quarter coin hand prop, her incorrect answer was that there were only five "fingers" (see Appendix K. Angela Episode 5). This illustrates her difficulty combining different units to reach a numerical value. Singing the song "How Many Pennies in a Quarter?" and the visual presentation with a quarter with 25 fingers did not help her to understand that the concept of a quarter being the same as 25 individual items. She could not make connections between these concepts by herself without direct instructions. It seemed that she had a hard time understanding how one thing can represent 25 things. This symbolic representation is an abstract concept, one that she had difficulty grasping, as well as the related concept of conversion.

Coin calculation. After Angela could relate the name and value of the each coin relatively well, she was asked to work on calculating the total amounts for several groups of coins. She shared that it was difficult for her to apply her knowledge (i.e., a quarter is 25, a dime is 10, and a nickel is 5) to solve coin calculation questions without help with her thinking process. She knew a nickel represented five cents and she counted intervals of 5 to 100, but failed to combine those two notions to figure out the value of just two nickels. The following conversation took place after we worked on the value of the nickel as 5 cents and operation that 5 plus 5 is 10. She eventually came to the correct answer; however, it was necessary to verbally redirect her to guide her thinking process.

Emily: (put down two nickels) How much is it?
Angela: And, 5 and.... 25.... (Thinks with tapping her chin)... 29
Emily: 29! No, No, No. This is 5. OK. Nickel five, (Sings *Nickel, dime, and quarter)*
Angela: (finishes the line for quarter) 25
Emily: (Sings *Nickel, dime, and quarter)* Nickel five. (points the second nickel) How much is it?
Angela: 10 (reading Emily's facial expression)
Emily: (points to a nickel to make sure she really has the right answer) This is???
Angela: 25
Emily: No, a nickel is
Angela: 5, 10!!!!!!!

Angela also constantly made obvious errors substituting the value of different coins (see following example; as well as Appendix K. Angela episode 1, 4, 6, 7, & 13). Like the previous example, she could not apply the abstract knowledge to solve the question. She needed to have helped to accomplish this task.

Emily: (points to a quarter) How much is it
Angela: 25.
Emily: This is 25. And this is (points to a nickel)
Angela: A nickel?
Emily: Yes! Nickel; and 25 plus 5 equals.
Angela: 29!
Emily: 29!
Angela: 90... wait. I am confused

She needed to be reminded that different coins have different values and that she needed to use different values for different coins. In addition, she needed to be assisted in adding 25 to 5. It was interesting to observe that she made the same mistakes in the first and second examples, where she added 25 plus 5 and arrived at 29. When she thought of two nickels as 5 and 25, she answered 29, and the question of a quarter plus a nickel and she answered 29. Any logical explanation was not available; however, she arrived at the same answer twice with the same addends, it suggested that in her logic it might make sense, and I was wonder how she arrived at that answer.

After working on the value of two quarters and a dime (50 plus 10) is 60 cents by written addition by emphasizing the vertical representation of the question, she was able to do so as shown in the figure 36. However, when the problem of adding two quarters and a dime (50 plus 10) was verbally asked, Angela proclaimed that is "65." It almost seems that when she is adding two digit numbers in vertical format, she think that the 5 or other numbers is mysteriously appeared instead of her comprehending the concept of the identity property of zero.

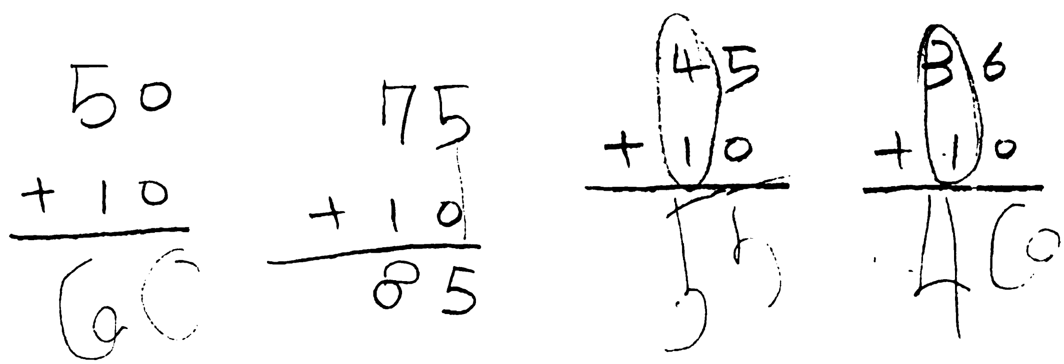


Figure 36. Two-digit addition formation. *

* Hand written

Angela appeared to be not ready to mentally calculate the problems of adding a number to 10, therefore she was taught the tapping strategy that is a dime is ten cents; and that a dime is also two fives, just as two nickels equal 10 cents. After she added up quarters in the coin-classification-chart by increments of 25, she was instructed to tap twice or once dependent on a nickel and say in increments of 5. This tapping strategy does not require *mental calculation* and has concrete and tactile components in the process. Angel's then became more accurate with the different combination of the coins.

Angela likes to manipulate with coins, especially pennies, which are the easiest way for her to count instead of the combinations of different values of coins. Once she asked me to say 16 cents and she cheerfully collected all pennies from the pile. This tendency was observed several times during the course of intervention. When Angela was asked to pull out a certain amount from an array of coins, she completed the task in the easiest way, for example, 4 dimes for 40 cents, three dimes for 30 cents, sometimes even wanting to use only pennies despite of the large quantity of cents, such as in the case of 55 cents; she asked me if she could use only pennies and happily counted out 55 pennies. Other combinations like a quarter, a dime and a nickel for 40 cents, or a quarters and a nickel for 30 cents did not flash upon her on mind. Angela was lather challenged to use other combinations.

Angela was asked to produce 55 cents. She previously solved this task by selecting two quarters and a nickel, or five dimes and a nickel. This time she was stopped initially because she could only find single quarter in the pile, similar to the real life situation. She was then reminded to use the coin-classification-chart (see Figure 15) which helped her too complete the task.

Emily:	You can't find any more quarter?
Angela:	Um... um... Where is it? um.... um...
Emily:	Let's use this. (points the coin-classification-chart) Let's put a quarter here.
Angela:	Ah!!!
Emily:	What is the next thing you can put it?
Angela:	(points a dime twice) 30, 35
Emily:	Ah-ha!
Angela:	(points a dime twice) 40, 45 (points a dime twice) 50, 55

During the next session, she was asked to collect 40 cents, and her response was to give four dimes. When she was challenged to use a quarter instead, she was easily able to adapt to the task and use nickels for the balance. She previously required some level of guidance to do so, but she was able to do this by herself for the first time.

Emily:	(sings *Give me a 40*?)
Angela:	(counts dimes but says) 1 nickel, 2 nickel
Emily:	That's a nickel or dime?
Angela:	Oh! Dime (laughs) 10, 20, 30, 40 (4 dimes)
Emily:	Can you use a quarter?
Angela:	Um~~~~~~~~~~~~~ quarter quarter quarter. Come on. Quarter 25, 30(a nickel), 30, 40 I mean 35 and 40 (1 quarter and 3 nickels)

She was next asked to present 55 cents. This time when she could not find a quarter, her response was to use dimes. She was able to find 3 dimes but no more were available; this stopped her and she appeared to have no idea of what to do next and she could not complete the task by herself. She was able to shift from a quarter to a dime, but when she needed to switch from a dime to another coin, she seemed to lose her train of thought and looked to me to help her. When she was redirected to use the coin-classification-chart (see Figure 15); she came up with the idea of using a nickel. The coin chart appeared to offer a way to organize the coins in order to make 55 cents. The chart seems to give a visual and concrete aid to think the next step.

Coin versus written. At the beginning of the project, she was better with the two-digit written format addition than she was with coin calculation; however as the project progressed, she became stronger in calculating using coins. When Angela became more familiar with coin calculation, she was asked to do addition in a written format. A very interesting incident happened when she worked on the written worksheets. The way in which the question itself was presented, vertical or horizontal format, appeared to change her way to complete the problem. She calculated the problem in vertical formation by writing the "5" for the first column, and then do addition for "2+1" and writing down "3" in the second column. She differently calculated the problem in *horizontal format.*

She perceived "1. 9" as 19 and "2. 5" as 25. Then, she attempted to solve the problem. She was able to solve 19 plus 2 by doing 19, and holding up one finger, and saying 20, and the second finger 21. Her mistake was missed until it happened again. She struggled with adding 25 and 5, and used the same strategy as she had to work with 19 and 2; that was saying 25, and holding up one finger, and 26, and the second finger 27 and so on.

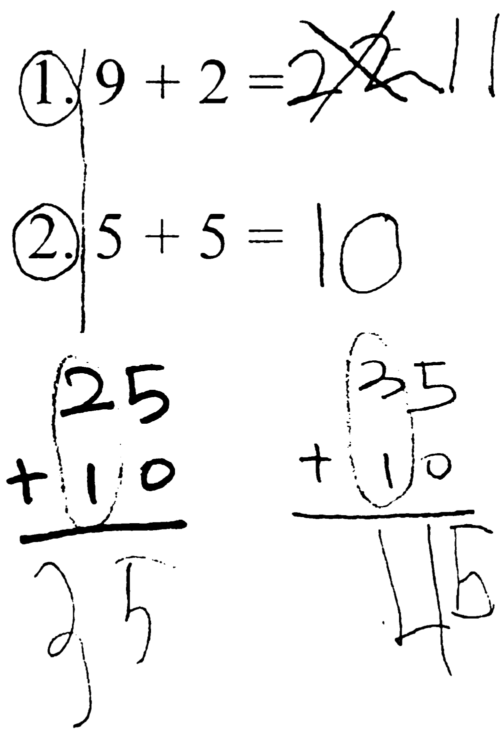


Figure 37. Two-digit addition in horizontal and vertical formation. *

* Hand written

Previously she worked on a quarter plus a nickel, i.e., 25 + 5, and quickly and successfully came up with the answer of 30. When the same question was presented in a vertical written format, she sighed, tapped the table, touched her nose, said "*um*" 4 times; and then she held up fingers to add up from 25. When she reached the answer, she yelled "*30.*" I drew the line between "2." and "5" and she was able to instantly answer 10. In the example of another problem, 50 + 20, she was able to add 2 quarters (knowing 2 quarters equal 50) and 2 dimes (20); however, she was not able to repeat this in the abstract written form. These examples indicate that she did not comprehend the sameness in three different formations and she perceived three different addition formats as three separate problems, and uses three different strategies.

Written addition. The song, "Finding the Bigger Number," was developed to help with written addition. Before introducing the new strategic song, I wanted to confirm that Angela had solid and effective strategies for written addition, because it had been observed that when the new strategy is introduced, Angela, as well as other participants, was confused between the *old* and the *new* strategies. Therefore, if she already had her own way of doing, I wanted to reinforce and respect her own strategy. To verify whether she had or did not have a strategy for written addition, the addition worksheet was provided and her reaction and way of working on the worksheet was observed and analyzed.

The analysis of the two successive sessions on the written addition suggested that she seemed to not possess her own strategy for the calculation. It was observed that she could add "7 + 2," but not "2 + 7." The way that she adds two one-digit numbers is that she spoke the value of the first addend, and then hold up her fingers. She could easily do

7 plus 2, by sequentially holding up another two fingers, however with 2 plus 7, when she began with 2, and tried hold up additional fingers one at one time, from 3 to 4, to 5, she seemed to lose track of her progression.

When Angela worked on the question on the worksheet (9 + 6), she held up 6 fingers, looked at the ceiling, tapped her lips thoughtfully, looked at the questions again, said "um" twice, and then tapped her lips again, and desperately looked at me. I allowed about 30 seconds passing to see if she needed to have additional support or if she could figure it out on her own. However, she did not seem able to solve the given question, even though its pattern and presentation were the very similar to that of the previous session, and we went through steps very similar to the lyrics of "Finding the Bigger Number," but without the melody. She was asked if she was willing to learn a song that might help her solve the problem. She excitedly agreed to learn the song, which was sung, and the corresponding steps were taught with the lyrics. The 10 questions were practiced with the song "Finding the Bigger Number." She was able to sing along after a few practice rounds and knew what the next step was. While she worked on the worksheet with song, she maintained eye contact with me and she did not tap her lips or the table, or look away from the worksheet.

Another technique was also provided to make addition easier and more effective: the concept of the *teen* numbers, which is fourteen to nineteen, as similar to using four to nine and adding teen. The concept was introduced using a simple chanted rhythm while Angela held up her 10 fingers and, I changed the fingers 1` held up from 4 to 9. After working on this concept with different combination of fingers with chant, Angela had her 'ah-ha' moment. When she worked on 6 plus 7, she counted up to 10, and then she noticed that she had another 3 fingers left and she yelled "13!! Woo-hoo!!!" instead of keeping counting her fingers.

With two-digit vertical addition practice, she indicated she did not completely understand the concept of carrying (A digit that is moved from a given place value, or column, to the another column of greater place value). The numbers in the questions are the common numbers in combinations of coins. It was intentionally delivered in that manner in order to make connections between coin calculation and written addition. Figure 38 illustrates that she was able to add "5 + 5," and other questions using the identity property of zero, but made a mistake with "15 + 10" (the second question of the first line. It indicated that she still did not completely understand the identity property of zero.

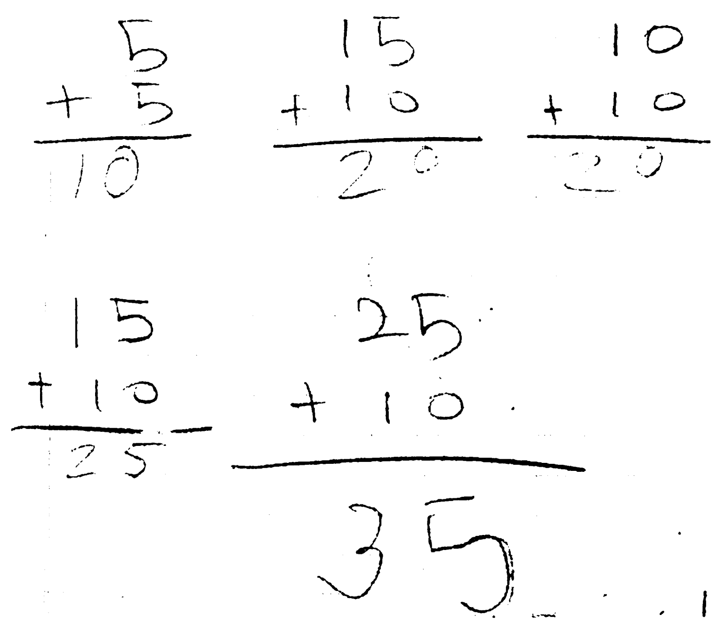


Figure 38. Addition in the vertical formation. *

* Hand written

Figure 39 displays Angela's mistake. She added "5 + 5" and wrote "0" for the first column and "2 + 2" and wrote "4" for the second column. When I mentioned about carrying and wrote "1" for Angela, she said "ah-ha!" and wrote 5. When the same question was presented a second time, she answered 50.

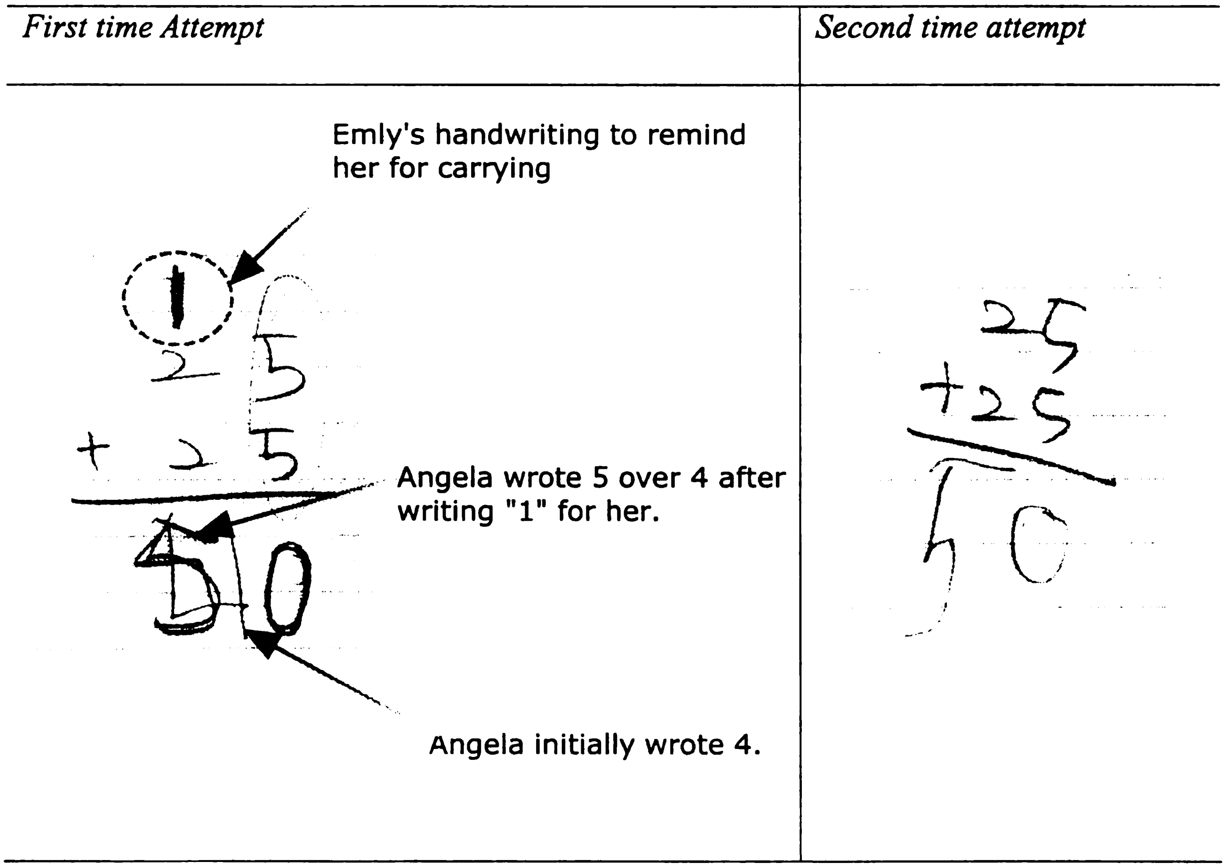


Figure 39. 25 + 25 in the vertical format. *

* Hand written

Figure 40 shows the difficulty of carrying for Angela. She got the answer of "1070" for the problem of adding 75 and 25. The process seemed to be "5 + 5" and wrote "0,"she wrote 7 from some where—might be from the question—and "1 + 7 + 2" is 10. And wrote down before "70," and arrived at "1070."

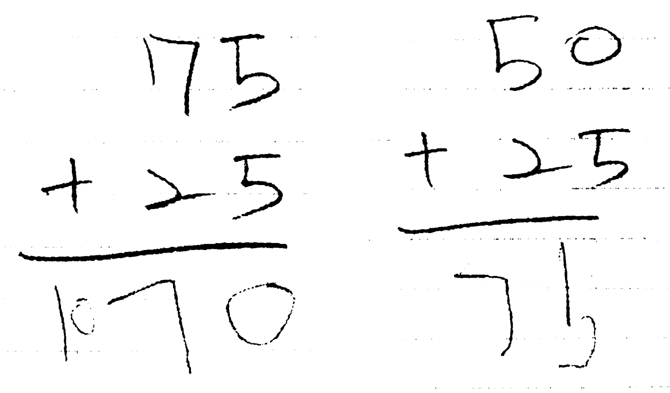


*Figure 40. "75 + 25" and "50+25" in the vertical format.**

* Hand written

Number buddies song. During the initial interview, Lee reported that Angela was working on her subtraction in school at that point. The song "Number buddies" (see Appendix A. Figure A-2) was composed and taught in order to help her subtraction skills. This song was developed based on the concept of complements of ten. The concept is that if number X and Y summed equals 10, then X is Y's complement of 10 and vice versa. In the example "3 + 7 = 10," 3 is 7's complement, and 7 is also 3's complement; they are partners and buddies. This concept gave the participants another tool to use in solving math problems. The entire song was sung, and then each line of lyric (9 and 1 equals 10, 8 and 2 equals 10, 7 and 3 equals 10) was separately reintroduced with many repetitions. Each line was repeated (at least 15 to 20 times) in different registers using a keyboard, as well as a different tone for voices (such as singing baritone or soprano) and in different voice qualities (such as singing like a bird, or a dog) to help keep her attention. The glockenspiel was also used to provide a different tonal quality to keep her attention. Angela was able to sing along with my accompaniment and had no difficulty memorizing the lyrics. There were a number of props to turn the abstract concepts of numbers and values into tangible and concrete images including a children's abacus with 100 beads, and a number chart (see Appendix I. Figure I-1). She had no problem using the abacus to solve problems; however, it did not appear as beneficial in facilitating her mathematical development. She easily answered questions using it, but when she was asked to solve the same question without it, even though she had just answered that question, she was unable to do so. It was apparent that when she uses an abacus, she did not use her mental arithmetic skills, but counted to solve the problems.

When the worksheet that a directly applied the elements of the song *Number Buddies* i.e., "10 – 9 = ____," "10 – 7 = ____," and "10 – 8 = ____," was used, she was able to solve the problems immediately. However, when she was presented with the application problems, "11 – 7 ="and "11 – 8 =" and "11 – 9=," she wrote down "3," "2," and "1" as answers same as the complements of 10 (see Figure 41). She did answer the application questions based on 7, 8, 9, and did not think of the relationship to 11. She needed help to apply the knowledge to solve these applied problems. This indicates that she memorized the matching numbers, but did not understand how to apply to the question.

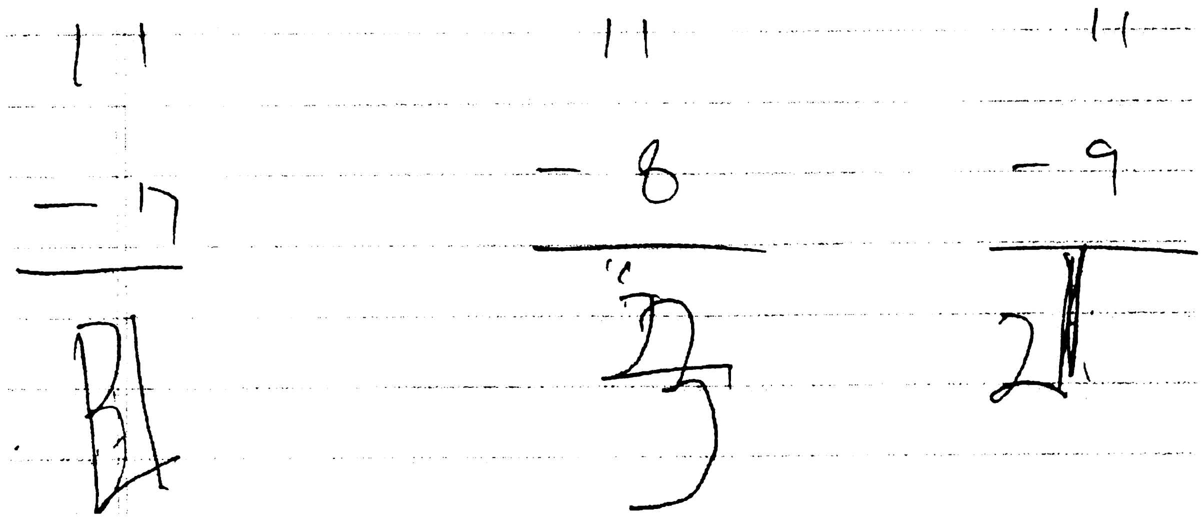


Figure 41. Angela's subtraction. *

*Hand written. 4 is wrote over 3. 3 is wrote over 2. 2 is wrote beside 1.

Sense of Numbers. Angela did not exhibit any difficulty with the magnitude of numbers or their cardinality. She could pick the appropriate number flash card when requested. However, she did not skip numbers even though the diagrams were organized in sets of 3's, 2's, or 5's as illustrated in Figure 42. After she was instructed to count objects in increments of 2, 3, and 5, she did not understand the purpose of doing so. I explained that it is important to do so in order to speed up the process of counting objects. We counted the object together in increments of 1 and increments of 3s. She recognized the differences in the increments and understood the reason behind the instructions. After a couple of attempts, she was able to do so. Nevertheless, without my redirection and reminder, she preferred to count by 1's.

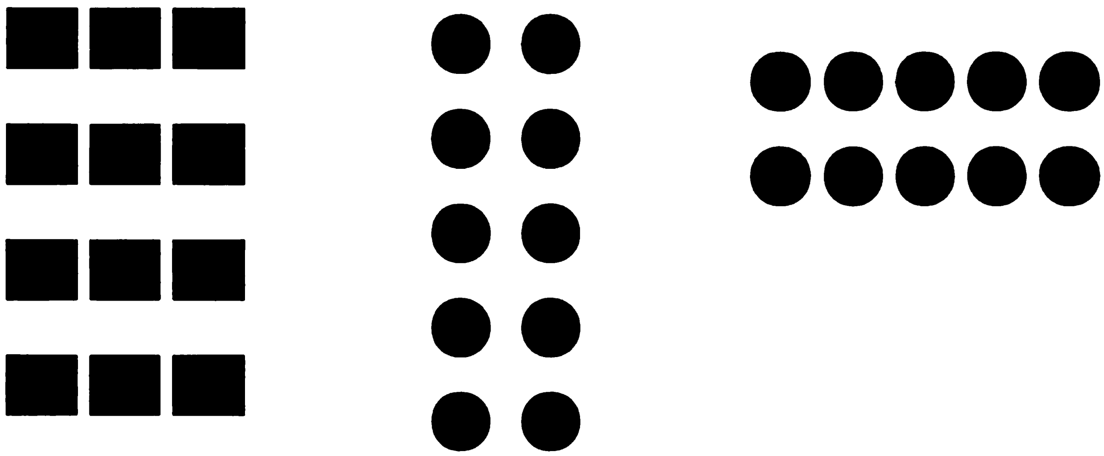


Figure 42. Number flash card examples.

Angela could subitize up to 4 objects. In other words she did not need to individually count groups of less than 4. She did prefer to count groups of more than 5 objects. She easily adapted the technique of counting from 5 and was able to use this tool without my verbal directions. She did understand the concept of composing and decomposing using 5 as a complement and was able to say '6 is 5 and 1' and to use the concept to hold up 6 fingers.

Lack of strategies. The sessions with Angela revealed that she lacked a range of strategies to solve math problems. Lack of strategies is often mentioned in WS literature, and her preferred way to count using her fingers provided some insights.

There are a couple of ways to solve mathematical tasks: one is to break down the task and make the problem solving process easier, a technique that children with typical (TDC) development develop by interaction with older individuals and manipulating objects without specific instructions. For example, most TDC can flexibly start verbal counting in increments of 1 from any point by age 6. If more than five fingers were held up, she did not skip count up to five; she counted from 1. That is if 7 fingers were held up (5 in one hand, and 2 in another hand), she had to count from 1 to 7 instead of 5, 6, and 7.

Counting from 5 was encouraged and practiced many times. When five fingers in my right hand and other combinations of fingers in my left hand were presented and she was asked to answer how many fingers were up, she counted from her left side. This is a good indication that she has a solid strategy for organized information from left to right. However, it also indicated that she did not develop a strategy to glance at the five fingers first, and then count from 5. She was finally able to count from 5 at the end of the project without verbal redirections. According to Clements' (2004) *Developmental Guidelines for Number and Operations*, (see Appendix H), TDC can glance at and identify collections of or collections of 1 to 6 objects and if the objects are organized in patterns up to 10 objects (that is objects in groups of 2s, 3s, 4s, and 5s). This incident provides an indication that she lacks this type of pattern recognition. Angela eventually learned this strategy by the end of this study, which was evidenced by her spontaneous counting of objects using increments of 3. When 9 objects in groups of 3s, were presented, she counted "3," "6," and "9" and arrived at 9.

Clock. The song "Increments of 5" (see Appendix A. Figure A-1) was introduced to help her read the analog clock. The lyrics of this song simply utter numbers in 5's with very succinct wording. Angela could easily recite multiples of 5 with the song and pointed out the numbers along with singing. We sang the song up to 60 and 12 o'clock was presented as 60 minutes. The problem occurred when she tried to read the clock with an hour. While Angela was previously able to read hours, she now said "3:60" for 3 o'clock and "4:60" for 4 o'clock. After 3 sessions of working on reading a clock, it was observed that she used the same wording and tactile cues to read the clock. While working with Angela, additional tactile cues were cultivated along with verbal instructions. To help with the difficulty to distinguish the big and little hand, she was instructed to put her left index and middle fingers between the end of a hand and the side wall of the clock. The hand which she can put her two fingers is a big hand (a clock hand), and the one she cannot is a little hand (a minute hand).

The next step was to put her right index finger from the 12 and go toward the larger numbers on the clock with verbal instruction of "the clock goes this way." When her right index finger met her left fingers, the number on that spot indicates the hour. She occasionally confused the process, but in general, was able to accurately read the clock by the end of project.

Music

Angela had no particular musical ability and played no instruments, however she liked to listen to music of many different genres and to sing along with recorded music. Lee (her mother) stated that it is very hard to find a song she does not like. She was fascinated with almost everything related to music including my iPod, a rainstick, a glockenspiel, and a piano. I organized my iPod for the sessions and it includes various genres and each participant's favorites. She was amazed at the number and variety of songs stored in the tiny iPod. When she had a chance to choose a song from an iPod, she wanted to listen to Hannah Montana, the Beach Boys or Christian gospel songs especially by Steve Green. Her choice of the Beach Boys was interesting given her young age; even considering the Beach Boys are timeless; it felt like a little odd choice.

Angela's singing quality is not notable; her voice is stretched, pushed and pinched; but she surely enjoys singing and dancing. Although she could not play instrument, she showed a great deal of interest in the piano and the glockenspiel. She was taught for her to play a simple melody the glockenspiel by demonstrating and modeling with a modified scores (see Appendix E) and she was joyful when she was able to play by herself. She enjoyed different percussion instruments—practically anything provided— including a rainstick, finger cymbals, and wind chime; practically anything provided. She was able to play "Number Buddy Song (see Appendix A. Figure A-2)," "Mary Had a Little Lamb," and "Twinkle, Twinkle Little Star" on the glockenspiel and could play *Chopsticks* on the piano.

Angela has a very interesting speech pattern. She repeats words and phrases three times: "Ten cents, Ten cents, Ten cents," and "a quarter, a quarter, a quarter" in a manner of chanting. She made many different exclamations with different intonation and used sound effects such as "woo, wow, opps, hee-haw, and hurrah." She seemed to enjoy the diverse vocalized sounds. Her repetitive speech patterns sometimes were used as motives in improvisation and became a song.

Angela's chant evolved into melodic lines, which were more often observed after the 6th session on. Her melodies were often based on descending minor-3rd and similar to motives from the well-known songs like *Chim Chim Cher-ee,* as seen in the following example. Improvised songs are sometimes identifiable like the *Westminster Quarters*, but most often the familiar melodic line was not identifiable.

When she recited numbers and reached "100," around 90% of the time when she sang "100" it was in a big operatic voice producing—a dramatic ending. Her musical responses were encouraged and applauded; her rhythmic and melodic patterns usually became the motive for improvisation and sometimes turned out to develop into a song. Angela demonstrated her ability to make cadences. She was able to match the rhythmic pattern and melodic contour of the beginning of the song. We enjoyed our musical dialogs, which deepened our relationship, and out later sessions developed into something similar to movies and musicals.

Angela did not feel comfortable during the first session because of a dental visit and during the fourth session because of cold-like symptoms. She wanted to continue our session even though she was not feeling well; she even returned home early from school because of how she felt, but she did not want to cancel the session. Her mother was concerned and asked her if she wanted to take a break, but she said that she wanted to continue, and she insisted that she was fine. This episode suggested that the power of music as a motivator; she wanted to participate in the music therapy session despite of her physical discomfort.

Music can influence her attitude, mood, and behavior. As the Angela's dance with *Surfin' USA* illustrated, to see this dramatic change in her behavior speaks loudly for the power of music in her life. Normally a very shy girl with a calm demeanor, she changes to a dancing queen when music is in the air. Angela was in awe of a flowery piano style with fast moving passages, glissando, and ornamented riffs. She often asked me to play "one more time" and expressed that she wants to play like that. Therefore, playing her favorite passage worked as a very effective reinforcement for her.

In addition, Angela's tempo of the physical movement has been changed by the tempo of music. At the beginning of the project, I often improvised a simple motive to provide background music for her while she worked on her task. For example, when she worked on the finding nickels from the pile of coins, she moves her hand too quickly to match the tempo of my playing and cannot find any nickels. I did not notice this during the session; however, while monitoring the video clip, it was observed. After noticing this, I varied the tempo of music, and she changed her movements along with the tempo of the music. It was remarkable how much impact music had on her.

Learned hopelessness and emotional support

Angela did not clearly show signs of learned hopelessness in her math skills, until we worked on the similarities between written format and coin addition. She had two sets of strategies, one for written format and one for coin calculation, she was unable to recognize similarities to cross utilize concepts. I thought if she understood the sameness in two formats, it could be a major break through in her mathematical development. After several parallel explanations between written equations and coins, she became very agitated and said "I'm confused," "I cannot do" and "I don't know" and finally stated "**I CANNOT LIKE... DO LIKE... THE HARD MATH.**"

Another case in point, after struggling with distinguishing different coins and adding up, Angela affirmed, "I'm always confused." There are few incidents that she made negative declarations toward her mathematical ability; however those general statements imply she has a general notion that she is not good at mathematics.

The negativity toward her performance was redirected by "Nobody's Perfect" and "You Can Do It." At the beginning of the project, the songs were used to prevent any apprehension she might feel about her abilities. That faded with the progression of the study. Later sessions, when she made negative comments, and I played "Nobody's Perfect" and "You Can Do It," she began to sing the song and was able to regain her composure and could focus on her project. Short musical phrases for approval, congratulation, and disapproval worked very well conveying the meaning of what I was communicating without verbal explanations, and she enjoyed listening to those phrases, as evidence by her smile, and request for more playing.

In summary, Angela has such a cute and adorable smile. When she smiles, I feel I need to do whatever she wants me to do so. She makes me feel like I am one of the best musicians in the world and that she wants me to play more for her. A short musical excerpt reinforced her as much as a piece of candy for young children. She was relatively good at mathematical problem solving compared with the other two participants; however, she mentioned that she could not do "hard math" when she worked on the question "50 + 20." She did not display any particular musical ability, but she demonstrated potential ability in improvisation and was interested in learning how to play a keyboard instrument.

CHAPTER VI

ANALYSIS

In this chapter, stories of Big Red, Roxie, and Angela were collectively viewed as individual chapters in a book. While the chapters share commonalities, they are also different. After all thirty video recordings were transcribed and printed in color; the segments of mathematical mistakes were indexed and complied into a file for each participant using the Macintosh iMovie software program. The compiled files were individually reviewed, and then the same interventions used for two or three participants were simultaneously reviewed on two or three monitors. The similarities and differences among the participants became defined and specifics emerged from this method of observation.

The video clips were also edited and compiled dependent on the themes and/or purposes for the various presentations during this study. The unexpected benefit of this editing and compiling process was that while I tried to find the best clips and editing process, I had to watch the same clips frequently giving me additional opportunities to observe behaviors and responses. The participants' difficulties, mistakes, every movement, facial expressions, and gestures were imprinted in my mind, which, later, proved most helpful in finding the related moments out of 30 session recordings, as well as accessing the pivotal moments by theme. Sometimes, the same moment was used for different themes. For example, a clip could be used to identify the theme of mathematical mistakes as well as learned hopelessness. Side by side editing of three participants gave the viewer a chance to know and understand the participants, but at the same time gave me opportunities to observe them with a new lens. When I give public presentations of the work, the comments and questions from the audience also make me look at the clips with different perspectives.

The literature review on mathematical development, which concurrently occurred with the sessions and analysis, sheds light on the participants' mistakes and difficulties in mathematics. This process of seeking more information was begun out of the desperation. The participants' answers for some questions did not make sense, and at times I could not understand or even come close to speculating reasons for their responses. Having their mistakes and incorrect answers in my hand via the video recordings and reading literature from the books and articles about typical mathematical development as well as mathematical difficulties, provided insight into a deeper understanding of the participants as individuals and as a group. Many of the incidents and mistakes which are mentioned in this chapter were already described in the case studies, but here are collectively viewed in order to understand them as a group.

Case Study Summary

In broad terms, when compared to Roxie and Big Red, as well as other children with WS (from descriptions in the WS literature), Angela showed a higher level of accomplishment in mathematical tasks and her understanding of mathematical concepts was much faster than the other two participants, especially Big Red. While Angela improved in mathematical functions and learned advanced concepts, Big Red needed to go back to foundational mathematical concepts. It became clear that Big Red did not have the prerequisite concepts to work on addition. He could not figure out the quantity of the collections of 1 to 10 items, which is supposed to be developed by the age of 5 or 6. Roxie's functional mathematical level was in between that of the other two participants, and her other characteristics, such as music ability and attention span, were also between those of the other.

While Big Red was the oldest, Angela was the youngest, and Roxie was in between them. The level of functioning in mathematics for the three participants was in the opposite direction: in the music area, Big Red was the star. Big Red could play a drum like a professional drummer, and a piano with some I-IV-V-I basic chord progressions with two fingers, the other participants did not have any particular ability for playing an instrument. Roxie enjoyed singing along and was able to improvise a couple of songs during the project. Though Angela liked to listen to music, she did not particularly display her music-making ability. Angela exhibited much better attention, whereas Big Red could be very easily distracted, especially by auditory stimulation.

Mathematical Interventions

At the beginning of the study the same exercises and interventions were intended to be used with all three participants; however, during the course of the sessions these were adapted and individualized interventions by modifications made to suit individual participant's needs. This included the changes in the tempo of songs, and specific songs and subset of the verbal instructions. For instance, while the song "Finding the Bigger Number" was used for Roxie and Big Red, the tempo for Big Red's was much slower than for Roxie's. This difference was revealed by the video analysis with two monitors; it was not intentional. This adjustment occurred naturally as Big Red, for instance, required more time to register information, and to accomplish the task. In another instance, when one of participants did not understand a prerequisite concept in the song, another song was developed to teach the needed concept. Comparisons and contrasts of Big Red, Roxie, and Angela are discussed in four major categories of mathematical interventions—coins, written addition, magnitude and cardinality, and clock.

Coins

Roxie could distinguish between different coins; Angela could not identify the different coins at the beginning of project, however she mastered this skill within her first two sessions. Meanwhile, Big Red did not master this skill until the end of the project. The other coin related tasks were to be able to identify the sum of a combination of coins, and to be able to give them to me. A coin-classification chart was used to help clarify this concept and Roxie and Angela became familiar with the chart and effectively used it for coin calculation. When Big Red counted coins or the coin hand props, he displayed his confusion of quarters, dimes and nickels. Even though Big Red could sing the song *Nickel, Dime, and Quarter*, he could not determine which coin was 5 cents and which was 10 cents. Even though the sizes of each coin hand props was different and suggested a different quantity, none of those cues—songs, visual hands props, and the size of props—helped him to understand the value of coins. He seemed not to be able to grasp that one coin can represent 5 things (a nickel), or 10 things (a dime), or 25 things (a quarter); "1" is "one." Although he did not understand the value of each coin, Big Red practiced with the coin-classification-chart[9]. However, he failed to understand when he needed to use two taps for a coin (a dime), or only one tap (a nickel), and to count by 5's. While he struggled with these concepts, the necessity of retrogression to instill key elements of mathematical development became obvious. In Big Red's case it became necessary to work on the concept of quantities—magnitude and cardinality—rather than coin discrimination and calculation, and written addition.

On the surface, determining the sum of a group of coins and giving a certain number of coins to another person would seem to involve the same process; however, they actually require different skills. The identification of the sum of a group of coins can be simple addition: "25 + 5," "30 + 2" etc, but when we must to pay exactly 72 cents, for instance, the task also depends on what we have on hand. If we have 3 quarters, it requires handing over all three; if we have 4 quarters, 2 dimes, and 5 pennies, then we can offer 2 quarters, 2 dimes, and 2 pennies, or three quarters and expect change in return. Therefore, figuring out which coins are needed and paying the required amount involve different steps and strategies. All three participants had a difficult time completing this task, echoing the events at the Starbuck's coffee shop described in the prologue (see Prologue, p.1).

Roxie and Angela had difficulty calculating the exact change when they had more change than required. For example, when asked to collect 40 cents, they began with 2 quarters, but did not know how to proceed. They needed and an explanation that compared two numbers—the sum they have on hand and the required amount. If the sum

---

[9] After the experimental period was finished and analysis of sessions had bee completed, it was clear that without understanding the value of coin, the coin-classification-chart is not helping. But while I worked with the participants, the apparent logic was overlooked. This issue is discussed in limitation and consideration section in the conclusion.

is the larger number, put down the last coin added; and then use smaller value coins. Then they needed to repeat this step until they reached the required amount. Roxie and Angela had the same tendency to go for the simplest amount, such as a dimes to reach 40, rather than mixing coins and amounts, such as by using a quarter, a dime, and a nickel. While Angela became accustomed with the more complicated combination of coins, Roxie had a difficulty time to mix the coins and prefer to remain with the simplest way.

Written addition

A worksheet on single digit addition was used to work with written addition. While Roxie and Angela could do all 10 questions with some mistakes (about 60 % accuracy), Big Red could only answer 7 questions out of 10 questions without assistance (see Big Red section, Figure 25). While Big Red did not even attempt to work on those he perceived as 'hard' questions, Roxie and Angela did, but they also answered a few of those 'hard' questions incorrectly. The quantity of the second addend seemed to be a factor in the level of difficulty they perceived; if the second addend was larger, like 7, 8, or 9, Big Red did not even attempt the questions, while the others often made mistakes.

The reason for this tendency can be found in the way the participants solved problems. They appeared to add the second number either by using their fingers or by mentally adding one to their running total, and by speaking the new total. If the second number was too large, they became confused while using their fingers or during mental calculations. When Angela worked on "19 + 2,"she did not hesitate; she immediately answered 22 (even thought it was an incorrect answer), but when she attempted to add "25 + 5,"she became agitated and counted aloud, "26, 27, 28, 29, 30" while she held up her fingers one by one. Angela's attitude towards using the numbers 2 or 3, and the numbers 5, 6, 7, 8, and 9 was obviously different and suggested she expected this to be a 'hard' question. Roxie added "9 + 6" by mouthing the next height number while holding up her fingers, just like Angela did. Big Red occasionally used his fingers to guide him; however, he seemed to basically memorize some questions and answers like double numbers "2 + 2," "3 + 3." He would scan the questions and find the one he already knew like "5 + 5,"and "9 + 2. Then he would write those answers and leave the others blank.

The song "Find the Bigger Number" was used to help compensate for these difficulties and in an attempt to teach them commutative property (see Table 3). This song worked very well for Roxie and Angela, but not Big Red. He knew which number was bigger than the other; however, his difficulties with manual dexterity prevented him from successfully accomplishing the task while singing the song. Instead of working on the addition worksheet, Big Red practiced accurately holding up a certain number of fingers. Roxie and Angela continually worked on the written addition worksheets and they could finish the worksheet slightly faster than they first worked on the same worksheet before learning the song and singing it. Also, the accuracy of the answers greatly improved and the hesitative behaviors were not present.

It was interesting that Roxie and Angela could not recognize the similarities between written addition and coin calculation. The two girls were able to complete the written additions "5 + 3" by employing the finger counting strategy as a crutch. However, when the exact same numbers were used but presented as a nickel (5) and three pennies (3), Roxie and Angela were not able to use the same strategy. Since a nickel is a single object, knowing that it had an abstract value of five cents was not something they comprehended. Roxie and Angela "connected the dots" between the fact of "a nickel is five cents" and the process of converting a nickel to 5 cents in order to derive the sum of a group of coins.

Like Roxie and Angela, Big Red could not transfer their strategies from written addition to coin calculation, Angela could not transfer the strategy for coin calculation to written addition. Angela could do the a quarter plus a nickel by tapping the nickel and speaking the next higher number in increments of 4, but when she tried to add "25 + 5," she used counting strategy "26, 27, 28, 29, 30." This illustrated that she did not perceive the similarity between the coin calculation and written problems. She solved the problems using rote memorization, not by creatively employing the mathematical concepts.

Even after these similarities were pointed out and explained the two girls, they continued to have a difficult time using the same strategy for different tasks. I can explain the fact and knowledge to them, but I cannot make them understand; the understanding occurs within them. While Angela finally came to understand that a nickel is equivalent to 5 pennies, and she was able to use the same strategy for both version of the '5 + 3' problem, Roxie was unable to learn this concept.

Magnitude and Cardinality

Magnitude itself means the amounts of each group of objects. Understanding of magnitude in mathematics refers to recognizing which one of two or three sets of objects is the larger amount in the set. Cardinality is defined as the number of elements in a set. Understanding of cardinality denotes the ability to say the word for the number corresponding to the object and to know the last number said is equivalent to the total number of items in a set (O'Hearn & Landau, 2007). For example, when a child 'sees' two die; dice A with 1 dot and dice B with 6 dots, a child, who understands magnitude and cardinality, understands that dice B has more magnitude, and has 1 dot in dice A and 6 dots in dice B. If a child understands magnitude but has not yet developed an understanding of cardinality, the child knows dice B has more dots, but does not understand the last number he just counted means the amount of dots in the die. Understanding of magnitude is observed as early as 18 months for two groups of objects (Clements, 2004; Cooper, 1984). Understanding of cardinality is typically mastered by the age of six, for collections of 1 to 6 objects, and if the objects are organized in patterns of up to 10 objects (that is objects in groups of 2s, 3s, 4s, and 5s) (Clements, 2004).

Big Red displayed that he had not mastered cardinality, and might not be able to master even the concept of magnitude. Furthermore, it suggests that the mistakes—he counted his finger twice or skipped counting his fingers—might not be a mistake, but indication of his lack of understanding the one-to-one correlation with each number and each object (enumerating objects). He was able to distinguish the difference in magnitude between 10 and 20 objects, but not the difference between 6, 7, 8, 9, or 10 objects. While Big Red struggled with magnitude, Roxie and Angela both became accustomed to using the concepts of magnitude and cardinality.

All three of the participants had not learned the "teen" concept. When this concept was first introduced and practiced, Angela was able to learn the concept relatively quickly, and could readily use it to solve a single digit addition questions. Roxie did learn the concept and was able to use it; however, she needed to be reminded and redirected to use it at times; she preferred her old way. Because Big Red had to put great effort into acquiring and using small scale cardinality, we were unable to work with the "teen" concept during his sessions.

All three participants were good at reciting numbers in a sequence. Reciting numbers in increments of 5's and 10's were also not difficult tasks. However, the ability to recite numbers was not an indication of their understanding of the value of these numeric symbols. This is similar to when typically developed individual could learn how to count objects in other languages, such as in Spanish, German, or Chinese, they may memorize the numbers in the other language did not mean that the person has an understanding of the meaning of the numbers. An example might be not knowing the meaning of *cinco* in Spanish. This metaphor also can explain why the participants need to count from 1. We might not know what *cinco* means, but if we memorized the sequence of numbers in Spanish, we could figure out the meaning of *cinco* by counting from *uno* with one finger, *do*' with adding the second finger, and so on. Several incidents suggested that they appeared to be able to recite sequential numbers because they have memorized the words themselves, rather than having learned their abstract values.

The first example of their level of understanding the meaning of numbers is revealed by a comparison between Angela and Big Red. They showed the different levels of function with understanding of cardinality. While Angela could remember the different values an each card, Big Red pointed to any card in front of him as illustrated in Table 4. The cards were organized with the first line with 5 dots with the second line variations (see Figure 17). He seemed to distinguish cards with one line (a card with 5 objects) and two lines (cards with 6 and more objects) and could find the card with 5 objects; however he failed to discriminate between 6, 7, 8, 9, or 10 objects. The placement of the card was not changed between trials to enhance the opportunity to recognize different cards; but even then, he could not remember the different quantities represented by each card, even though their placement was the same. Roxie and Angela showed a similar functional level; after they counted all the cards, and knew where the cards were, they were able to identify them individually when asked. When the placements of the cards were changed, they still found the designated cards and that suggested they understand the cardinality of each card.

Table 4. The comparison between Angela and Big Red

Angela

Emily:	(sings *Which one is 8?)*
Angela:	(her lips formed 8 and she picks a card with 8 objects)
Emily:	(sings *Which one is 7?)*
Angela:	(picks the 9-card and quietly counts and touches her mouth; picks the 7-card)
Emily:	(sings *Which one is10?*)
Angela:	(whispers 10) This one.
Emily:	Yeah!!! I think you are right. Oh! Yes. Oh! Yes. (sings *Which one is 5?*)
Angela:	(pick the one; whispers 1,2,3,4,5)
Emily:	(sings *Which one is 10?*)
Angela:	(immediately points to the 10-card) This one
Emily:	(sings *Which one is 7?*)
Angela:	(immediately points to the 7-card) This one

Table 4 cont.

Big Red

	(Previously each card was counted together.)
Emily:	(points to 10-card) This one?
Big Red:	5… Think before you answer.
Emily:	You need to count by 5
Big Red:	5, 10
Emily:	(points to the 9-card) This one is?
Big Red:	5, 10; No. 5, 6, 7, 8, 9
Emily:	Which one is 8?
Big Red:	We just went over it.
Emily:	Yes, Can you find it?
Big Red:	(sighs) OK.
	(points to the 10-card) This one, right?
Emily:	No. This one is?
Big Red:	Oh! (points to the 7-card) Here it is.
Emily:	Let's count it.
Big Red:	5, 6, 7
Emily:	How about this one.
Big Red:	1, 2, 3, 4,
Emily:	Uh-uh! Don't count from one. Count from 5
Big Red:	5, 6, 7 Oh! This one is 8.
Emily:	Yeah! Yes!!! That's great!!!
	Which one is 5?
Big Red:	(points to the 5-card)
Emily:	Right! Which one is 7?
Big Red:	(scans; points 5-card, and then 8-card) This one right Here.
Emily:	Uh-uh (no)!
Big Red:	That's 8. This is…
	(points to the 10-card) This one is 7.

The second example of the understanding of the meaning of numbers is based on an observation of the meaning of a quarter. The first time I asked Angela what a quarter represented, she answered 52 pennies. After this mistake, I asked her the same question a second time, she got the right answer. It could have been considered a simple mistake, but as since 52 was not a random number, it raised a question of the reason for the mistake.

Emily: I have four quarters and how many pennies?
Angela: (shrugs her shoulders) I don't know.
Emily: You don't know. One quarter equals...
Angela: 52 pennies?
Emily: One quarter?
Angela: 25

A possible explanation came from Roxie's mistake rather than an assumption that it was due to dyslexia. When Roxie worked on the value of a quarter, she often used 2 finger with her right hand, and 5 fingers with her left hand, while she spoke "25." This kind of presentation had been used habitually in various situations and I thought that it could not hurt her development, and she was so cute when she did that. However, it became a problem when we worked on addition using fingers as a reference tool. We worked using fingers on both hands such as "2" using fingers of the right hand, and plus "3" in from the left. When I asked her what five fingers rose in my right hand, and two from my left hand meant, she proudly announced "25." At that moment, I realized that for individuals with WS, symbolic gestures can be confusing. When Roxie made her gesture of "25," I assumed she understood the concept of 2 fingers for two groups of 10, and 5 fingers for 5, but that was only my wishful thinking. If this is the case, Angela's mistake in saying that 52 cents were in a quarter, might not have been *a sheer mistake*; it may have been an indication of confusion of the concepts.

Each participant displayed a different mathematical level when identifying the value represented by a set of fingers (always the 5 fingers of one hand and another combination on the other hand). While Angela could easily identify the value with or without counting the actual fingers, Roxie needed to count all of the fingers on both hands beginning at "1." Big Red yelled out random numbers; he even offered "15" for

"7" fingers. However he could answer "5" by one hand and "10" by two hands. When I presented different combination of fingers, Big Red tried to reproduce it with his own hands, and then to count his fingers by touching them with his other hand. Even with touching fingers, he sometimes counted the same finger twice or skipped a finger. All of the participants were instructed to count beginning at 5 when more than 5 fingers were presented; however only Angela adapted to this method and used it appropriately. Roxie understood the concept and occasionally used it, but preferred to count from 1 and she seemed to be more confident using that as her main strategy. Big Red did not understand the concept, he could not use it by himself; I needed to start with him. While Angela showed composing and decomposing of numbers by saying "5 and 1" for 6, "5 and 2" for 7, neither Roxie or Big Red display the understanding of composing and decomposing of numbers. Roxie was taught the concepts of composing and decomposing, especially in relationship to units of 5; for example, 8 as "5 + 3," 7 as "5 + 2." While she did not fully understand these concepts, she memorized the fact and for addition questions in coordination with the song "Finding the Bigger Number."

Clock

Reading an analog clock is a comprehensive test of accumulated knowledge and concepts. Many smaller ideas lie hidden within this task and each concept must to be mastered before a clock face can be read successfully. All three participants had difficulty telling time using an analog clock, a problem elaborated at length in the WS literature. Big Red, Roxie, and Angela revealed their similarities and differences in their skills in the following ways:

1. The comparison of the little hand and the big hand

Big Red, Roxie, and Angela could not identify which hand was longer than the other due to visuospatial deficits. Besides recognizing the different hands by size, these conceptual values were counter-intuitive; as the "big hand" represents minutes, the smaller unit and the "little hand," the hour, or larger unit. The tactile information provided by touching the end of the hand and the inside wall of the clock helps them to determine which hand is the little or big. Because of Big Red's problems with manual dexterity, this was not an easy task for him. It took him too long to check with his two fingers, and to process this information in a reasonable timeframe. Angela and Roxie made a great improvement after they were prompted to touch the clock. This tactile method appeared to offer a way to confirm their speculation, as well as give them the opportunity to correct themselves.

2. Clockwise

Roxie and Angela appeared to understand "clockwise" as the direction that hands travel around a clock face. Angela and Roxie could also understand that the clock advances from smaller numbers to bigger numbers, however, Big Red was occasionally confused by this.

3. The different systems of numbers for the little hand and the big hand

The hours are counted by the little hand: 1, 2, 3, 4, 5 etc. through 12; and for the big hand, the minutes were measured in increments of 5 on the clock they used, thus 5 – 55. All three participants could not grasp the concept of the two different number systems in a "same" clock. However, they could count in units of 5 from memory. Angela was confused when she reached 60 minutes and needed to switch back to "00." For example, when the clock read 3:00, and Angela said 3:60. In response to Angela's mistake, Roxie and Big Red were taught to count from 5 to 55, and 0. The participants occasionally confused which system to use in formulating their answers, and needed to be reminded which system should be used for the minute hand and for the hour hand. However, Roxie and Angela were eventually able to correctly choose the relevant system, even though Big Red continued to make mistakes.

4. When the little hand is between two numbers and seems to be closer to the bigger number

Different clock designs and differences in visual acuity, even for TDI, can result in frequent mistakes in judging the positional of the hour hand on many clocks. Big Red, Roxie, and Angela and had a very difficult time with this function. After suggesting that they place their two fingers from right hand at the end of the hour hand and move their left index fingers from the small number to the big number, and when two hands meet, the number at which the left index finger point is the number for hour, their performance improved (see Figure 41). While Angela was able to accurately read the clock by the end of project, Roxie was still occasionally confused, and Big Red had few opportunities to develop this skills because of his other issues.

5. Switching between increments of 5 to single minutes to reach the actual time, such as 4:27

This skill is typically introduced in Grade 3 mathematical curriculums based on *the Standards and Focal Points* adopted by the National Council of Teachers of Mathematics (NCTM, 2008). None of the participants had attained this level of skill.

Fine Motor skills

Fingers can provide a useful and versatile reference for someone who has just started working with the concept of addition. In order to effectively use their fingers in such a way, the manipulation of fingers must become automatic and facile. If it requires physical manipulation and/or mental effort, if it takes too long, the usage of the fingers themselves becomes a distraction and interferes with the task. While Roxie did not have difficulty with her fine motor skills, Angela and Big Red had difficulty with their manual dexterity.

In Angela's case the problems were more physical, while in Big Red's case it was both cognitive and physical in nature. Angela's pinky was a little shorter than that of the average individual; her pinky did not reach the first joint of her ring finger. Because of this structural difference and the actual stiffness of her joints (contractures), she had a hard time holding up three fingers, especially with her left hand. Big Red's contractures appeared to be more advanced and especially hindered his finger movement, which was very awkward and labored. He could not subitize nor did he understand the concepts of composing and decomposing numbers. This meant that when he held up a certain number of fingers, he also needed to hold up each finger individually, from one through the number. He did comprehend the units of "5"and "10,"but any other unit he needed to count by using his fingers. In addition, because he could not flexibly start counting numbers, he would hold his hand open to display five, and then add the fingers required to get to a certain number. In other words, he did not have any means to expedite the process of holding up a certain number of fingers, and his finger dexterity hindered him from doing it efficiently and smoothly. Furthermore, his attention deficit hindered his focus on the task. As a result of all these factors, he did not have many chances to finish his task holding up 7, 8, and 9 fingers.

Music

Big Red, Roxie, and Angela loved to listen to music. They liked many different genres, from musicals, gospel, to popular music, and all shared a love of the Beach Boys. Angela and Roxie both loved Hanna Montana. They were mesmerized with the different and unique sounds created by different instruments including the glockenspiel, rain stick, saxophone, and finger cymbals; they wanted to play with each.

Roxie and Big Red showed their ability to improvise. Roxie was able to express how she was frustrated by her inability to solve some math questions by singing an improvised song. Roxie showed that she could predict the next melodic line, and so improvised with the therapist. Big Red composed four songs for this study, and numerous songs and musical phrases for his own use, and exhibited a great sense of rhythm for the lyrics and catchy melodic lines. His ability to change the lyrics of existing songs or to add lyrics to complete an improvised song was very impressive. Angela did not show any particular ability in improvisation, but she did have the tendency to complete a number sequence by singing it operatically.

Their ability to improvise inspires awe, especially when considering that they have no formal music training and improvise solely by listening and informal learning. They create musical dialogues while not consciously understanding the formal elements and rules of music. It is understood that for individuals with WS learning the structure and language of music is the same as learning any language. People communicate even when they do not understand formal grammar, the rules of syntax, or even all the jargon they use. It is speculated that people with WS might understand music in the same fashion, by learning by ear. By listening, they learn where the harmony changes; when they need to take a break or a breath, and when to emphasize a particular note or syllable.

Big Red can play the drum set, the djembe, and the piano. He could play a drum set like a professional drummer. He knows many popular rhythms, and can successfully accompany a band. His piano skills are less developed than his drum skills. He can play with both hands; melody with his right hand and 2 finger accompaniment patterns with his left. Roxie and Angela did not have any particular ability to play instruments. Roxie did play *Mary Had a Little Lamb* in a minor key on keyboard and Angela was able to learn to play a part of the song *Chopsticks* using a modified score on the keyboard and to play "Number Buddy Song (see Appendix A. Figure A-2)," "Mary Had a Little Lamb," and "Twinkle, Twinkle Little Star" using a modified score on the glockenspiel. Roxie showed a great interested in playing the saxophone, but she was not able to develop the breath control necessary to use the instrument by the end of project.

All three participants were influenced by music, and when it was presented, Big Red wanted to harmonize with the song or tap along to the beat, Roxie wanted to dance; and Angela wanted to just listen the song. Angela occasionally matched the tempo of her movement to the music. When Roxie did not dance with the song, she had a similar tendency like Angela did, she moved to the tempo of a song. After this discovery, the tempo of music and the types of music were considered to be congruent with the type and pace of their movement (Patterned Sensory Enhancement)[10]. In addition, if they moved too quickly, or if I tried to push them a little faster, I could use the tempo to alter their pace within a limited range. For Big Red, complete silence was often necessary because of his poor attention focus. When music was provided to fill the break between a question and an answer, instead of working on the task, he focused on harmonizing or tapping on surfaces. Individuals have a tendency to unconsciously move to the tempo of the music with a tapping on the desk with fingers, keeping time with their feet, and/or nodding their heads[11]; however these three participants displayed that they were more responsive to the music. Other individuals would more likely still attend to the task and change the pace of their movements to match the tempo of the background music within the range of adaptable tempo; however, the participants' responses to the tempo of the music were instantaneous and replaced the physical movement of the task even out of tempo range for their current tasks. They wanted to forget the task and move with the music by dancing, tapping, etc. This phenomenon can be explained by the different degree of activation in the amygdala, cerebellum and brain stem in the WS' brain (Levitin et al., 2003) (see Neurobiological factor, p. 35). The cerebellum and brain stem are directly related physical movement of muscle group. There might be some explanation of their immediate physical response to the beat of music.

---

[10] Patterned Sensory Enhancement (PSE) is defined as "rhythmic, melodic, harmonic and dynamic aspects of music to provide temporal, spatial, and force cues for movements which reflect functional exercises and activities of daily living" (Thaut, 1999).

[11] External rhythmic auditory stimulation (music) is mediated by internal perceptual shaping, and can arouse and raise the excitability of spinal motor neurons mediated by auditory-motor circuitry at the reticulo-spinal level (subcortical level). As a result, individuals are unconsciously influenced by the tempo of music, and the groups of muscles involuntarily move to the tempo of music (Paltsev & Elner, 1967; Rossignol & Melvill Jones, 1976; Thaut, 2005).

CHAPTER VII

INTERPRETATION

The individual stories of Big Red, Roxie, and Angela depict the uniqueness of each participant. The comparison and contrast of their stories shed insight into the meaning behind the scene. In this chapter the meaning of this study, based on their stories and various theories from many different disciplines is seen through my lens. The body of literature regarding Williams Syndrome establishes the difficulty for people with the syndrome when attempting to use math, both in understanding abstract values and in processing or manipulating numbers. While the difficulty is well documented, its causality seems to have been overlooked in the literature. It quickly became apparent during the experimental phase of this study that some interventions were more effective than others, and that specific techniques worked better with some participants than others. One immediate example—the limited ability to perform addition—is itself a complex combination of different cognitive and perceptual limitations, as well as conceptual difficulties. Mathematical development theories give a basis for understanding their difficulties. Neurobiological, behavioral, and physical factors in WS might seem unrelated at first, but produce a Gestalt effect, one that severely restricts the capabilities of these participants beyond what I expected. A detailed analysis of observations, session notes, and digital video recordings were used as an instrument to reveal the bases of mathematical difficulties and responses to music. The results helped to refine the theories underpinning interventions and suggested more effective strategies to compensate for deficits and future music therapy practice.

Roadblocks to Mathematical Development

Over the course of these sessions all three participants continued to repeat the same or similar mathematical mistakes, which provided a sort of window into their thought processes. These observations lead to the identification of several roadblocks that stand in the way of their mathematical development and improvement. These deficits stem from difficulties in WS. It is not enough to ask what these roadblocks are, or how they may inhibit the WS; we must also ask what those with WS are still able to do and how capable they remain in the face of these obstacles. The analyses of the session data suggest the following roadblocks: lack of metacognition, visuospatial deficits, attention deficits of various levels of severity, slower data and problem processing, fine motor skill deficits. As a result of those five factors, individuals with WS miss mathematical developmental milestones, and they learn hopelessness.

Metacognition

Metacognition is typically defined as knowing how to think; it can also be defined as the ability to understand a task and to choose appropriate strategies specific to the task or a series of tasks, as well as the ability to organize the order of the problem solving, such as in a flowchart (Hallahan & Kauffman, 2003; Overy et al., 2003). There are many different names and terms for cognitive limitation in WS literature. Out of the many different forms and descriptions of cognitive limitations associated with WS, the analysis of the participants in this study suggests that metacognition is a more serious and core problem than is indicated in the existing literature. Metacognition is the broad enough and specific enough to describe the difficulties in their cognition and can be the best option to be used. All three participants showed various levels of difficulty with metacognition. During an individual's early years, an infant or toddler learn some facts and strategies along with their physical development. These facts and strategies are informally learned early and reinforced cognitively and socially, through rewards and recognition, as they are incorporated into more sophisticated structures. However, in the case of WS these more complex strategies either do not develop or are slow to develop, leaving them with only simple and basic tools and strategies.

The typically developed individual learns the basic properties and concepts of mathematical processes at an early age, including commutative and identity properties (see Table 3), as well as other miscellaneous concepts. For Big Red, Roxie, and Angela, these concepts often remain beyond their grasp, although the memorization of specific facts in mathematics and solution to specific set for the certain questions can simulate the development of these skills, they appeared to *memorize* the facts and the solutions case-by-case, rather than by *understanding* the *big picture.*

The following example is drawn from the music therapy sessions with the study participants and reveals this limitation. Each participant was given the same worksheet of math problems; one specific question asked for the sum of the values of 5 and 25, a task that typically requires few steps to solve. It also takes little effort for most people to switch the order of the variables from "5 + 25" to "25 + 5," but those with WS are unable to make this switch. In addition, it became apparent that some participants did not seem to understand the addition of actual abstract values, but had memorized sequences—the multiples of prime numbers, the number 5, doubles (2 + 2, 4 + 4, 7 + 7) for example—in order to simulate the use of addition or multiplication.

One potential explanation for the inability of the participants to add "25 and 5" is the inability to apply the commutative property, to switch "5 + 25" to "25 + 5,"which is easier for them to manipulate, because they can associate values with their fingers in a quick hand-calculation. In Roxie's case, she could only add "25 + 5" by using the coin mechanism, or multiples of 5 to add the value of a quarter to that of a nickel to then reach the sum of 30. In Angela's case she was only able to add the specific sequence "25 + 5" as abstract values, but not the converse, "5 + 25." Even then, Angela only arrived at her solution by talking herself through this process one integer at a time: "1, 26; 2, 27; 3, 28; 4, 29; 5, 30." When "5 + 25" was presented, she was unable to solve the problem with any method. In a similar vein, she could solve "2 + 9," but not "9 + 2." Based on these observations I speculate that participants are not able to use an associative strategy to switch the order of the variables to sequences they can solve, a method typically taught to elementary school students

Several incidents detailed in the case studies suggest that the participants overused specific strategies incorrectly for unrelated problems; it appears that the participants cultivate a single successful strategy at a time and discard earlier techniques after a new tool produces success. The ability to differentiate between strategies and recognize when and where they are best employed is not part of their consideration. As a result, rather than develop repertories of strategies for different situations, the latest strategy overrules the older approach. In Angela's case, she had previously recognized 3 o'clock by matching the hands of an analog clock to their positions or as she put it, when the hour hand is on the "3" and the minute hand on "12" it is 3 AM or 3 PM. However, after she learned the technique of reading the minutes within an hour, her description of 3 PM became "3:60"; she added the multiple of 5 minutes, 60, the base time of 3 PM, as identified by the hand positions, and she lost the distinction between "0" and "60" as both occupy the same visual position.

Mathematical problems and their solutions involve the manipulation of signs and symbols, typically in a textual or written format. These signs and symbols are both abstractions and the difficulty of WS to solve mathematical problems seems to lie in their inability to understand the abstractions involved: the "1" is as much an object as an apple, or a penny and as an abstract principle, like the representative value of a coin, is difficult to grasp. Numbers, sequences, the value of a specific denomination of money, for instance, are memorized absolutes rather than being understood as representative values.

Because of their limitations in transferring knowledge and strategies from one format (physical calculation: coins) to another (written calculation: worksheet), participants perceived the two formats as unrelated sets of tasks (see Figure 43).

Coin Calculation	Vertical Format Addition
A quarter + A nickel	(2.) 5 + 5 = 10

Figure 43. 25 + 5 in two different formats. *

* Partially hand written.

Angela added coins by saying 25 and then tapped a nickel while saying the next factor in the series of 5 (30). For vertically formatted written addition problems, she did this by talking through this process one increment at a time: "1, 26; 2, 27; 3, 28; 4, 29; 5, 30." In Angela's case the process of adding coins did not transfer into the written format, a more abstract symbolic process of manipulating numbers.

Although the participants had previously acquired strategies to solve mathematical problems, the participants responded to newly successful strategies as their latest universal tool, and abandoned their previous strategy. In order words, instead of accumulating concepts and strategies, and evaluating their appropriateness, they immediately attempted to apply acquired techniques to all tasks. It was very interesting to observe, and it raised the question of how to teach them the ability to discern the differences between situations.

Angela, nevertheless, showed promise; she displayed spontaneous learning and understanding. When she needed to count a group of several nickels, she spontaneously suggested arranging them in rows of 3. Previously she had counted coins in a random order; her suggestions came just after she had counted "smiley faces on a card in rows of three in increments in 3. This indicated that Angela has the ability to *understand* the concept in some degree—the "ah-ha" moment.

The mistakes, which the participants made, are not new or unique mistakes for young children; these mistakes are common in the early developmental path for typically developed children. The seriousness and significance of these mistakes are the participant's ages, 21, 16, and 10 years. The counting mistake (counting an object twice or skipping counting an object) made by Big Red is a mistake made by 2 or 3 year olds.

The questions we might encounter are "Would and/or could he pass this developmental age?" and "Is it merely significantly delayed or a definite deficit?"

Visuospatial Perception Difficulties

Several reasons have been considered for these missing early developmental milestones in WS. The visuospatial perception difficulties may impact the development of children with WS in more ways than discussed in the literature. The difficulties in visuospatial perception and tasks that rely on such perception have been reported in the literature from a number of sources (Bellugi et al., 2001; Mervis & Klein-Tasman, 2000; O'Hearn & Landau, 2007; Semel & Rosner, 2003); yet the relation of this issue to problems using math have not been clearly stated and may not be fully understood. On the other hand, the visuospatial skills and their association with performance in math in TDC and in Fragile X syndrome have been recently reported, and that gives the possible explanation for the deficits noted (Bull, Espy, & Wiebe, 2008; Mazzocco, Singh Bhatia, & Lesniak-Karpiak, 2006).

While computation does not particularly require visuospatial perception, recent articles have pointed out that visuospatial perception and discrimination appear to be important in order to understand basic math concepts (Aunio, 2008; Booth & Siegler, 2006; Bull et al., 2008; Holmes & Adams, 2006; Jarvis & Gathercole, 2003; Jordan, Hanich, & Kaplan, 2003; Mazzocco et al., 2006). In comparing the test results, a strong correlation between visuospatial ability and mathematical ability is apparent (Bull et al., 2008; Mazzocco et al.;, 2006). Based on their longitudinal study, Bull, Espy, and Wiebe (2008) suggest that the function of visuospatial perception on the formation of short-term memories during the first year of primary school (age 4-5) strongly correlate with achievement at age seven in math. The ability to organize and process the visual stimuli is a necessity in establishing the sense of magnitude; however, the deficits in visuospatial processing of WS seem to hinder the ability to absorb the concept of quantity (Geary, 2004; Mazzocco et al., 2006).

There are many theories of how visuospatial difficulties interfere with mathematical development. One is that visuospatial perception hinders the development of the sense of magnitude further impeding an established mental number line. Also, alignment of digits is very important to understand place-value and to borrow and carry in arithmetical calculations (Mazzocco et al., 2006). The concepts of borrowing and carrying are a known difficulty area for individuals with WS.

Big Red was not able to tie his shoes, to fold a paper in thirds in order to put it in an envelope, and had difficulty plugging in a cord. He did not develop the sense of magnitude and has difficulties with very fundamental mathematical concepts. He is not necessarily typical of the entire WS population, but his symptoms in the visuospatial area and his ability in mathematics are suggested in the literature. During free play or in instructional settings, children engage in various types of everyday math-based activities, and they intuitively learn these mathematical concepts. In contrast, because of their visuospatial perception difficulties, children with WS may participate in the activities but be limited in that they learn from these ordinary activities.

Attention Deficits and Slower Processing Speed

All three participants have different measures of attention deficit disorder, as well as different mental processing speeds. Big Red had a very difficult time focusing on tasks, he was quiet sensitive to stimulation, especially auditory stimulation, and had difficulties in self-regulation, Roxie showed these tendencies, though to a less severe degree. Angela, in contrast, was fairly well disciplined and maintained focus well in comparison to the other participants. Attention deficit alone affects performance; however when it interacts with processing speed, the difficulties becomes much clearer.

There is no standardized definition of processing speed, and it varies depending in discipline. In addition, the mechanisms underlying processing speed remain elusive, and the factors involved in processing information, perceptions, thinking, and output speed are still speculation and debate (Benner, Nelson, Allor, Mooney, & Dai, 2008; Shanahan et al., 2006). In this study processing speed refers to how fast participants solve a task. The comparison among three participants and their performances during the coin discrimination tasks revealed several differences that Big Red processes much more slowly than Roxie and Angela, perhaps partially due to his problems in fine motor control. By comparing their use of tempo with the song "Finding the Bigger Number," Angela was slightly faster than Roxie. Big Red was about half of Roxie's speed. Big Red required more time to register questions, to cognitively solve the problems, and to physically execute the tasks than did Roxie and Angela. Roxie missed more concepts and facts in math than Angela: that missing pieces slow down her process speed. For example, Angela could hold up 6 fingers by 5 and 1 concepts, while Roxie needed to hold up fingers one-by-one.

In addition to slow processing speeds, the attention problems in WS also make the matter worse. As seen with my participants, they were always aware of the video camera. I assumed that after five or six sessions, they would forget that I was videotaping, but this was not the case; occasionally, they would stop in their task to wave and say hello to the camera. While working on a task, if some distraction occurred, the participants lost their focus, which necessitated starting from the beginning again. For this reason, Big Red did not have many opportunities to go through the practice sequences and attempt to solve the math problems. He would restart, become disturbed, stop and have to star over. While he was the one who required the most practice, he was also the one with the least opportunities to practice. Angela processes faster and has a relatively good attention span. In contrast, Big Red both processes more slowly and has much more difficulty concentrating on a specific task. If the processing speed could be enhanced there would be less of an opportunity to become distracted. While attention deficits and processing speed might not be the primary factors of mathematical development, they do influence overall mathematical performance and training.

Fine Motor Skills

While fingers can be a very useful and handy gadget for individuals who learn counting and number sense, because of difficulties in fine motor skills, Angela could not effectively use her fingers. While working on Angela's finger dexterity, a short musical phrase was established. The lyrics suggest putting down the pinky first and then holding it with the thumb. During the music camp for the young children with WS from 6 to 12 years of age, there were more children who have the same type of pinky as Angela has and they have the same difficulties as Angela did. "Thumb and Pinky Meet Each Other" (see Appendix A, Figure A-3) was used to help Angela as well as with the children at the music camp. The other finger gestures which I practiced with Angela could be also used to develop fine motor skills.

Missing Developmental Concepts

When limited ability to calculate is further scrutinized, the more obvious it seems that this might not be due just to misunderstanding the concepts of addition and subtraction. Because of difficulties in 5 identified areas, the three participants appear to have missed many developmental milestones in their mathematical development. It is relatively easy to recognize that in order to answer questions requiring division, an individual must also understand the concepts of addition and subtraction, and know how to handle remainders. However, it was not as easy to identify the lack of prerequisite concepts required to handle basic addition. To perform addition, individuals must fully grasp the number sense, which includes the meaning and use of quantity, and composing and decomposing. In addition, understanding of the concepts of comparison between two numbers, adding to and taking away, and grouping and place value is beneficial and can expedite the processing speed.

Big Red was able to verbally count using integers of 1 to 100, and this seems to be his only solid comprehension he has about *number and operations* area. He counted by multiples of 10 or 5, to reach 100. (We did not attempt to count beyond 100.) However, he appeared to not understand how to use his ability to skip numbers (that is using multiples of 5) for nickel counting. In this respect, Roxie was more skillful in mathematical operations than Big Red.

Roxie had already internalized some basic number skills including magnitude, and cardinality. She could subitize up to 2 or 3 distinct objects but preferred to count each object. She still struggled with groups of more than 4 objects; she needed to count each object individually rather than using smaller sets of group to reach a total in order to expedite the process of counting. She could neither group the objects nor compose and decompose numbers. In contrast, Angela showed, even though she did not completely comprehend it, the ability to group objects, and compose and decompose numbers, especially using units of 5 as an aid. Angela also showed that she could use of the concept of the complement of ten, which was introduced to her during this study. In addition, she demonstrated an understanding of the concepts of addition and subtraction. Angela was able to advance her mathematical knowledge base on this foundation. However, Big Red and Roxie could not advance to the next concepts because they did not possess the foundational skills that were needed, and I had to develop an understanding of their functional level. Big Red, especially, needed to begin with the basic concepts of magnitude, and this lead to the realization of the length and depth of the difficulties he faced in mathematical development.

The importance of the "key elements" of mathematical development was especially apparent in the use of the concept of "teens." While transcribing Roxie's video clip, it became apparent that while Roxie used the song "Finding the Bigger Number" to solve the addition questions, she had also counted using her fingers. While many typically developed individuals count a group of 20 objects by first grouping 10, and then continuing upwards using 11, 12, 13, etc: Roxie did not use this strategy, and she counted using individual fingers to add to her running total. It seemed that she might not understand the concept of numbers of the "teens." To verify this suspicion each participant was tested on the concept, which confirmed that none of them understood it. It was quite interesting since they enjoyed finding patterns in language, and they enjoyed different prosody. Why they did not master the language pattern of the 'teens' by the ages of 21, 16, or 10? After working on this concept, Angela could use it for coin calculation and addition. Roxie did understand the concept, but she did not use it spontaneously. She needed to be encouraged to use it and retained her preference to count each object individually. Unfortunately, Big Red never learned the concept.

According to Developmental guidelines for number and operations by Clements (2004) (see Appendix H), TDC understand "teen" as 10 and more by the age of 6. The "teens" issue indicates a lack in their development of number pattern recognition. Clements (2004) explains this as language structure of the number system. In English the words for numbers for the hundreds and thousands are regular; the words between 10 and 100 have irregularities. For example, 3,333 is said "3 thousand 3 hundred thirty 3" not "3 ten 3" (Fuson, 2004).

The participants demonstrated that they had missed a several mathematical developmental milestones: counting by multiples, magnitude and cardinality, and having the mental number line. The lack of these underlying concepts appears to be the root of their inability to add. The participants, especially Big Red, appear to be missing several key prerequisites of mathematic development. This suggests that while the difficulties in mathematics became obvious during kindergarten or early elementary schools, the fundamental problems might have their origin as early as around the age of 2 or even earlier. While the *weak* foundations of mathematical development were expected, the severity and gravity of the issue was not accurately foreseen. The following figures illustrate the expected foundation of their mathematical development prior to the beginning of the study (Figure 44) and again, after the project was completed (Figure 45). I was expected that even the participants had *weak* foundations, they might able to build their mathematical development based on their *weak* foundation as illustrated in Figure 44.

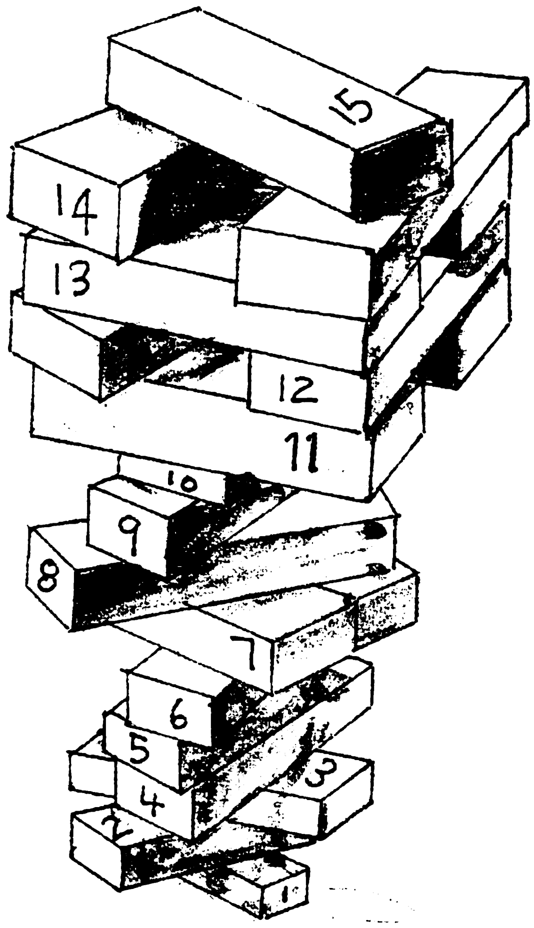


Figure 44. Expected mathematical foundation with the imagination of the game Jenga.

Illustration by Hyang Eun Lee

Unlike my expectation, their foundations for the mathematical development was practically *non-existent* especially for Big Red (see Figure 45). He memorized some facts in math, but he did not understand the concepts behind the facts.

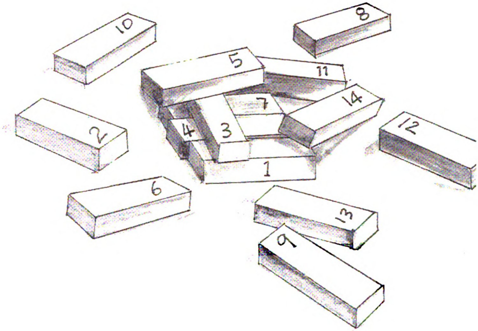


Figure 45. Perceived mathematical foundations after the project completion.

Illustration by Hyang Eun Lee

Learned hopelessness

Big Red, Roxie, and Angela all made numerous comments about their own perceptions of their performances.

Big Red	And think about me I have trouble with math. (Music) really help me. It really gives me ability to work with math in easier way.
Roxie	“I always messed up” “messed up every time.”
Angela	“I cannot like… do like… the hard math”

In addition to Big Red's verbal statements, the different attitudes and body langue he held towards math related tasks, and music-related tasks suggested that he was keenly aware of his relative inability to use math. When he was requested to work on math tasks, he kept popping up and down from his seat, or if he was standing, he moved back and forth and his shoulders were downcast and dangling. He asked repeatedly, "How am I doing so far?" and would nervously touch his chin or temple. "Let me guess." He specifically chose the word "guess" instead of "find" or "see" when he tried to figure out the different numbers of the object cards—"guess." While he offered answers to different problems, he keenly searched the researcher's facial expressions instead of concentrating on the task, props, materials, and actually solving the problem. He used the researcher's facial expressions as a barometer for the accuracy of his answers. In contrast, when he worked on his musical task, his shoulder was opened and broadened. He sat up straight, made eye-contact, and his eyes were sparking with expectations.

Roxie was readily distressed by her confusion with mathematical concepts and was too willing to quit and give up too quickly. While she said that she did not want to make mistakes, the missing elements of her mathematical development inhibited her performance and really upset her. Angela did not clearly show her distress regarding math related task until she commented about her statement about "hard math." She categorized tasks as easy or hard, and she defined "50 + 20"was "hard math." She was definitely aware of her limitations concerning math.

The participants showed learned hopelessness to different degrees: Big Red was terrified, Roxie agitated, and Angela concerned and aware. After years of frustration and repeated failures gave them reason to believe that they are not able to use math, something which is a fact to some degree. They were all missing some of the basic tools necessary to solve mathematical tasks. They felt hopeless, but it is a "learned hopelessness" which might not be the most appropriate term in their cases. This hopelessness leads to "giving up"; they are ready to give up at any give moment. The years of experience with math tells them 'no matter what, I am not going to understand the concept.' One more trial, or one more day of practice could make the breakthrough, but they do not even want to try. That eventually means no attempt, no opportunity to learn, and no gain. That is the real problem in 'hopelessness.' When their answers were correct and when they truly knew that they had succeeded, they were truly happy and gained a huge boost to their self-esteem, at least for the moment. It they could achieve more successes and victories, especially in their "war with math," they might be able to reverse some of this learned hopelessness.

Judgment: Music as a Therapeutic Medium Based

on the Results of this Study's Interventions

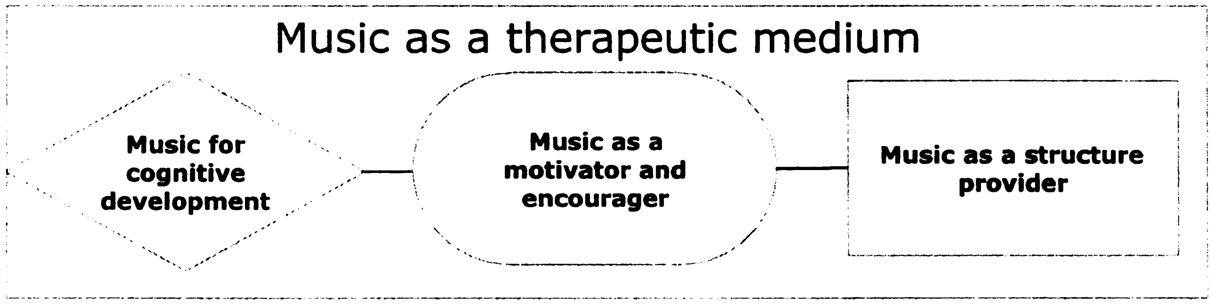


Figure 46. Music Therapy Theory Diagram.

The discussion of the use of music as a therapeutic medium for individuals with WS will consider three primary functions: music used to advance for cognitive development; music used to encourage and motivate; and music used to provide structure. This discussion will also consider the benefits, limitations, and additional considerations drawn from the responses to the interventions.

Music for Cognitive Development

Music used as a memory aid or a mnemonic device proved successful and was a useful tool for the participants of this study. The key to this success was mainly the structure of the songs. Participants could quickly learn and easily sing the mnemonic songs developed and used in this study (other than the songs "How Many Pennies in a Quarter?" and "Five Pennies Make a Nickel.") The participants memorized the songs in fewer than four iterations and showed no difficulty in retrieving the melody, but the information contained built into these songs had a little different aspect. Although the melodies were simple and catchy, if the lyrics were too verbose and became distracting and meaningless, the result was that the participants frequently used incorrect lyrics. For the songs "How Many Pennies in a Quarter?" and "Five Pennies Make a Nickel," the participants randomly replaced "penny" with nickel, dime, or quarter. In later sessions, these two songs were replaced with "Nickel 5, Dime 10, and Quarter 25" which is much more succinct and directly connects the name of the coin to its value.

As suggested in the literature review, songs used as memory aids and mnemonic devices should be succinct and the musical motives for each concept need to be distinct. In addition to a distinct melody, using interesting sound effects from different instruments (such as rain sticks, glockenspiel, and wind chimes) seemed to help hold their attention due to their affection for different sounds. Concise lyrics and distinct musical motives appear to be the key to success for these songs to work as mnemonic devices.

Learning involves several steps. While facts can be memorized fairly easily using mnemonic songs, the other aspects of learning—comprehension, application, the analysis and synthesis of the information, and the ability to apply knowledge to new situation—are not as easily transferred. Ann Badeau (Carpenter et al., 1999, p. xiii), a second-grade teacher said, "It is only when you build from within that you really understand something. If children don't build from within and you just try to explain it to a child, then it's not really learned. It is only rote, and that's not really understanding." Understanding of knowledge cannot be forced and music therapy intervention cannot provide the illuminating or the "ah-ha" moment. However, music therapy interventions could give individuals with WS more opportunities to have the "ah-ha" moment. Very few opportunities are available for individuals with WS; because they avoid working on the math related tasks as much as possible. This is because they have tried it before and they knew they do not perform well on those tasks.

The participants had difficulties applying the information they memorized to new situations. Strategic songs were designed to help compensate for this difficulty. While the participants were readily able to recite the lyrics of the mnemonic songs, using those songs as aids to solve math problems proved a different issue. The mnemonic songs were not used unless the participants were given specific instructions to use them. Knowing the song "Nickel 5, Dime 10, and Quarter 25" may have provided the answer to the direct questions of "how many cents in a nickel," but it did not immediately help them identify the total amount of a mixed group of coins. That would be an example of applying the knowledge gained. In order to calculate the value of a more random combination of coins, the participants needed to classify them first by type, using a coin-classification-chart, and then to calculate the amount for each coin: in increments of 25 for quarters, tapping method for dimes and nickels, and in increments of 1 for pennies. Verbal instructions were used to guide this process. "Finding the Bigger Number" was developed based on these repeated verbal instructions; it worked very effectively to guide the process using written addition. The participants were able to solve the written addition questions slightly faster without verbal instructions.

The mathematical tasks used in the study required the participants to follow a series of logical sequences, such as "Finding the Bigger Number," the lyrics of song guide this logic. The key element to development of this song was the analysis of the task, which in this instance was single digit addition, a relatively simple task to base a strategic song upon (see Figure 47).

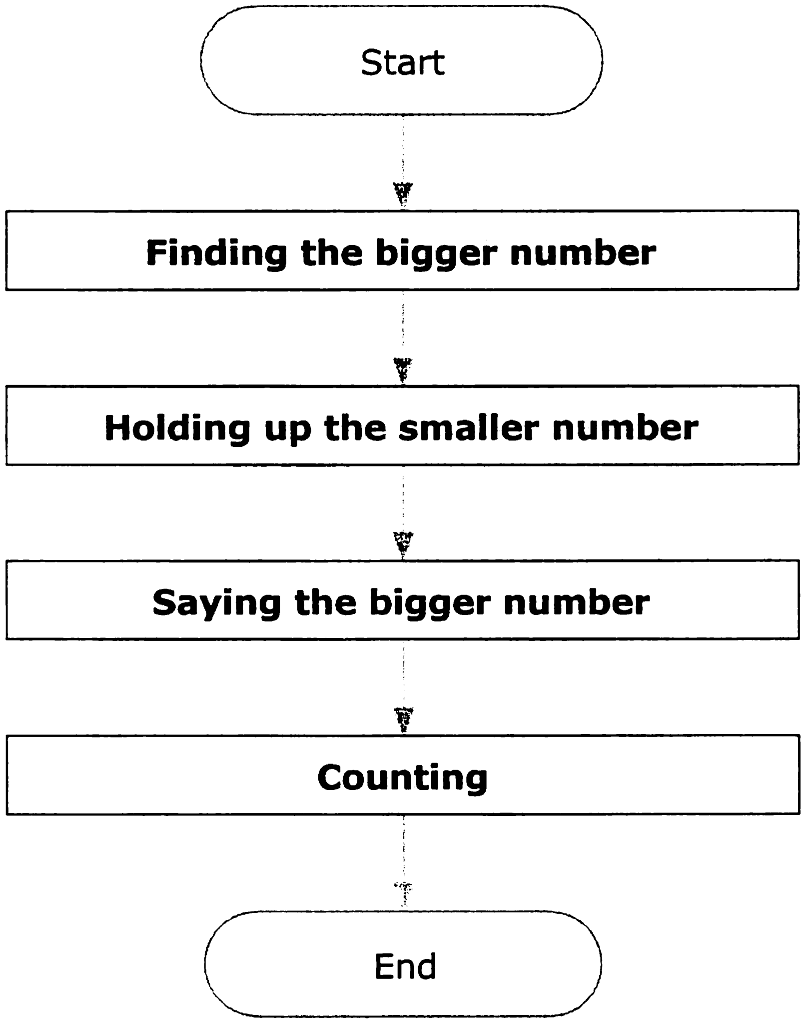
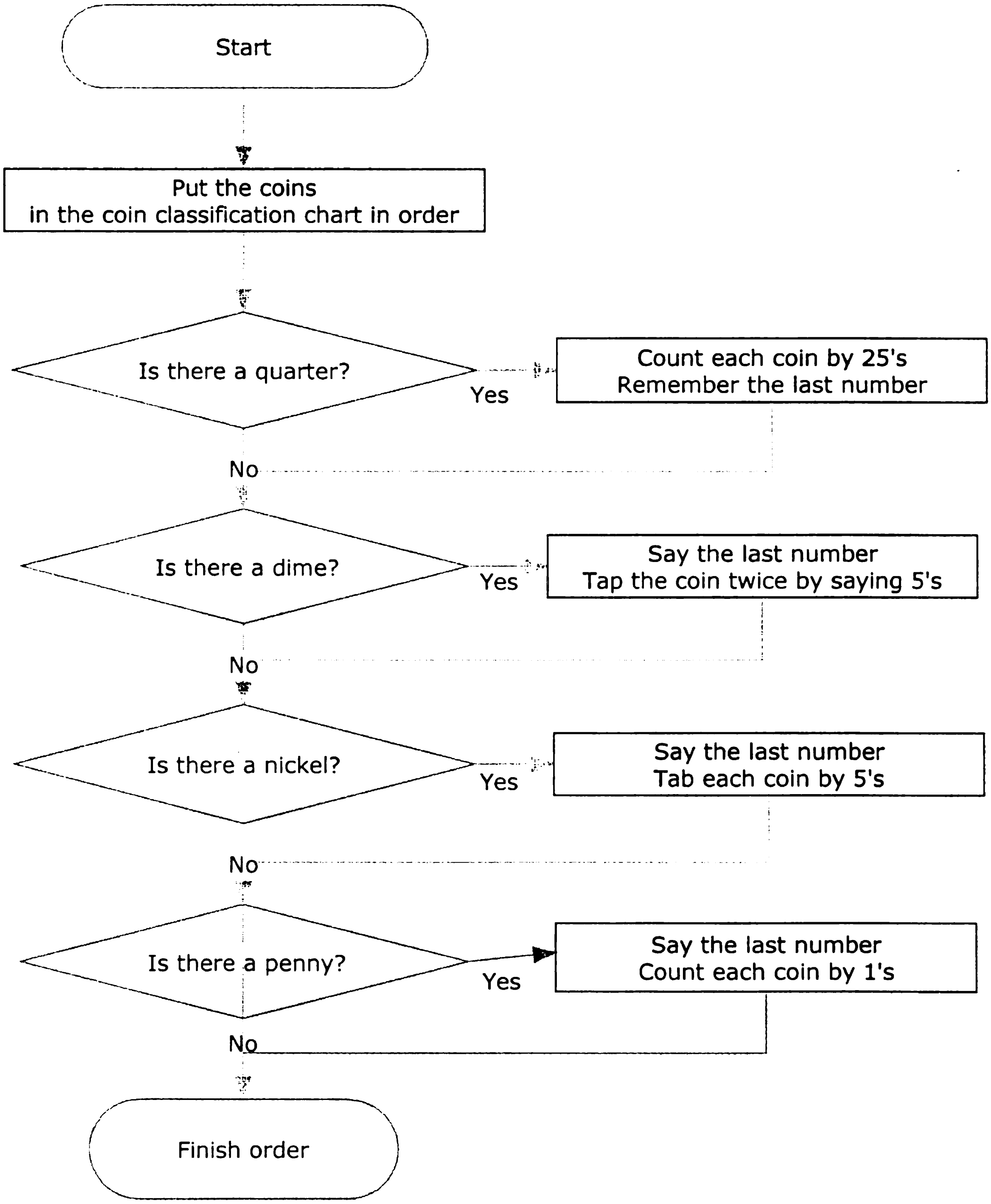


Figure 47. Flowchart for Finding the Bigger Number Song.

Other tasks required different types of decision making dependent on the requirements of the process. For example, coin calculation requires a rather complicated procedure. As shown in the following flowchart (see Figure 48), the song for this procedure should direct the learner to the next concept, and move them through progressively as indicated in the chart.

Figure 48. Flowchart for coin calculation.



The difficulty with this concept is that each condition statement of the point of decision needs to have a distinct melody. If the melody is too similar to others or if each condition statement has a much different verse, individuals with WS will mix-and-match, and lose the process embedded in the song. In both cases, "How Many Pennies in a quarter?" and "Five Pennies Make a Nickel," the participants reshuffled and mixed the lyrics. This makes composing strategic songs much more challenging than mnemonic songs. If the task is appropriately analyzed, and the logic flow is developed considering their skill level, individuals with WS can be taught the new strategies by strategic songs. These songs can be beneficial and effective for supporting their particular mathematical task.

Music as a Motivator and Encourager

The participants showed the advantage of using music as a motivator and encourager and suggested that a music therapist can effectively use music for that purpose for individuals with WS. Gfeller (1999) states that "Music is a valued, enjoyable stimulus and social event for many people. As such, the opportunity to listen to music or participate in musical activities can be used as *a reinforcer* (reward) in behavior modification programs (p.267)." In addition to these, music attracts individuals with WS as a magnet draws iron or steel objects.

At the camps, conventions, and meetings of individuals with WS, they gathered around a performer using an instrument forming lines similar to those in a magnetic field. At these events, if there was music, there were individuals with WS and if there was no music, they had a tendency to make music by singing and tapping. They crowded so close to the performers that the performers did not usually have elbowroom to play their instruments. The staff members at these events often warned performers of the tendency of WS to crowd too close to performers, and tried to set the boundaries. Even then, the performers were usually overwhelmed by the crowd and their enthusiasm. Throughout this research, indicators remained strong that music can be a motivator, and serve to encourage participating math-related music interventions for individuals with WS.

Angela's willingness to participate in music therapy session despite her physical discomfort suggests that music has some power to alleviate this discomfort and to motivate her to work. Big Red demonstrated the benefit of music activity for mathematical development by his attitude and behavior toward music-related math tasks as opposed to math tasks that did not incorporate music. As previously mentioned, his attitude and behavior altered dramatically when he was presented with a task involving math. He became very tense, and agitated. However, when this same task incorporated music, in even as simple a form as asking a question in a song, he relaxed. Roxie typically sighed and rolled her eyes when she was given a worksheet, but she swung her forearms from side to side along to the tune of "Finding the Bigger Number" while she worked on the worksheet. When Angela worked on her worksheet and could not remember how to do solve a problem, she stopped, tapped her chin and looked up the ceiling. When she was informed that she could learn a song that might help her face lit up with a big smile. These are all instances indicating that when math tasks are synchronized with music, the participants perceive a math task that incorporated music as a musical task more than as a math task at least, until they begin to have difficulties.

The participants enjoyed listening to short selections of musical pieces as a reinforcer, in addition to verbal reinforcement, or just by itself. At the beginning of project, verbal reinforcement was provided in addition to musical reinforcement, but this was no longer necessary after a couple of times of demonstration with verbal and musical reinforcement. Angela was fond of the little excerpt from "Congratulation and Celebration" by Cliff Richard. This song used to praise her successes, and she always wanted to hear the excerpt again. She often asked to for this excerpt to be played, but to keep it as a reward it was only played when she successfully accomplished her tasks. The music reward was more powerful than was verbal praise.

Roxie also enjoyed *Congratulation and Celebration*. However, there was a short improvised musical phrase used to congratulate Roxie, and she preferred to listen to it rather than *Congratulation and Celebration*. In Big Red's case, giving him the opportunity to play his drum after a success worked as encourager. At the end of a task or at the end of a session, we played songs together; we used the songs that supported tasks or any other music he chose. He liked sharing musical moments with others, and he took our playing together as a reward.

Minor descending scales or minor chord progressions were used to indicate incorrect answers rather than spoken responses. Since the participants often required redirection, this was a better way to handle the errors than to repeat negative statements. Because they were easily frustrated and often ready to give up, these musical phrases conveyed the same error message but in a more constructive manner. In Big Red' case after I played these minor themes, Big Red would look at me, smile, and say, "Let me start over." Roxie usually burst into laughter and started the task again. Angela typically said, "That's so cool." They needed to know that they had not gotten the correct answer, but at the same time their disappointment should be turned into a positive and reinforcing experience whenever possible. It is a way to avoid self "put-downs" affecting their self-perceptions of their math performance.

Using music to focus attention was discussed in the literature as a potential tool. Music does hold their attention; however, the participants sometimes became too attracted to the music itself and could not remember their task or did not want to work on their task. Big Red would harmonize with the song or tap the table instead of finding the designated coins. Roxie liked to dance with the songs, and more often than not, she danced to the music. While Angela worked on finding designated coins, she moved her hands too quickly to match the tempo of the music and she was not able to find the coins. When I provided some background music while she completed a worksheet, she often looked away from the worksheet and said, "I like it" or "That's pretty." There is a very fine line between music as an attention holder or as a distracter. Music has a powerful influence on the participant's attitude, mood, and behavior. That power allows music to work as a motivator and encourager for individuals with WS.

Music as a Structure Provider

From the beginning of music therapy history, the time aspect in music and the physical structure (forms and patterns) in music have been pointed out as one of the major therapeutic tools in music. Gaston (1968) stated that "Music is structured reality (p.24)" and Sears (1968) pointed out that "The music must be carried through in its time order (p.35)." A musical tempo helps structure the perception of time and can be used to adjust processing speeds of individuals with WS when music accompanies a task. The structure of music can help to organize information in order and provide opportunity to express their feelings and emotions in musical context. Lathom (as cited in Peters, 1987) states that "For the child [or adult] whose world is often a confusing chaos, the order of music is a welcome structured experience in which the child [or adult] may feel free from confusion and safe in the ability to predict the activity and the person associated with the music" (p. 51). Musicing and listening to music is not a 'total' chaotic experience; there are expectations, unwritten rules, and certain level of predictabilities. As well the order and structure in music provides the framework to work on the participant's mathematical tasks.

There is relatively well-established theory and practice in the role of rhythm and tempo in physical movement (Thaut, 2005). Rhythmic auditory stimulation influences kinematic movement in a person, and it is reported that when rhythmic auditory stimulation is applied, the parameters, such as a cadence, spatial trajectory, and efficacy, in physical movement can be modified within a 5% auditory time perception threshold limitation[12] (Thaut, 2005). When Angela worked on finding different types of coins, she matched the cadence of her arm movement with improvised music. According to the tempo of the music, she moved faster or slower.

The time structure (or tempo) provided by music appears to be used to control process speeds in individuals with WS. It was possible to challenge Angela and Roxie to complete tasks by playing a song with a faster tempo, yet still within a threshold. If the tempo was changed too noticeably, the participants typically looked at me and wanted to

---

[12] The increase or decrease in 5 % from the current tempo of movement was suggested by a "Weber fraction." The "Weber fraction" is the percentage of the different thresholds obtained for different sensory stimulus. For example, in order to perceive the difference between electric shocks, a person needs to have 1.3 % difference between them. In comparison, to taste sodium, 8.3% difference is needed. It was found that the Weber fraction for auditory time perception is 5 % from 0.4 sec to 2.0 seconds interval auditory stimuli. The imperceptible changes in the tempo of music were essential to make training as comfortable as possible (Epstein, 1985; Getty, 1975; McBurney & Collings, 1977).

know the meaning of sudden tempo change; sometimes they appeared to become confused, other times they took as it a game and laughed at the assumed challenge. Although it is difficult to gauge how far they can be challenged, it is worth researching the possibility of using the tempo of the song to alter or enhance their processing speed.

Playing a musical instrument, especially those with keyboards, requires hand-eye coordination and visuospatial perception. When playing a song on a keyboard or an instrument, it requires the coordination of different muscle groups to play the next note or passage. The player needed to know the distance between the notes; calculate how much movement is required for the next note by the visual information; and then physically manipulate their hands to move that note. The relationship between instrument playing skills and visuospatial ability has been mentioned in anecdotal examples. The individuals who have better instrument playing skills, appear to have a better visuospatial ability. It is not clear whether they are able to play an instrument because they have a better visuospatial ability, or they have a better visuospatial ability because they practice with an instrument. However, it is clear that playing an instrument demands eye-hand coordination and practice with an instrument will strengthen this ability.

One unexpected benefit during the study was seen in the participants' ability to improvise. Big Red was particularly talented in improvisation. Roxie showed a great deal of possibility, but her improvisation ability appeared to not be fully developed yet. Angela's improvisation was made up of excerpts from miscellaneous songs rather than her own original work, though she exhibited that she has potential by embellishing given motives and phrases from a song. Big Red and Roxie seemed to know the basic chord progressions and were able to improvise songs. Big Red, without apparent conscious deliberation, extended three line lyrics into four line lyrics on the spot, and added a word phrase to finish the song with a tonic chord. Such a musical framework (physical structure) allows a musical conversation to be possible between two individuals, a conversation enjoyed by both participants and researcher.

Big Red has had drum lessons for more than a decade and has been exposed to many different musical settings. Roxie and Angela listen to music in a great deal, but are not involved with the formal music training. However, the participants were acquainted with the musical style. Their understanding of music allowed the music therapists to work with them at an advanced level.

Improvisation was used mainly for two functions: to express feelings and emotions, and individual compositions to match their specific cognitive needs. In Big Red's case, he improvised a song not only for himself, but for other two participants. When Big Red experienced difficulty counting increments of 25 for quarters, he was encouraged to chant the numbers (25, 50, 75, 100) and he improvised a simple melodic phrase to help him memorize the numbers, which worked very well. He improvised the songs "How Many Pennies in a Quarter?" and "Finding the Bigger Number," which became the two major songs used in this research; after the songs were introduced to and used by the other participants. When he was told that his songs had been introduced and used for other participants, he showed a great deal of pride in his accomplishment, especially as he knew the others through WS gatherings. He expressed his pleasure to have had a chance to help Roxie and Angela. Roxie was able to vent her frustration with her poor performance by her improvisation, and was able to positively redirect herself to focus more attention in her next effort not the final product (process vs. product).

Summary of Interpretation

The following diagram (see Figure 49) offers a visual relationship of several of the key elements discussed in this interpretation. Individuals with WS have many stumbling blocks during the course of their mathematical development. They have difficulties in metacognition, visuospatial ability, attention, processing speed, and fine motor skills. The length and depth of these difficulties vary by individual. While many of the effects of these difficulties overlap and are interrelated, each can require a different form of intervention and music therapy can offer various approaches to help them cope.

Metacognition difficulties can be helped by using mnemonic and strategic songs. While the participants did not have difficulties memorizing the mnemonic songs, they needed help with the procedure in solving the mathematical tasks. Strategic songs must be composed based on the steps or logical flow produced from the analysis of specific tasks. Practicing how to play the instrument by using music as a structure provider might be a tool to improve WS visuospatial abilities

Music used as a motivational tool and as positive reinforcement can help focus attention. The participants are drawn to music; they enjoyed listing, playing, singing, and improvising. Music is the powerful tool used that can gain their attention and redirect it or lessen outside distractions. Once music had their attention, they tried to focus more on their task; however, there is the risk that they may enjoy the music and become distracted. The time taken to process information can be affected by music tempo. The participants were easily influenced by music and its tempo. For fine motor skills, playing an instrument as well as working on action songs that require finger movement might be another tool to investigate.

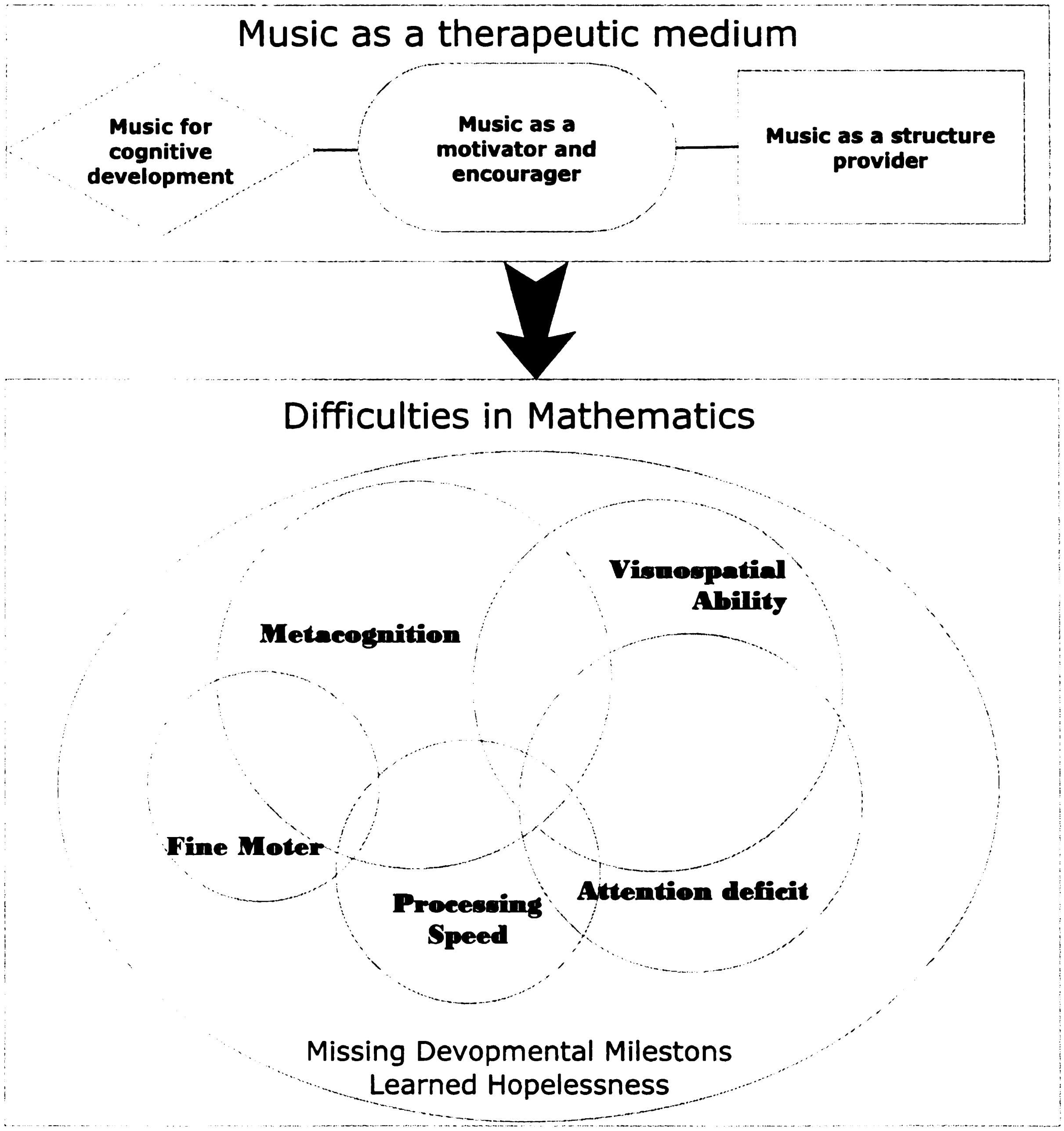


Figure 49. Diagram of interpretation.

Improvisation in musical structure could be used to aid their emotional needs and their cognitive needs for memorization. Their hopeless feelings were eased by singing encouraging songs. The various functions in music allow helping with participants' different needs. Understanding music's foundational function in human behavior is a highly useful to define how to skirt many of their cognitive deficits.

CHAPTER VIII

CONCLUSION

This study investigated the teaching of mathematical concepts to children with Williams Syndrome (WS) through music to provide a foundation for developing music therapy interventions in their cognitive development. The results of this study suggest a number of possible limitations, considerations, and suggestions for the practice of music therapy in relation to individuals with Williams Syndrome, and future avenues of exploration.

Suggestions for Music Therapy Practice

In this section, the thoughts, ideas, and clinical applications for music therapy practice are shared. Some are the direct observations from this study, and others are additional suggestions based on my experiences and observation with individuals with WS and their parents.

Think Like Individuals with WS

A key to finding a more effective way to help individuals with WS might be to attempt to think like them. Many unforeseen impediments became variables and factors during the course of this study. The specific example of Roxie's confusion with 2 fingers on one hand and 5 fingers on the other as representing "25," or Big Red's mistakes in counting, or Angela's shorter pinky. A greater understanding of neurological pathology and attempting to more accurately predict reactions might have helped to avoid potential obstacles that limited the effectiveness of the techniques used to advance cognitive development.

Hallahan and Kauffman (2003) summarized the differences in different genetic disorders as illustrated in table 5. Each genetic syndrome has different characteristic, strengths, and weaknesses. There is an enormous amount of information behind simple descriptions of WS, which is to be expected of any genetic disorder.

Up to this point, music therapists have overlooked these differences in cliental and applied practice based on prior knowledge, theories, and research regarding cognitively challenged individuals and other similar symptoms. With a vast array of genetic disorders and conditions in existence, it is impossible for any therapist to be familiar with all of them. There is no way to know each disorder in advance and in many cases, music therapists are overloaded because of large caseloads and required documentation. However, this study suggests that it is *necessary* to know each disorder in order to help therapists understand WS's cognitive development and become more familiar with possible techniques and approaches.

*Table 5. Links between genetic syndromes and behavioral phenotypes**

Genetic syndrome	Behavioral Phenotype: Relative Weaknesses	Behavioral Phenotype: Relative Strengths
Down Syndrome	Verbal skills, especially grammar Problems interpreting facial emotions Cognitive skills tend to worsen over time Early onset of Alzheimer's	Visuospatial skills
Williams Syndrome	Visuospatial skills Fine-motor control Anxieties, fears, phobias Overly friendly	Expressive language, vocabulary Facial recognition and memory Musical interests and skills
Fragile X syndrome	Short-term memory Sequential processing Repetitive speech pattern Social anxiety and withdrawal	Verbal skills, including vocabulary Long-term memory for information already acquired
Prader-Willi syndrome	Auditory processing Feeding problems in infancy Overeating, obesity in childhood and adulthood Sleep disturbances Compulsive behaviors	Relatively high IQ (Average about 70) Visual processing Facility with jigsaw puzzles.

* From "Exceptional Learners: Introduction to Special Education" by Hallahan and Kauffman (2003), p.126. Copyright 2003 by Pearson Education, Inc. Reproduced with permission

It is not practical to do intensive research on every incoming client's disorder. A solution might be to research a particular population and share information through publications and presentations. An individual cannot know every disorder, but music therapists, as a collective group, could hold requisite knowledge. There are experts in various areas, such as hearing impairment, neonatal intensive care, and physical rehabilitation. There should be more experts in genetic disorders. Individuals who have genetic disorders often share the same etiology, neuropathology, and characteristics within a range. This provides a good opportunity to develop a complete set of music therapy programs that incorporate research and develop assessment tools or interventions.

In order to further development of the profession of music therapy, it is necessary to examine the effectiveness of music therapy interventions, not only as they bring about improvement in individual clients, but also as they reflect on etiology and neurology, and as they are relevant to of the phenotypes of each client.

What is the Most Crucial "Key Element" in Mathematical Development?

While it is relatively easy to figure out what milestones the participants missed and which key elements the participants did not have, it was more difficult to define which milestones and key elements were indispensable to understanding "number calculation," "coin calculation" or other targeted mathematical skills. After the therapist "chooses the battle," individuals with WS need to achieve the target "goal" with as few new concepts as possible. Unlike typically developed individuals whose education attempts to build up a foundation for future education by learning all five mathematical foundation areas, individuals with WS are not always able to master even one. It may be analogues to working on the foundation for a pentagon-shaped building with ten stories. Individuals with WS may benefit most by building a triangular-pyramid-shaped building with one or two stories (see Figure 50). They might not need to build the foundation for the other part of the building. Therefore, it is crucial to focus only on the necessary concepts and skills. At this point, it is essential to research early mathematical development of children in order to identify the "crucial key element" in mathematical development for each target goal. The importance of assessment has been emphasized, but because of complexity and breadth, a standardized assessment tool has not been developed in the music therapy field. We often have the same difficulties as other areas working with other clientele. However, when music therapists can identify the crucial key elements for each target area, the assessment tool could be developed based on those key elements.

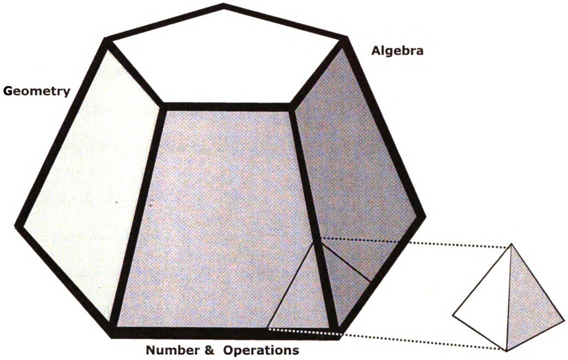


Figure 50. A pentagon-shape building versus a triangular-pyramid-shaped building.

Based on these assessment tools and identified key elements, music therapists could develop sets of music therapy interventions for at least three different levels of functioning. The first group is individuals with WS, like Big Red, who do not develop the comprehension of magnitude and cardinality. The interventions should be focused on developing magnitude and cardinality. The second group is individuals with WS who develop these basic concepts, but still struggle with operating numbers such as composition and decomposition. Based on identified key elements for the readiness of addition and subtraction, the individuals in this group need to work on those key elements. The last group is individuals with WS who develop a basic understanding of numbers and operations and are ready to move on to addition and subtraction. There are ways to help with processing addition using songs such as "Finding the Bigger Number" and "Number Buddy." According to this study, the chronological age of participants was not a precise indicator of the mathematical development age. Therefore, knowing the mathematical level of functioning of each individual and using an appropriate set of interventions, it may be possible to move to a higher level of mathematical development.

Music Score Reading and Ear Training

Music score reading is not an easy task for individuals with WS. Considering their visuospatial deficits, the lines, spaces, and symbols in the score have too much visuospatial information to assimilate. There are anecdotal reports by parents that children with WS gave up music lessons because they could not learn to read music. This does not mean they *cannot* learn to read music; there are some individuals with WS who can. However, since there are so many other skills for daily life that they need to master, perhaps their ability to learn by ear should predominate. Teaching individuals with WS to read music notation should not be a primary focus, and the inability to read music should not be a good reason to give up music lessons. There are other music pedagogical methods, such as the Suzuki Method, which emphasizes earning l "by ear" that would give better opportunities to learn how to play an instrument.

Another tool to teach an individual with WS to read music is a modified score. In music therapy field, score modification has been developed using numbers, letters, or colors. Roxie and Angela used the scores modified by letters (see Appendix E).

Individuals with WS have a very good memory for rhythmic patterns, but sometimes cannot figure out the melody by ear. Chromatic and accidental notes in music often confuse them, and large intervals often pose difficulties in figuring out the next note in a sequence. They might not need to have notation for the rhythm, but the adapted melody notation could help a great deal when playing instruments.

Ear training appears to be necessary to enhance the ability to learn music by ear. As mentioned earlier, the participants in this study had difficulty perceiving half-step intervals, leaps, and accidentals. Similar tendencies were noticed during interactions at the music camps. Many individuals with WS who are able to play keyboard instruments have difficulty finding the notes with accidentals and chromatic notes. While they were able to identify typical intervals and progressions, they had a hard time figuring out less familiar melodic lines.

Besides traditional ear training, another method can be used in music therapy. When individuals with WS listen to music and want to play, they learn the chorus part first, and then the verses. The bridge and introduction are often the last section to be learned, or they may never learn those parts of the song. iTunes, Windows Media Player (digital media players for computers), or other MP3 music players with minute and second indicators which displays how many minutes and seconds have either elapsed or remain might be very useful tool. When they do not grasp a certain part of the song, those players can be manipulated to play the exact spot (for example, 3 min and 22 seconds is the starting point for the bridge). Then the individual can work on small segments of music, instead of hearing the entire song and losing focus. Compact disc players and tape players could work in the same way using the rewinding function, but they do not work as precisely as digital media or MP3 players do. The other benefit of using an actual song for ear training is motivation. When I used this method for the campers at the WS music camp, I could use their favorite songs, and they were highly motivated to learn. They appeared not to perceive this process of ear training as a tedious or unnecessary chore.

Choose Your Battles

There are five major areas in preschool and kindergarten mathematics: number and operations, algebra, geometry, measurement, and data analysis. There are six major sections in the number and operations areas alone: counting, comparing and ordering, addition/subtraction, composing and decomposing, grouping and place value, and equal partitioning. Each of these areas contains several key elements. In the case of WS, participants did not exhibit the ability to apply analogies or similarities. They did not transfer techniques or tools across tasks, such as from physical (coin) calculation to written calculation, or *vice versa*. While written mathematical tasks are dominant in academic settings, the usage of more practical forms to handle daily life skills is an issue of some debate.

There are ongoing discussions on the WS online discussion server concerning mathematical difficulties and strategies to overcome difficulties in the WS population. I monitored the server discussions to help develop a better understanding of the needs and wishes of parents. One discussion began with a parent asking for help for her daughter's mathematical difficulties. This parent focused on what the parents did to address their children's difficulties, as did the responses. The age range of the WS children in the discussion appeared to be from eight to 20 years old. After a long debate about the best way to cope with mathematical difficulties, the discussion split into two fundamentally different groups of parents The first group had a "been there/done that," attitude and felt that further gains were not worth the effort. They felt that mathematics was a weakness and that the emphasis should be on their child's strengths, not weaknesses. The other group believed that their child should be given as many opportunities as possible to learn. One parent said, "I don't want to give up while my kid is in elementary school." There are so many difficulties to overcome and so little time in which to do so. The parents worry about what will happen when they are no longer around Sometimes they only wish that they may live just one day longer than their child. Some basic mathematic skills are not academic skills, but life skills. No one but these parents can make these decisions, but we, as therapists, can help inform their choices.

The decisions are not in the therapist's hands. We can merely address aspects of math and the benefits and disadvantages of working on them to guide the parents' decisions. Besides mathematical difficulties, individuals with WS have other major issues that affect their daily lives: medical issues, reading difficulties, emotional crises, etc. Instead of sprinkling water over a burning house, we need to focus the fire hose on the origin of the fire, one room at a time. The wishes and needs of individuals with WS and their parents need to be seriously taken into account. There are many areas where music therapists can assist individuals with WS, and teaching parents so they can make informed decisions about what they want for their child is the most important. "*Choose your battles*" is the best approach.

Miscellaneous Thoughts

Recorded as opposed to live music. As explained in the analysis and interpretation chapters, the same songs for all three participants were used, but with different tempos, especially for Big Red. This was not planned but was a response to their different processing speeds. The songs were slowed downed or the tempo was increased. The tempo adjustment between Roxie and Big Red points to the need to respond and spontaneously adjust to the needs of the individual. The tempo of the songs, especially strategic songs, must match with the individual's processing speed. If the tempo of a song is faster than their processing ability, or the learner does not understand one of the concepts in the song, and the song will not be beneficial for that individual. Therefore, when each song is introduced and practiced, live music has a considerable advantage over recorded music. With live music, the tempo and content of the song can be adjusted and individualized. Only after the individual masters a song should the song be recorded and used as a tool to maintain the acquired knowledge.

Managing with coins. The name of a coin is a practical concept. However, is it absolutely necessary? When Big Red, Roxie, and Angela worked on coin tasks, their struggles reminded me of when I first moved to the U.S. I had a difficult time learning to quickly identify different coins when I paid for merchandise. Knowing the value of each coin is more important than knowing the proper name of the coin. And, as I admitted earlier, I did not know the names for 5 and 10 cents until this study. "The big one is a quarter, and the value is 25 cents." Within that simple statement, individuals with WS need to understand the spatial concept (big), the name of the coin (quarter) and the value of the coin (25 cents). It might be better to focus on the value of the coin first and then move on to the name of the coin.

When I moved to U.S, it was not easy to distinguish between different coins; why was the smallest coin's (dime) value more than a larger one (a nickel)? Silver shiny coins that look similar and a small coin that has more value do not make the task easy. It was not easy to determine the exact amount quickly, especially because of quarters. While other coins are based on 5s and 10s, a quarter falls out of logic and developing strategies took me quite a while. Eventually I had my own "ah-ha" moment and started counting 25 first and then adding the others, just as I did in teaching the participants.

Meanwhile, instead of figuring out the exact change, I gave cashiers only dollars or let the cashiers pick the change from a handful of coins. It was not easy to stand in line paying with cash, trying to identify each coin, and then calculating the total needed while others stared at me—making me uncomfortable. It is important to be able to solve money related mathematics but the processing speed of the task is also a very important factor in daily transactions. The participants' slower processing speed in general adds more weight to their difficulties in coin calculation. Some individuals with WS might need to learn to ignore the coins and use dollars that add up to more of the sum needed and simply receive change. At the end of the project, Big Red learned the following song, and practiced it with paper money. That might be the helpful for some individuals with WS.

One More Dollar

Big Red

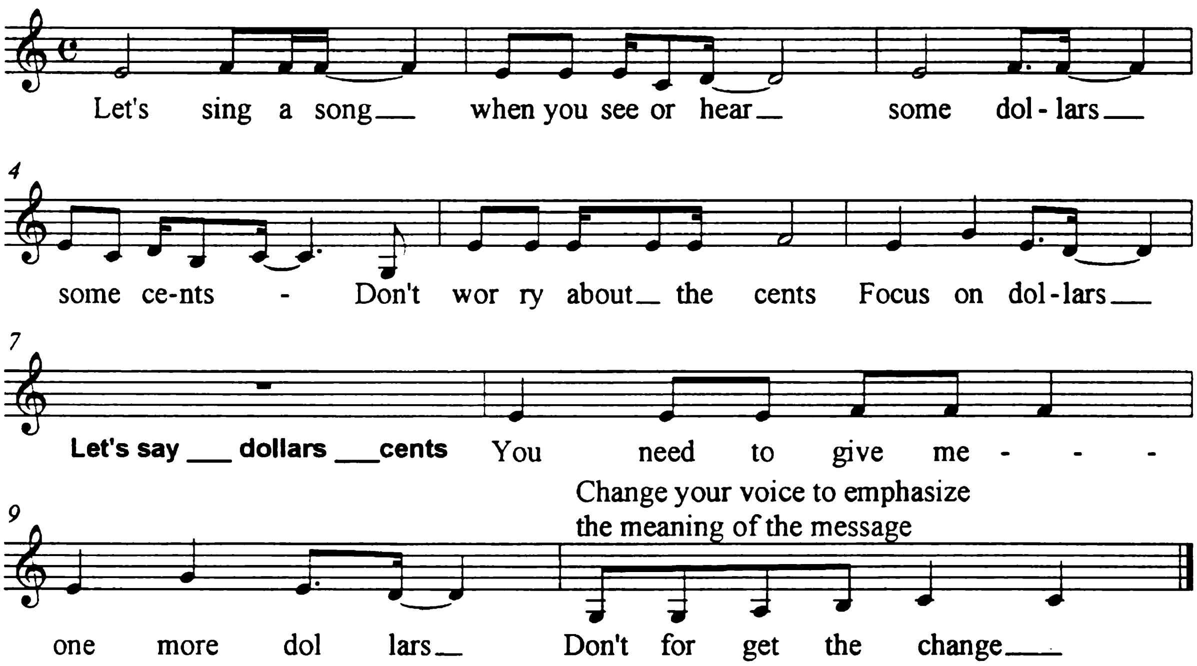


Figure 51. Big Red One More Dollar.

Importance of props. Special education and music therapy practices rely heavily on visual props rather than tactile or auditory props. Individuals with WS have adequate vision, but their perception and ability to process visual information is different, and it is unclear how much it deviates, and how big a problem it may create. It was interesting to find props that did not rely on visual information. Although the greatest effort was made to use tactile props in this study, it was almost impossible not to incorporate visual materials. This project was a great example of the predicament therapists face when choosing which props to use for the WS population. For example, the number cards require visual information. I was wondering if there was any other way to present the same information. The following questions exemplify some unanswerable questions I had during the project:

1. "Is it necessary to use tactile information, like felt-tip stickers or push pins?
2. Because individuals with WS need to improve their visuospatial function, should only visual presentations be used?
3. Is it possible to start with tactile information coupled with visual cues and then gradually focuses only on visual stimuli?
4. How do auditory stimuli fit into the picture?

The participant's performance in organizing coins was greatly improved by the coin-classification-chart. While Big Red did not have the benefit of the coin-hand-props, Roxie and Angela understood counting by different units, i.e., hands and fingers. Big Red's inability to distinguish between coins is most likely due to his lack of comprehension of the comparison words: *normal, big,* and *tiny*. Without those concrete reference points, the words *normal, big,* and *tiny* were meaningless to him. It might be beneficial to have some tangible reference. For example, I used three real coins (without a penny) as a reference point, or a card that reproduces the actual outline of each type of coin. These props could be used as educational tools, or on a quick reference chart, like typical consumers employ a tip chart.

Transcription of a session as an educational tool for music therapy students whose first language is not English. Transcribing the sessions produced an unexpected benefit. As a non-native speaker, a major struggle was to improve the way I could articulate in English. After several sessions, I found that I made many grammatical mistakes and did not have enough verbal expressions to explain the mathematical concepts to the participants. There were certain things I could not succinctly articulate, and I felt there was a better way to explain the facts and concepts. I looked for professional help and found a speaking tutor to help me with these difficulties. At the end of the sessions, I realized how much my English had improved. The process of transcribing gave me opportunities to monitor my own speech patterns, mannerisms, and mistakes. Working on specific expressions for particular situations gave me the chance to learn new expressions and verbal usages. Sometimes, I did not understand the meaning of what the participants' said, but the video material allowed me to review the clips with another therapist and figure out the meaning of what was said. For example, when Roxie sang "nothing to it" for "You Can Do It," I perceived the meaning as "there is nothing she could do about it" instead of "it is easy." Since the meaning did not fit into the song, I asked a music therapist and she explained the meaning to me. Another example was Angela's *thingamabob.* At the first listening, I thought she was talking gibberish. Two sessions later, she used it again, I was not sure about the meaning, and I again asked another music therapist what *thingamabob* meant. I might have heard this before, but did not grasp the meaning of it. Therefore, I think that transcribing the sessions and walking through them with a supervisor or peer could be very beneficial in working on subtle language skills, which are necessary for non-native speakers.

Attention and study room environment. The question about a study area environment was raised when analyzing the data. Since the participant's were easily distracted by even minor incidents, especially auditory stimulation, is it better to have fewer distractions in the environment to keep them on task, or is it better to work through those distractions so they could improve their self-regulation skills? While this may generate differing opinions, the issue does need to be thoroughly examined. At this point, I am in favor of having fewer distractions. Individuals with WS need to have an environment in which they can truly focus on the task. Because of their distractibility, figure-ground difficulties, and slow processing speed, new knowledge did not always go through their short-term, and into their long-term memories. Providing an atmosphere with as few distractions as possible might be the best way to learn new information for the WS population. Self-regulation skills could be simultaneously treated in other settings for generalization or by other interventions that are designed to address those skills.

Limitations and Other Considerations

Mathematical Difficulties are the Tip of the Iceberg

Mathematical difficulties in individuals with WS appear to be the just the tip of the iceberg of cognitive limitations. Visuospatial difficulties, fine motor skills, attention difficulties, and self-regulation deficits are entangled in the iceberg. I performed a review of the literature of mathematical development in WS prior to this project and focused on the use of addition and subtraction. However, the actual difficulties originate in more basic math skills that were overlooked until they became apparent in the middle of this project. Big Red's inabilities indicated that his problems were not caused by a *weak* foundation, but by *no* foundation for mathematical development.

Ten sessions over ten weeks were not enough time to make substantial progress in understanding the mathematical concepts addressed. The project moved too quickly for the researcher to fully understand individual abilities, or to test ideas, speculations, and interventions. There was not enough time to adapt and modify the strategies for each participant. Once a lack of foundational knowledge became apparent, all three participants required different sets of interventions: songs, props, and worksheets. After the sessions ended, and even while analysis and interpretation were in process, the study seemed like nothing but a series of chaotic observations. The analysis of what seemed to be chaotic observations revealed a connection. Repetitive elements in the video recordings and artifacts became themes reinforced by more focused surveys of the literature. In addition, consultation with experts drawn from other fields and researchers who have worked with WS greatly helped to define and delineate the embedded meanings.

In retrospect, I do not understand why I worked with the participants for such a brief period; the sessions now seem hurried. Big Red did not understand some fundamental concepts in mathematics throughout his 21 years of life, but I expected them to happen during my 10 weeks with him. It became obvious that each participant did not understand prerequisite concepts to some degree, nor did they have a solid enough foundation to move on to the next level. I, however, moved on at the next session nonetheless. This proved especially problematic during initial sessions. Since Big Red began the sessions first, Roxie second, and Angela third, he and I traveled further in the wrong direction than the other two. I expected more from him because of his age, social interaction skills, and musical skills. Unfortunately, those proved irrelevant in predicting his mathematical ability. My previous impressions and experiences with him did not indicate such a high degree of difficulty using math. I knew that he needed to have time to process, and that it was important to verify his comprehension, but I was clouded by my eagerness to successfully complete the project. I attempted to test too many concepts, interventions, and techniques. The freedom and flexibility granted by using a qualitative research method was misapplied. It is more important to teach one concept at a time and to take the time to make certain each participant understood the concepts than to move through each successive concept in a chain. After the analysis and interpretation were finished, I felt as though I had only explored a continent by flying over it, when the continent needed to be explored by walking on my feet. While this is obvious now, I believe I missed it in the course of the study. This study is, therefore, a pilot study to stimulate further research.

Fish is Fish

The beginning of the book *How People Learn* by the U.S. Research Council (2000) uses quotes from *Fish is Fish* (Lionni, 1970) to point out the danger of interpretation and construction of new knowledge based on existing knowledge. *Fish is Fish* is a children's book that tells the story of a fish and a tadpole. The two became very close friends when they were young. As they got older, the tadpole moved away from the pond and the fish remained in the pond. When the tadpole came back from his journey as a frog, the tadpole tried to explain what he had experienced living on the land. No matter what the frog described, the fish could only imagine it from a fish perspective; a bird is a fish with wings, cows are fish with udders, etc.

While working on this project, I was frustrated by the enormous amount of knowledge required to understand the difficulties in mathematics experienced by individuals with WS. The participants' simple mistakes often led me into a completely new world where I needed to learn a new language and culture. A simple mistake was often not *simple* at all, but one rooted in much deeper difficulties. There were too many speculations on my part, and no answers forthcoming on my own. I needed to have in-depth knowledge about child development, cognitive development, neuroscience, and mathematical development. I did my best using my limited knowledge, but I wanted to be able to interpret what really happened in the mathematical development of the participants. I wanted to understand my participants' responses to my music therapy interventions and I kept thinking that I might miss some of the major points going on in the process. I feared I might overlook something crucial. I might not make connections between obviously related events. I sincerely hope that this study leads to more thinking, more questions, and even more wonderment about cognitive function in WS. Even if my theories and suggestions are supplanted by new ones, I will be highly gratified to be the one who stimulated a process to help us understand more about intervention strategies for WS. I sincerely hope my study will be a springboard to help them overcome cognitive deficits. However, my experiences with music and individuals with WS were able to turn a noxious task into a joyful one that instilled confidence in myself. This last observation served to remind me what an effective tool music can be to improve quality of life. I also shall never forget that *Fish is Fish*.

Future Research

The Mental Number Line

While working with these participants, the underlying rational of dyscalculia was continually researched and evaluated. One of the themes that manifested during my study was the possibility that individuals with WS have an inability to visualize a mental number line. A mental number line refers to the way numbers are represented conceptually or spatially within the mind, possibly with a left to right orientation and in continuous format analogues to that of a ruler (Bachot et al., 2005; Dehaene et al., 1990; Zorzi et al., 2002). While the process of manipulating and calculating numbers in the brain is still elusive and controversial, the visuospatial aspect of mathematics is also not clearly defined nor thoroughly researched (Dehaene et al., 1993). While there is no particular research on the use of the mental number lines in individuals with WS, it has been suggested that the visuospatial difficulties within the WS population might manifest themselves as an aberration of the visualization of such a "line" (Ansari et al., 2003; Bachot et al., 2005; O'Hearn & Landau, 2007; Zorzi et al., 2002). Research on the mental number line suggests that this concept might not be a learned concept, but rather an inherited aspect of human psychology. Even people in a culture who use right to left oriented writing indicate that their conceptions of numbers run left to right (Dehaene et al., 1993; Zorzi et al., 2002). The area of the parietal lobe is thought to be responsible for this inherited ability (O'Hearn & Landau, 2007; Zorzi et al., 2002).

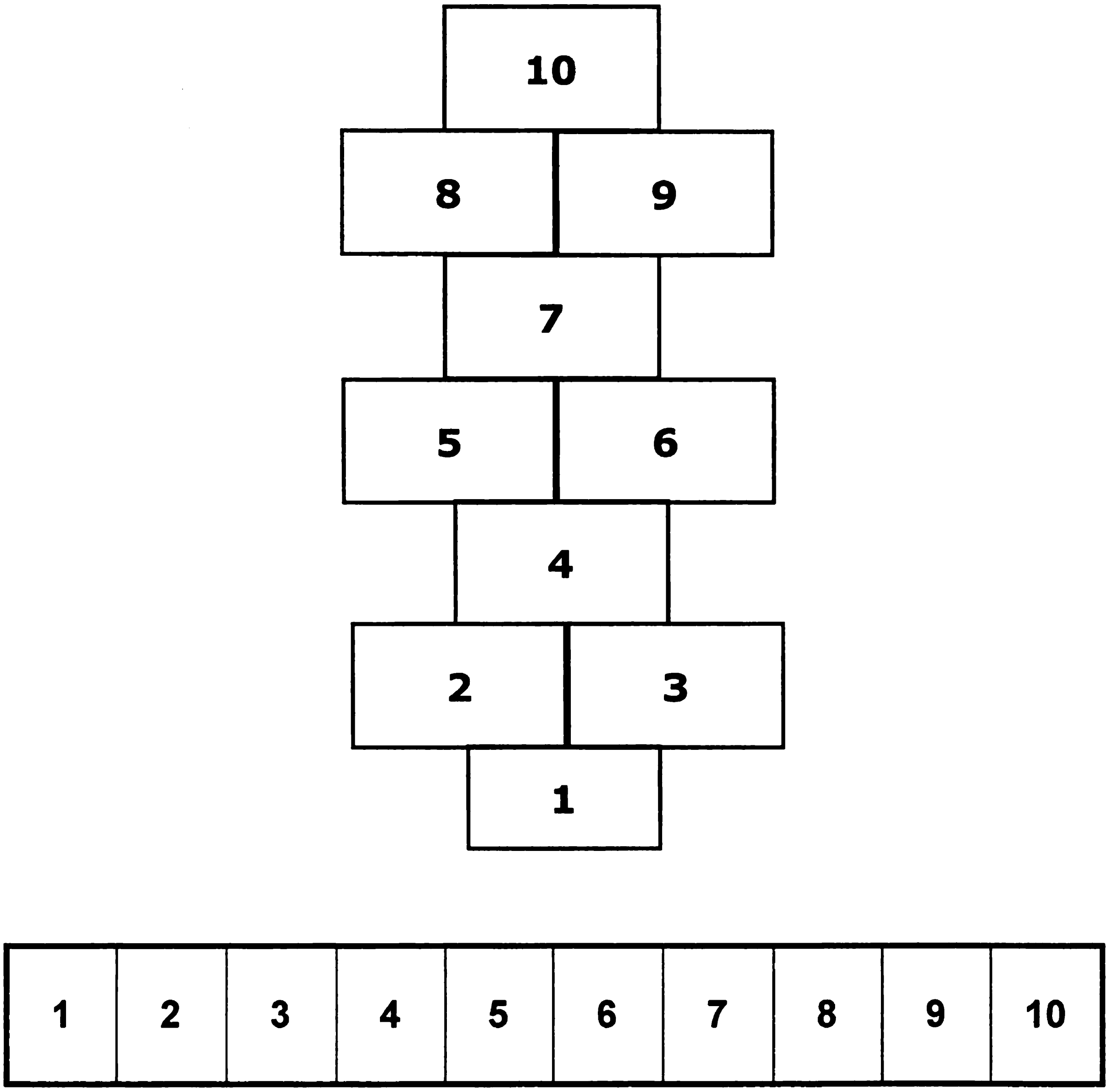


Figure 52. Hopscotch in a vertical line and a horizontal line.

A handful of interventions were considered to compensate for this lack of ability, such as walking or jumping, or hopscotch using a horizontal linear number-line, instead in a vertical line (see Figure 52). Another intervention is to use keyboard instruments with numbers on the keys in order to help organize thoughts based on auditory (pitch) and visual information. The instrument can be marked with the Arabic numeral 1 for middle C, 2 for the middle D, and so on, up to 10 for E one octave higher (see Figure 53).

Possible music therapy interventions using this concept are singing songs that relate to number concepts with the instrument, counting a number of objects with an ascending scale, and playing a song with a modified number score[13]. The duration of the intervention also needs to be tested; how long it will take? Ten sessions a week? Everyday 5-10 minutes for a month? In order to conceptualize this intervention, the frequency and duration of need to be taken into consideration. Using keyboards as described above might have great potential for the WS population and beyond.

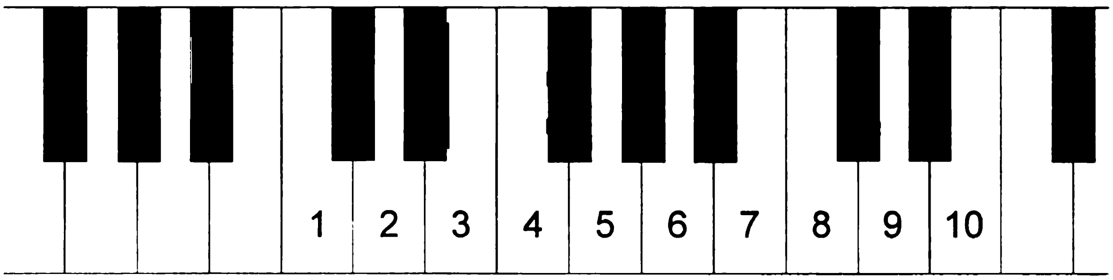


Figure 53. A keyboard instrument with numbers.

Music Aptitude Tests and Musical Abilities

The musicality of individuals with WS has been well publicized and has drawn great interest within the WS community and beyond because of some well-known music geniuses who have Williams Syndrome. Unfortunately, there is little intensive research. The music abilities of the participants in my study covered a broad range. While Big Red has taken private music lessons and performed in various bands, Roxie and Angela did not have such a background and had less opportunity to be exposed to different musical environments. It was unclear whether Big Red's advanced musical ability was due to his

[13] "Twinkle Twinkle Little Start" can be played by 11 55 77 5 44 33 22 1 in key of the C.

exposure to music, or because of his innate musical ability (nature vs. nurture). Roxie showed her ability to improvise with her spontaneous song about her feelings. One could wonder if she had more training and opportunities to improvise, her own skills would advance.

The potential for music aptitude can be measured by using a music test such as the Primary Measures of Music Audiation (PMMA; Kindergarten through Grade 3), the Musical Aptitude Profile (Grades 5-12), the Intermediate Measures of Music Audiation (IMMA; grades 1 through 6), and the Advanced Measures of Music Audiation (Grade 7 through adult) (Gordon, 1997). While some of these tests are standardized, they have not yet been actively applied to the WS population. Two studies using Gordon's aptitude test as a measurement tool have been published (Don, Schellenberg, & Rourke, 1999; Hopyan, Dennis, Weksberg, & Cytrynbaum, 2001). Don et al used PMMA for 8- to 13-year-olds (n=19), and Hopyan et al used MAP for average 12 year olds (n=14). Don et al concluded that the performance of the WS group showed results similar to the matched group on receptive language skill (average 7 year old), but below the chronological age. Hopyan et al (2001) reported that the WS group scored lower on tests of pitch, rhythm, and interpretation, but were similar to the chronological age group on the musical expressiveness subtest. Research on music abilities with standardized music aptitude test will help to identify WS individual's musical ability. Is it myth or truth? The previous research on their music abilities suggests the results are inconclusive (Deruelle, Sch, Rondan, & Mancini, 2005; Don et al., 1999; Hopyan et al., 2001; Lenhoff et al., 2001). In addition, because of the disconnect between chronological and cognitive ages, difficulties with visuospatial perception, and in format test settings, the most appropriate of these tests need to be researched and identified.

"Think before you answer" (see Figure 54) is a song composed to emphasize the use of the strategies taught in sessions. Big Red and Angela could not sing the song in tune[14]. Considering their ability to memorize other melodies, it may be that this specific melody uses half-step intervals. While Big Red and Angela have fewer difficulties with stepwise or other intervals, the inability to identify the half step needs to be investigated. It might be related to the discussion of potential talent and learning opportunities, i.e. the argument of nature or nurture. This would be an intriguing investigation, especially if the ability to produce these intervals can be gained through training and practice.

Figure 54. Think Before You Answer.

Attention Deficit, Hyperacusis, and Odynacusis

Distractibility, especially from auditory stimulation and poor concentration, was a very serious issue in the learning process with the participants. Their hyperacusis and attraction to auditory stimulation appears to be partially responsible. According to parents' reports on hyperacusis questionnaires, the incident of hyperacusis ranges from

[14] This song was not used for Roxie as much as others, and she did sing the song with me but not sing the song by herself; therefore, it was not clear she could or could not sing it herself.

84% (Gothelf, Farber, Raveh, Apter, & Attias, 2006), 92 % (Udwin, 1990), to 95% (Nigam & Samuel, 2007). The medical definition of hyperacusis has a slightly different meaning; 'heightened sensitivity to sound, with aversive or pained reactions to normal environmental sounds' (Dirckx, 2005) and 'an abnormal sensitivity to sound' (Venes, 2005). Levitin, Cole, Lincoln, and Bellugi (2005) point out that while 'sensitivity' in medical terms refers to "lowered hearing thresholds, that is an ability to hear soft sounds that others cannot" (p.515). Using the term "hyperacusis" indiscriminately to describe for different reactions to auditory input is not appropriate. Levtin and his colleagues establish the detailed descriptive terms for four different conditions; true hyperacusis, odynacusis, auditory allodynia, and auditory fascinations. True hyperacusis is characterized as "an ability to hear soft sounds that other cannot." (p.515). Odynacusis means there is a lower threshold for the volume of sounds. Auditory allodynia refers to fear toward particular sounds that do not evoke any aversion responses or pain in typical individuals. Auditory fascinations indicate fascination or unusual attachment to certain sounds. They concluded that while there are only 4.7% of the subjects in the true hyperacusis category, 79.8% were in odynacusis and 90.6% in the auditory allodynia category, 9% of the participants were identified as having auditory "fascinations." Odynacusis and auditory allodynia are speculated to be due to neurobiological and structural differences and auditory nerve dysfunction (Levitin, Cole, Lincoln, and Bellugi, 2005).

As shown in the participants of this study, Big Red was very sensitive to sound and had a very good musical sense. Angela was very sensitive to loud noises, and wears ear protection in noisy environments, such as at a party or the airport, but did not display any particular music ability except being fascinated with music. Roxie did not exhibit any particular sensitivity toward different sounds like Big Red or fear of loud noises like Angela. It would be interesting to research the relationship of the above conditions of auditory sensitivity and musical ability to what types of sensitivity play an important role in musical ability. Big Red seemed to hear what I did not hear, but he did not display particular difficulties with loud noises, but he was the most distracted individual. I kept wondering if the sensitivity to music hindered the participants' ability to focus. The relationship between sensitivity and distractibility would be a fruitful research agenda.

Research Opportunities in the WS population

Another difficulty in WS research is the accessibility of participants. It is not easy to find a large number of WS participants within one state, much less within a single city. If the study requires a certain age group, and/or a particular functional level, the availability of participants drops to almost nothing. The Williams Syndrome Association (WSA) and the parents of individuals with WS are very willing to participate in research in order to improve treatment options available for their children. The WSA convention, a biannual event, is a great opportunity to propose research. The WSA has accepted research proposals from various Universities, granted permission to conduct research on the conference site, and allowed researchers to gather prospective participants. The convention usually gathers between 200 - 300 individuals with WS from ages as young as 8 months, to some as old as 60.

Other opportunities to network and suggest research occur at the annual music camps. WSA has two music camps in Grand Rapids, Michigan; one for children 6 to 12 years old and another for those 13 to 30 years of age. Depending on the research proposal and goals, the association permits researchers to conduct research projects at the camp. These conferences and camp settings have definite limitations and restrictions to research designs, and ways of conducting the research; however, they can offer good opportunities otherwise unavailable [15].

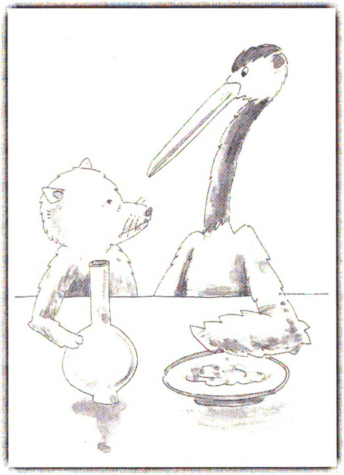
Final Thought

Individuals with WS are different. They are not the same as typically developed individuals, not the same as other persons with cognitive challenges, learning disabilities, or visual impairments. Individualized and specialized music therapy interventions for WS are necessary because of their different ways of processing auditory information and difficulties with visual perception. Often, these differences are overlooked when they are taught in a traditional educational setting. Even in a special education setting, such instruction often fails.

Individuals with WS' inability to learn using traditional means such as visual aids and rote repetition brings to mind the fable of *the Fox and Stork* by Aesop. Besides the moral of this fable, the container for the food draws my attention. The container and its manner of presentation determine the ability to absorb the contents. Mathematical facts and concepts in a musical "container" instead of a visual "container" may provide a better way for WS to absorb content.

---

[15] This statement was sent to WSA and they approved its inclusion in this dissertation.



The Fox and the Stork

After her long migration,
the fox sent the stork a dinner invitation.
When she came he served
thin soup in a marble dish so flat
that the stork could fish out nothing with her bill.
She served minced food in a narrow-mouthed urn
and tortured her hungry guest
by picking the best bits out till she'd had her fill.
While the fox was desperately licking
the neck of the urn, the bird
remarked, so I've heard,
'He got what he deserved. Tit for tat!'

Figure 55. The Fox and the Stork (Michie & Lord, 1989, p. 132)

Illustration by Hyang Eun Lee

Study participants liked mathematical manipulations when working on written addition with music, engaging with coins, and other manipulations. They did not *hate* "math." What they did not like were the struggles, difficulties, and frustrations. Just as in the fable, the presentation of numeracy to WS needs to fit with their learning style as a *musical learner* for internalization to occur. The natural repetition that occurs in melodies, and the attentiveness to music that individuals with WS all share, create a link to concepts and strategies that help usher them from short-term working memory to long-term memory to be used as tools that will be readily available for daily use.

When I started this journey for my dissertation, I thought I knew a great deal about WS because of my years working at various camps, attending conferences, gatherings, and past interviews with parents and professionals who work with individuals with WS. None of this had actually prepared me for the most basic discoveries, and what they revealed to me about the mind of individuals with Williams Syndrome.

The range, depth, complexity, and entanglement of the matter were much more complicated than I had expected. None of these factors is isolated and each day brought new theories, concepts, and idioms to my interpretation. New and updated articles were published during my research, increasing the resources available but, at the same time, overwhelming me. Besides being overwhelmed, I was frustrated, mesmerized, and full of remorse. I was overwhelmed because of the amount of knowledge I needed to absorb in order to analyze and interpret the observations. I was frustrated because I felt I should have known more before beginning the project. I was mesmerized because of the participants and their similarities and differences And, I was remorseful because I truly felt sorry for my previous clients with WS who had worked with me before I learned from this project. I do not feel I did my best for any of them.

The boundaries of knowledge in therapy are unclear. Obviously, training in the mathematical development of young children is not part of my curriculum to be a music therapist, nor part of my expertise. In my experience as a music therapist, I became aware that bridging the gap between knowledge of a particular disease and evidence-based music therapy strategies is important to further development in the music therapy profession. This project confirmed my belief that without understanding the condition being addressed, it is difficult, if not impossible to deliver the appropriate interventions. This study brought me to another place and has strongly affected my philosophy as a therapist. Where should the boundaries of knowledge be for the therapist? Within my own limits, how much do I need to know to treat people? Collaboration, interdisciplinary teams, and consulting might offer avenues to explore. The processes used to develop music therapy interventions for those with WS may also be applicable to other genetic cognitive impairments, such as Prader-Willi Syndrome (PWS), Angelman Syndrome (AS), and DS. My hope is that this study will not only suggest elements of music therapy programming for individuals with WS, but also provide a framework for developing music therapy interventions for those with related genetic disorders.

"What we discover by doing research is just how complex the world is (Strauss & Corbin, 1998, p. 55)." This statement encompasses the process of this dissertation. The more I learned, the more this study reminded me how much I did not know. This project raised more and more questions, but provided no concrete answers. The realization that more research, a more exhaustive review of the literature, and practice is necessary and possibly painful, but is more important than any single "answer." I tried to describe, as much as possible, what I observed in order to provide as much information for future researchers and clinicians involved with individuals with WS. It is clear for me now that individuals with WS have often untapped potential, that music therapists have effective tools, and that it is our responsibility to find the key to these often locked doors.

EPILOGUE

June 2008, Grand Rapids, Michigan: Music Camp for Children with Williams Syndrome

Eight Orff instruments were marked with the Arabic numeral 1 for middle C, 2 for middle D, and so on up to 10 for E one octave higher. Paul, Peter, Tom, Adam, Mary, Debra, Ellis, and Dina, with ages ranging from 9 to 10, enjoyed playing up and down the scale. They sang the scale using numbers; like fixed Solfegio using numbers instead of the sol-fa syllables. Their voices were stretched with higher notes such as C an octave higher. While Tom did a wonderful job playing the song *Itsy Bitsy Spider* with a modified number score (e.g., 1112 33 32123 1-CCCD EE EDCDE C in the key of C), Mary had a hard time playing her instrument. She could not move her hand fast enough to follow the song, and she did not know where the next notes were. Debra, Ellis, and Peter were better than Mary, but also needed assistance.

The children were next asked to play the pattern of CGEG (1 – 5 – 3 – 5) using a mallet. Adam had a hard time moving from C to G (1 to 5). Mary, Debra, Ellis, and Peter did not perform well either. Why was this hard for them? Was it because of a lack of experience or was it another manifestation of visuospatial perception problems? Perhaps it was an eye-hand coordination difficulty. A set of 6 different number cards with dots were given to those eight campers. We counted each card in the scale; "1" (C), "2" (D), "3" (E), "4" (F), "5" (G) for the 5-dot-card; 1 (C), 2 (D), 3(E), 4(F), 5(G), 6 (F) for the 6-dot-card. We sang the different cards up through the 10-dot-card. When they were asked to find the 7-dot-card by singing, "Which one is 7?" Tom and Peter were already holding up the card flashing beautiful smiles. Mary could not identify it. She desperately looked back and forth between the 6 different cards, the counselor, and me—as if she thought we would give her the answer. "Give me any sign, please"—her eyes were pleading. Her hands frantically moved between them. She picked the 5-dot-card and counted them one dot at a time, and put it away. She picked the 8-dot-card and counted them one by one. Sometimes she counted the same object twice, or skipped an object. This scene was too familiar. Mary's face was overlapped with Big Red in my mind's eye, displaying the same desperation, hopelessness, and disappointment. Mary started holding up random cards hopelessly. The counselor gently removed three cards from Mary's pile and Mary, now, only had the 5-, 7-, and 8-dot-cards. The counselor quietly counted with Mary until she finally got the 7-dot-card. I was left wondering:

Were these interventions helpful to developing a concept of counting?
Could playing Orff instruments with numbers help to develop a mental number line?
What prevents Mary and Big Red from grasping the understanding of numbers?
Why can't they identify those ridiculous number flash cards? Do they need to know the differences in numbers? Is it necessary?

I still wonder.......

Appendix A

Song and Lyrics

Increments of 5

Eunmi Emily Kwak

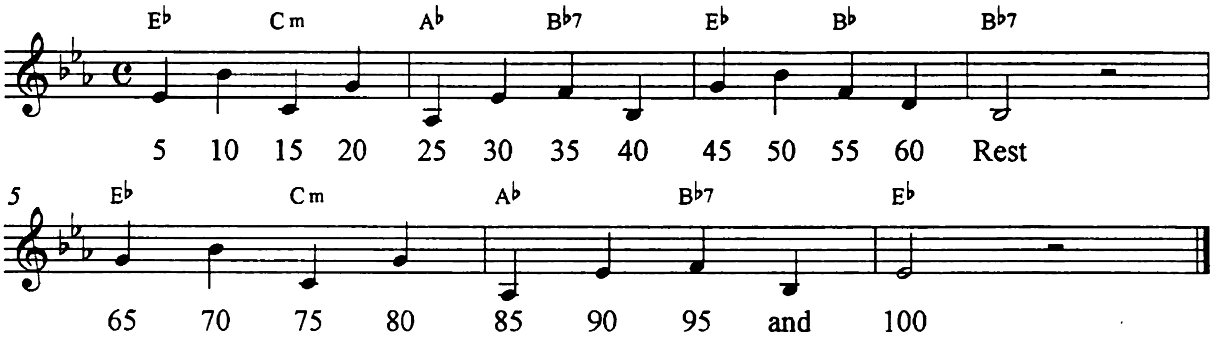


Figure A-1. Increments of 5

The lyrics of the song simply utter numbers in 5s with refined wording.

Number buddies 9 - 7

Emily Kwak

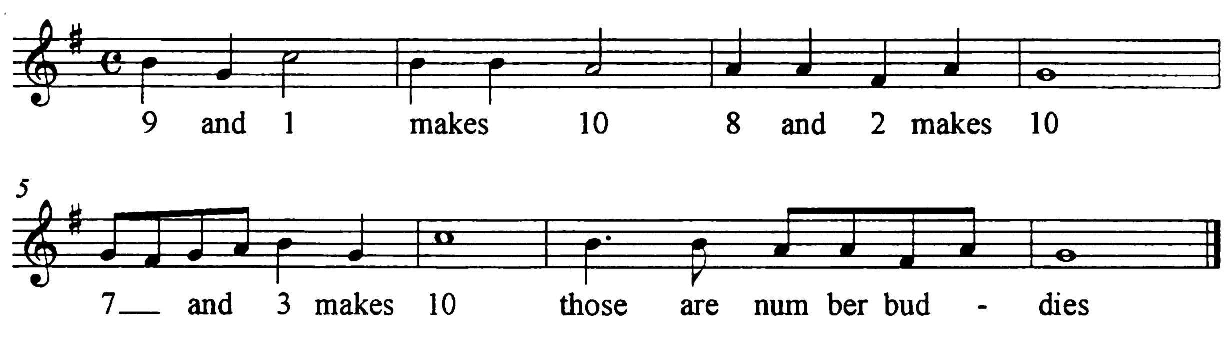


Figure A-2. Number Buddy.

This song was used for the concept complement of 10 for Angela.

Thumb and Pinky Meet Each Other

Eunmi Emily Kwak

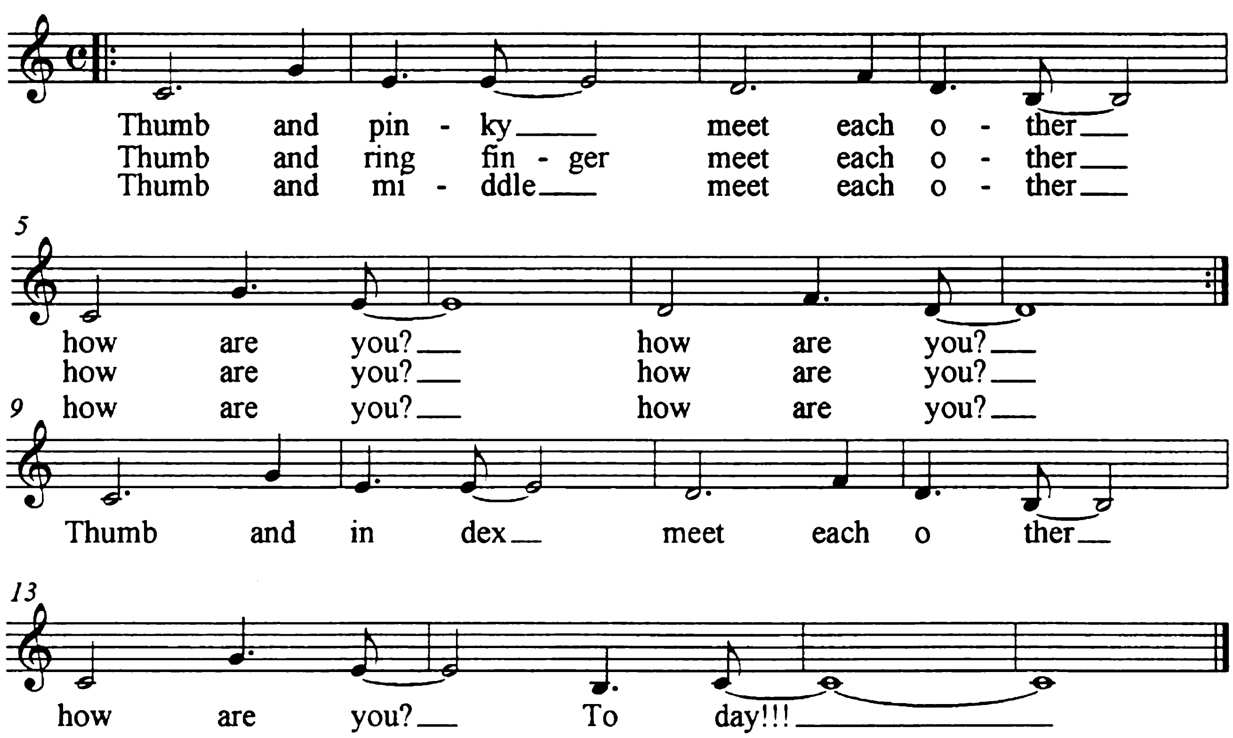


Figure A-3. Thumb and pinky meet each other.

This song was used to promote finger dexterity for Angela.

Appendix B

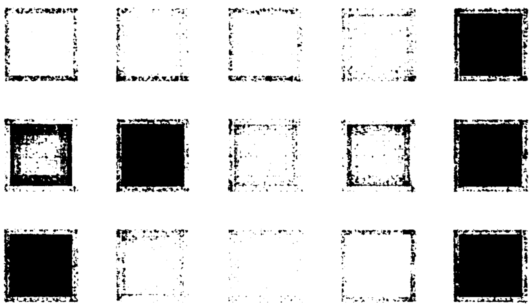
Final list of codes and themes

Symbol*	Theme
α	Negative comments or concerns about their performance (H:4×1)**
β	Positive comments about themselves (H 3×1)
χ	Gaps in knowledge of social interaction (H 2×1)
δ	Distractibility (H 1×1)
ε	Distraction present but can maintain focus on tasks. (H 1×1) and (F 4×4)
☹	Mathematical problems (H 2×1)
⌛	Clock problem (H 1×3)
γ	Lack of strategies (H 5×2)
η	Parent's comments (Red box)
ξ	Looking for mom's help (H 2×3)
φ	Interesting moments (H 2×3)
ψ	Language (H 4×2)
♌	**Musical responses (F 5×3)**
☺	**Happy moments (F 2×2)**
👍	**Got it right (F 6×2)**
♥	**Emotional support (F 4×2)**
Π	**Areas of concern (F 1×5)**
♍	**Therapist's musical Strategies (F 7×5)**
✋	**Fine motor (F 4×4)**
☆	**Developing Strategies (H 5×2) and (F 3×4)**

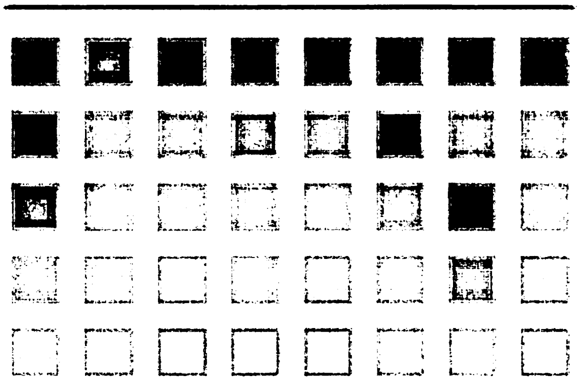
* Symbols were assigned to more readily access data by a word search for analysis.

** The numbers represent a column and row of either highlight color (H 4×1) or font color.(H 4×1). H 4×1 means 4th column and 1st row in highlight color chart.

Highlight Color Chart



Font Color chart



Appendix C

Table for Abbreviation

ADHD	Attention Deficit and Hyper Activity Disorder
AMTA	American Music Therapy Association
AP	Absolute Pitch
ASD	Autism Spectrum Disorder
CP	Cerebral Palsy
DAS	Differential Ability Scales
DS	Down Syndrome
ELN	Elastin Gene
FISH test	Fluorescence In Situ Hybridization
fMRI	Functional Magnetic Resonance Imaging
KBIT	The Kaufman Brief Intelligence Test
PPVT	Peabody Picture Vocabulary Test
PWS	Prader-Willi Syndrome
RAS	Rhythmic Auditory Stimulation
SVAS	Supravalvular Aortic Stenosis
TDI	Individuals with Typical Development
TDC	Children with Typical Development
WS	Williams Syndrome
WSA	Williams Syndrome Association.

Appendix D

Example of Session Transcripts with Codes

This is example of Roxy's 5th session. It is the beginning of the first three pages. In here is printed in black and white, but as indicated in Appendix C, the final copy is in full color. Different shades of gray highlight and font color indicate there are some codes in that transcription.

Session Transcription

Special interesting moment

She was tired because it was time for dinner(around 6 pm) and she had attended school that day. When I arrived at their house, she was a little grumpy; her mom warned me about her mood, "You will see what happens when she is t-i-r-e-d. However, she did not show much behavior changes during the session.

👍 Yeah! You can do 15. How much is it? ____________15 ____________ⓣ 25, 30.. 35 **(F 6×2)**
(around 22:50) ☹Ok. Let's figure it out.(there were 5 quarters and 1 nickel) ____________A dollar 20, 25 (tapping on the table) 6 6? This is five. **(H 2×1)**
ϕ 46:59 Good _________(she want to clap with *Congratulation song*, but when I play G to E for Roxy, she answered with Yes, Ma'am and back to question) (This is the great moment to explain how musical cue can get there attention) **(H 2×3)**

Good. If you play as written, you can play *Mary had a Little Lamb.*
0:10 ________(making lamb sounds)
(laughing)
____________(laughing)
0:29 _______(playing C instead of E)
Where is E?
____________Right here.
No, that's C
0:32 _______right here?

That's D

&________(playing Glockenspiel rhythmically) **(F 5×3)**
You can see it here (it is too small to see it as well as the lighting)
E, D, C
0:56 ________Oh! Wait. E, D, C (playing *Mary had a Little Lamb* with glockenspiel; I was
pointing the note which need to be played)

Ɛ 1:35______Yeah!!! (even though there was a lot of noise and music going on, she could concentrate and could finish the song.) **(H 1×1) & (F 4×4)**
You play and I will accompany you.

& 1:40 to 2:47 (she moved the score to her right side; ⓟ by herself) **(F 5×3)**
Great
2:51 ________(trying to play mouth piece)
You need to stretch your lower lip over your teeth.
2:54 ________(she wasn't able to make a sound out of 7 attempts) I did it before.
3:05 Yes you did it before. You can make it.
____________(4 attempts; sighing)
3:17 ________(1 success out of 3)
3:25 _______(1 attempt; sighing) I can't do it.
3:47 ________Yeah
Can I have a mouthpiece and put it here? (I wanted to end the saxophone)
____________Wait. (1 success out of 3)
____________(1 success out of 3)
4:00 _______(1 success out of 3) Yeah!!!
(ⓣ laughing)
4:17 ________(2 success out of 3)
That's the sound I am looking for. That's the sound. Great.
____________(3 success out of 3)
Yeah!!!!
4:39 ________(1 success out of 3: very nice sounds but high tone)
4:48 _______(2 success out of 5)
Practice it.
____________Practice makes perfect.
Yes. Yep, Yep, Yep
5:14 _______(1 out of 3)
Good
5:20 _______(1 out of 3)
You need to make lower tone. You make high tone (ⓟ the piano), I want you to make Low tone (ⓟ the piano)
____________(1 out of 3)
____________(1 out of 4)
Good, Thank you.
You want to play this one more time. Actually I have *Nobody's Perfect* here. You want to

play this one. (ⓟ *nobody's perfect*). Play from here. AAAAAB…
6:24 ________(ⓟ *nobody's perfect:* pointing #s)
7:10 _______Yeah!
You want to play *Mary had a Little Lamb.*
7:26 ________I'm just looking at.
7:30 ________Roxy! Is my name.
Yes, that's your name.
____________Roxy, Roxy
Roxy is your name.
7:38 ________Roxy. Roxy Roxy (language rhythmic pattern)

7:51 ___(unidentifiable melody; ⓟ*Mary had a Little Lamb*; made mistake)
8:05 ________(sighing) wait (playing *Mary had a Little Lamb*) Yeah!!!
Just doing one more time. You're doing great. **(F 5×3)**
____________(ⓟ*Mary had a Little Lamb*)
9:07 Ah-ha. I love your playing.
____________(ⓟ unidentifiable melody)
9:14 I want you practice with it. I will leave the glockenspiel and I want you practice it.
____________OK
9:31 OK Go away. Let's put it here. Today I want you to do. This one
9:55 Roxy …
____________Yeah!
I want you to say Yes, Ma'am
____________(laughing) Yes, Ma'am

(ⓢ *addition song*) 2 + 2
____________(making 2 and making 4) **(F 4×4)**

10: 5- 11:3 (good example with fine motor skill problem; remark video clip Roxy Fine motor clip 1)
Let's 2. Making 2 …1, 2,
____________(she is able to make 2; adding 1, 2) 4
Yes, that's four. You need to have 3, 4.
You need to make 4. You need to make 4
1… That's 3. Let's do it this way. Can you make four?
10:47 _______(holding 4)
You already have 2.
____________3, 4, 5, 6, **(H 2×1)**
Can you write down 6?
11:03 ______Hey! Tom!!! You are on Camera. You are famous. (Does she feel good on camera?)
Good
11:14 _______I will do my hair done on Saturday (that day, WSA will have a Christmas party
and she is so exited about that)
Saturday; Ah-ha

___________(nodding)
Did you get the dress for this Sat.?
☺ ________I get it tomorrow. But I am exited. **(F 2×2)**
Good. Which color do you want to have?
___________Red
11:25 Ah-ha: Christmas color.
___________(nodding) yeah!
Tom, you will be there?
___________(brother) Yeah!
Yeah!!! We have a big party.
11:37 _______Is it gonna be huge?
I heard it will be around 70 people. It is huge. I will bring some pecan pie.
___________Em… pecan. I never try pecan pie. How many people are there so far?
70. 7 .. 0
___________70 people!!! Oh! My God!
It will be big party.
___________Roger will be coming (her WS friend from WS camp). I am exited.
12:05 (Ⓢ *addition song*) 2 + 5 Let's make 5.
___________(holding 5 with left and adding 2 with right)
You already have 2. Don't make it.
___________2, 3, 4, 5, 6, 7   7
How much is it? Doesn't look like seven. (remark 11/29/07 worksheet)
Don't erase it. I want you write down here another one.
___________(writing 7)

Appendix E

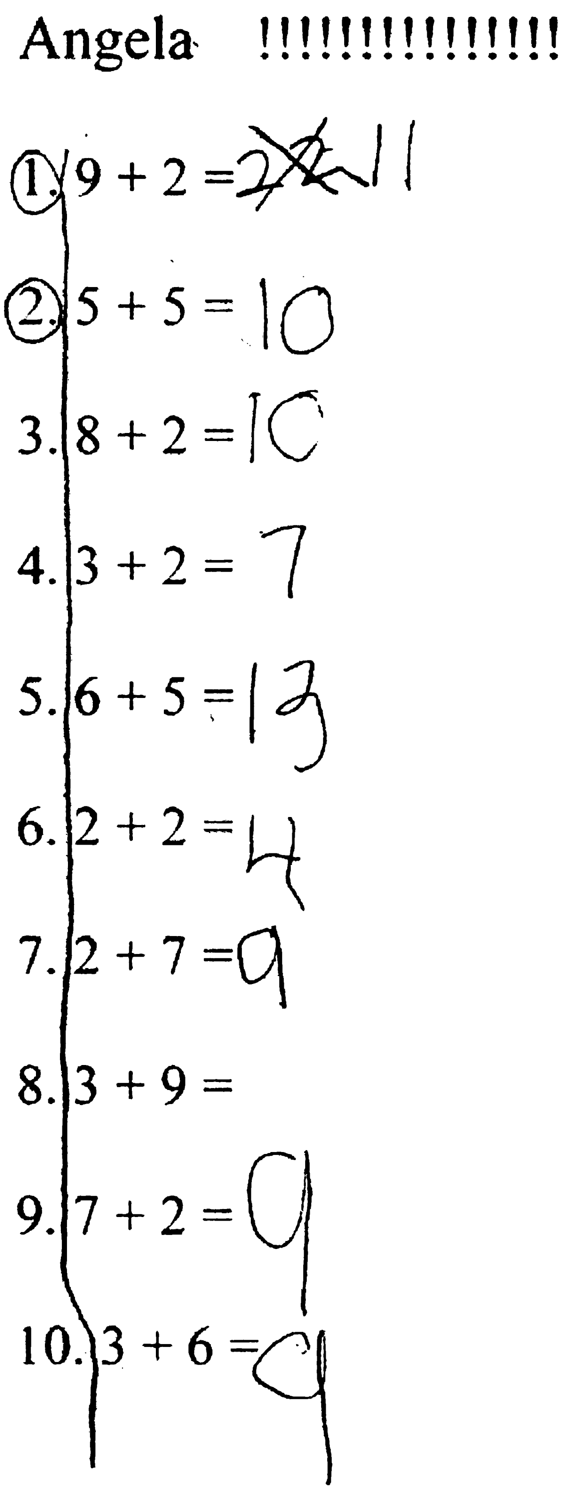
Modified score for Angela and Roxy

Twinkle Twinkle Little Star

C C	G G	A A	G
F F	E E	D D	C
G G	F F	E E	D
G G	F F	E E	D
C C	G G	A A	G
F F	E E	D D	C

Appendix F

Handwriting Samples for Angela



Angela thinks the question numbers are the part of question, i.e., 9 + 2 as 19 + 2. She did not get the right answer for 19 + 2. When she worked on the second question, I notice her mistake and drew the line between the questions number and the question. It is understandable, but at the same time raises the question about the reason of question. She did not answer questions four and five correctly. The reason for this mistake might be because of her way of doing some of additions; she doubled the number and subtracted; i.e., for question number three, she doubled 3 and got 6, and need to subtract 1, but she added 1. She made the same mistake for the question number five: she doubled 6, and got 12, and added 1, instead of subtracting 1.

Appendix G. *Example of Session Progress Chart*

Name: Angela Hill

Session 1	Session 2	Session 3	Session 4	Session 5
• She does not feeling good because of her dental appointment just before the session. • She did not speak that much. Sucking her thumb a lot. • Introduce an Abacus and *Number Buddy Song*. • Introduce number chart. • 27:17 She could use number buddy song for a direct application but she made a mistake with 11- 9, 11-7, 11-8	• Her affection is changed compared to last week. • She did not suck her thumb. • Introduce quarter hand prop • 10:29 She counts 25 fingers in the prop as 5. Same thing observed with Big Red. • 1350 Calculate a quarter plus a nickel equals 29. She stated, "I am confused" • 14:58 "Fogged up" Window incident occured • 21: 13 "I'm always confused."	• Introduce coin classification chart • Giving me certain amount of money was started. • Address numbers are used for clock interventions. • 23:16 When she said "100", she said it in singing manner • 23:15 Can do 25 + 10 on written form, not with a quarter and a dime • 26:53 2 quarter plus 1 dime ➔ 55… • She did not understanding the basic rule for adding 10.	• She was sick; but wanted to keep the session. She was quieter than usual • 9:04 75 + 10 ➔ 100 • 14:17 After she intensively worked on a quarter plus a dime (25 + 10) and 3 quarter plus a dime (75 +10), she answer 2 quarter and a dime equals 55. • 18:12 She effectively used coin classification chart and was able to change the values based on different coins. i.e., 5s for nickels, 1s for pennies. • Started using Congratulation Song instead of verbal reinforcement.	• The idea of using clock with two fingers for the short hand was applied. • 10:33 Spontaneously improvise a song about her task ➔ I encouraged her to do so.➔ Angela proudly announced to mom she made a song and wanted to sing for her. • Paper money is introduced. • 16:50; 18:50; 19:31 Fine motor skill difficulties observed with handling paper money and coins • Angela wanted me to play a congrat.song after completing her task.

Appendix H

*Developmental Guidelines for Number and Operations**

Topic	*Pre-K*[a]		*Kindergarten*	*1*	*2*
	2-3 years	*4 years*	*5 years*	*6 years*	*7 years*
			Counting Counting can be used to find out how many in a collection		
a. A key element of object-counting readiness is nonverbally representing and gauging the equivalence of small collections.	Make and imagine small collections of 1 to 4 items nonverbally, such as seeing which is covered, and then putting out. Find a match equal to a collection of 1 to 4 items, such as matching :: or 4 drum beats to collections of 4 with different arrangements, dissimilar items, or mixed items (e.g.,).				

Appendix H cont.

b. another key element of object-counting readiness is learning standard sequences of number words, learning that is facilitated by discovering patterns.	← Verbally count by ones from →				
	1 to 10	1 to 30 (and more) with emphasis on counting patterns; e.g., knowing that “twenty-one , twenty-two..” is parallel to “one, two…”	1 to 100, with emphasis on patterns (e.g., the decades “sixty, seventy” parallel “ six, seven”; also, the teens such as “fourteen” to “nineteen” parallel “four” through “nine”)		1 to 1000, with emphasis on patterns (e.g., the hundreds, “one hundred, two hundred” parallel “one, two”)
		Flexibility start verbal county-by-one sequence from any point- that is, start a count from a number other than the “one” (ends early in first grade for some)			
	← Flexibly state the next number word →				
	… after 2 to 9 with a running start	….after 2 to 9 without a running start to 9; also, the word before from 2 to 9			
		← Verbally count backward… →			
		From 5	From 10	From 20	
			← Skip count … →		
			by 10s	by 5s, 2s	by 3s, 4s

Appendix H cont.

C Object counting involves creating a Appendix H one-to-one correspond-dence between a number word in a verbal counting sequence and each item of a collection, using come action indicating each action as you say a number word.	← Count the items in a collection and know the last counting word tells "how many" →				
	1 to 4 items	1 to 10 items	1 to 20 items	1 to 100 items	
	← Count out (produce) a collection of a specified size (lags a bit behind counting items in a collection) →				
	1 to 4 items	1 to 10 items	1 to 20 items	1 to 100 items, using groups of 10	
				← Use skip counting to determine how many →	
				2, 5 or 10 at a time	Switch among counts (e.g., "100,200,300, 310, 320, 321, 322, 323")
d. number patterns can facilitate determining the number of items in a collection or representing it	← Verbally subitize (quickly "see" and label with a number) →				
	Collections of 1 to 3	Collections of 1 to 5	Collections of 1 to 6; patterns up to 10		
	← Represent collections with a finger pattern... →				
	1 and 2	Up to 5	Up to 10	Teen as 10 and more; used flexibly to count on, etc.	

Appendix H cont.

e. Estimating the number of a collection builds number sense.

← Estimate the number in a collection →

- To 10 (some to 30), guessing "small" or "large" numbers
- To 100, using mental number line, benchmarks, and, later, composition strategies

f. Representing collections and numerical relations with written symbols is a key step toward abstract mathematical thinking.

← Draw pictures or other informal symbols to represent a spoken number →

← Draw pictures or other informal symbols to represent how many in a collection →

← Use numeral skills →

- Recognize one-digit numerals
- Write one-digit numerals; later, teens
- Write two-digit numerals
- Write three-digit numerals
- Read number words one, two ,three, ten
- Read two-and three-digit number words

- Informally represent the equivalence or in equivalence of two collections.
- Use symbols $=$, $\neq$, $>$, $<$ (w/ single-digits)

Appendix H cont.

Topic	*Pre-K*[a]		*Kindergarten*	*1*	*2*
	2-3 years	*4 years*	*5 years*	*6 years*	*7 years*
Comparing and Ordering Collections can be compared or ordered, and numbers are one useful tool for doing so.					
a. Comparing and ordering build on non-verbal knowledge and experience with real collections	Identify whether collections are the "same" number or which is "more" visually	← Use counting or matching → (one-to-one correspondence) to determine the equivalence or order (smaller or larger) of two collections, despite distracting appearances, and use words equal, more, less, fewer To 5	To 10	To 18	
b. Children compare, first visually, then using the verbal counting sequence.			← Determine how many more/less? → Matching, counting, 1-10	Counting, counting on, 1-20	Adding, subtracting, 1-100
c. Learning language for ordinal numbers can build on children's concrete comparing and knowledge of counting words	← Understand and use verbal ordinal terms → "first" and "last	"first" to "fifth"	"first" to"tenth"	"first" to "thirtieth" Read written ordinal terms first, second, third, ninth and use them to represent ordinal relations.	

Appendix H cont.

Topic	*Pre-K*[a]		*Kindergarten*	*1*	*2*
	2-3 years	*4 years*	*5 years*	*6 years*	*7 years*
Adding To/Talking Away A collection can be made larger by adding items to it and made smaller by taking some away from it					
a. Nonverbal problem solving supports later adding and subtracting	← Nonverbal addition and subtraction → One item + one item or two items – one item	sums up to 4 and subtraction involving 1 to 4 items			
b. Solving problems using informal counting strategies is a critical step in learning adding and subtracting.		← Solve and make verbal word problems; add and subtract using → Concrete modeling (objects or fingers), totals to 5	Counting-based strategies such as counting on, totals to 10	Advanced counting strategies, e.g., counting on or up (for subtraction and unknown addends) to 18; adding 3 #'s ≤ 10	
c. Solving problems of different "types" or structures extends ability to succeed in varied situations and helps them build connections.		← Solve verbal word problems of the following types: → Join result unknown	Join result unknown; part-part-whole, whole unknown; separate, result unknown; some can do simple compare and join change unknown	[all previous types and] part-part-whole, part unknown; compare problems	[all previous types and] start unknown

Appendix H cont.

d. Linking symbolic addition and subtraction to concrete situations and solutions is necessary for meaningfully using formal symbolic

Translate word problems (and their solutions) into number sentences and vie versa; determine sums and differences of number sentences by various means.

←————————————→

e. Facility with basic number combinations is achieved by making a variety of strategies, particularly reasoning strategies, rapid.

Find and use patterns and relations to devise reasoning strategies

e.g., number-after (or before), i.e., + 1 is next counting word

e.g., doubles +/-1 (6+7 is 6+6+1 is 12+1=13), 3+5= 5+3 (commutativity), addition complements, 5-3=? as 3+? = 5

Facility with basic addition and subtraction combinations

Appendix H cont.

Topic	*Pre-K*[a]		*Kindergarten*	*1*	*2*
	2-3 years	*4 years*	*5 years*	*6 years*	*7 years*
Composing and Decomposing A quantity (whole) can be "broken apart" (decomposed) into parts, and the parts can be combined (composed) to from the whole.					
a. Reasoning qualitatively about part-whole relations provides basis for more advanced composing and decomposing.	Understand and reason qualitatively and intuitively about part-whole relations				
	Increasing (decreasing) size of an uncounted part increases (decreases) the whole (visual only)	Changing a part changes a counted whole; (e.g., adding to a collection creates a sum greater than the starting amount)	In a missing-addend word problem, a part (e.g., starting amount) is less than the whole		
b. Number sense include knowledge of number partners (other names for a number).			Construct partners with objects up to 10; knowing partners to 5 (e.g., 5= 1+4, 2+3, 3+2, 4+1); doubles to 10 (e.g., 3+3=6)	Know partners up to 10 (e.g., 1+9), especially with 5 as a partner (e.g., 6=5+1); doubles to 20 (e.g., 12=6+6)	Know partner involving decades up to 100 (e.g., 50= 10+40, 20+30,…40+10, 100= 10+90,…90+10)
c. Part-whole knowledge extends addition, subtraction.			Informally solving part-part-whole, or "combine," word problems, sums to 10	Recognition of additive communtativity (e.g., 3+6=6+3); addition-subtraction complement (e.g., 5-3=?, think of 3+?=5), and inverse principle (e.g., 5+3-3=5)	

Appendix H cont.

Topic	*Pre-K*[a]		*Kindergarten*	*1*	*2*
	2-3 years	*4 years*	*5 years*	*6 years*	*7 years*
Grouping and Place Value Items can be grouped to make a larger unit and, in a written multidigit number, the value of a digit depends on its position because different digit positions indicate different units.					
a. Concrete activities provides a conceptual basis for these grouping and place-value concepts.	Trade several small items for a larger one		Trade, involving…..		
			grouping into 5s or 10s; recognizing place value, e.g., 23, 32 are different	Decomposing a larger unit (esp. 10 and 100) into smaller units; composing larger units.	
b. Connecting multidigit numerals to concrete/pictorial models provides a meaningful basis for multidigit numeral skills.				←—— Translate between grouping/place-value models, count words, and numerals, and read/write multidigit numerals meaningfully to… ——→ 100	1,000
			←—— Recognize base-ten equivalents		——→
			1 ten = 10 ones	1 hundred = 10 tens or 100 ones	1 thousand = 10 hundreds, etc.

Appendix H cont.

c. Relating written multidigit addition and subtraction to concrete or pictorial grouping and place-value model promotes understanding.	View concretely determined sums to 18 as a composite of ten and ones.	
	←-----Invent concrete and mental procedures for adding and subtracting multidigit numbers, including shortcuts involves 10s, to..... → 100	1,000
		Use and explain renaming algorithm, up to 1,000.
d. Grouping/ place-value knowledge helps estimate sums and difference.	← Use a front-end strategy with ... → two-digit numbers (e.g., 51+36+7 is at least 5 tens + 3 tens or 80)	3- and 4-digit numbers (e.g., 563+222+87 is at least 5 hundreds + 2 hundreds or 700)

Appendix H cont.

Topic	*Pre-K*[a]		*Kindergarten*	*1*	*2*
	2-3 years	*4 years*	*5 years*	*6 years*	*7 years*
Equal Partitioning A quantity (whole) can be partitioned (decomposed) into equal size pieces (parts)					
a. Concrete equal-partitioning experiences with collections and then continuous quantities lay the groundwork for understanding division and fractions.		← Use informal strategies to solve divvy-up fair-sharing problems with collections of… →			
		Up to 10 items between tow people	Up to 20 items among 3-5 people; knows fairs shares have same number	Up to 100 items (grouped by tens and ones) among up to 10 people	Up to 1,000 (grouped by hundreds, tens, and ones) among up to 20 people
			← Use informal strategies to solve measuring-out fair-sharing problems with… →		
			Up to 20 items and shares of two to five items	Up to 100 items (groups of tens and ones) and shares up to 10 items	Up to 1,000 (grouped by hundreds, tens, and ones) and shares of up to 20 items
				← Use informal strategies to solve divvy-up fair-sharing problems with continuous quantities →	
				1 to 10 wholes and two to five people	1 to 20 wholes and two to ten people

Appendix H cont.

b. Connecting fraction names to equal-partitioning experiences builds knowledge that fractions involve a whole divided into equal size parts.	← Verbally label a fair-share of →		
	One of two as "half" or "one-half"	1/2, 1/3, 1/4, 1/5	non-unit fractions, e.g., 2/4, 2/8
		← Compare verbal or part-of-whole meaning of fractions involving.... →	
		unit fractions 1/2, 1/3	nonunit fractions

Note. This is the first of several tables of developmental guidelines. It is essential to note that theses are developmental guidelines from research. All such tables should be interpreted or used after reading the description and caveats in the section "Developmental guidelines" on p. 25:38. Table 1.1 was developed by an initial structure developed by a subset of the Conference Working Group led by Karen Fuson, and was then greatly elaborated in collaboration with Arthur Baroody (see his chapters in this volume-most of the tables' content original was written by Barrody in a draft of those chapters), to whom we owe a great deal of appreciation.

[a]Ages reflect t those typically found in classes or groups of children; for example, the first category, a typical classroom of "3-year-olds" may begin the year with some 2-year olds and end the year with some children just turning 4years of age.

* Note. From Engaging young children in mathematics Edited by D. H. Clements and J. Sarama, 2004, New York, NY: Lawrence Erlbaum Associates, Publishers.

Appendix I

Props and Visual Material

The props and visual materials presented here are actual size.

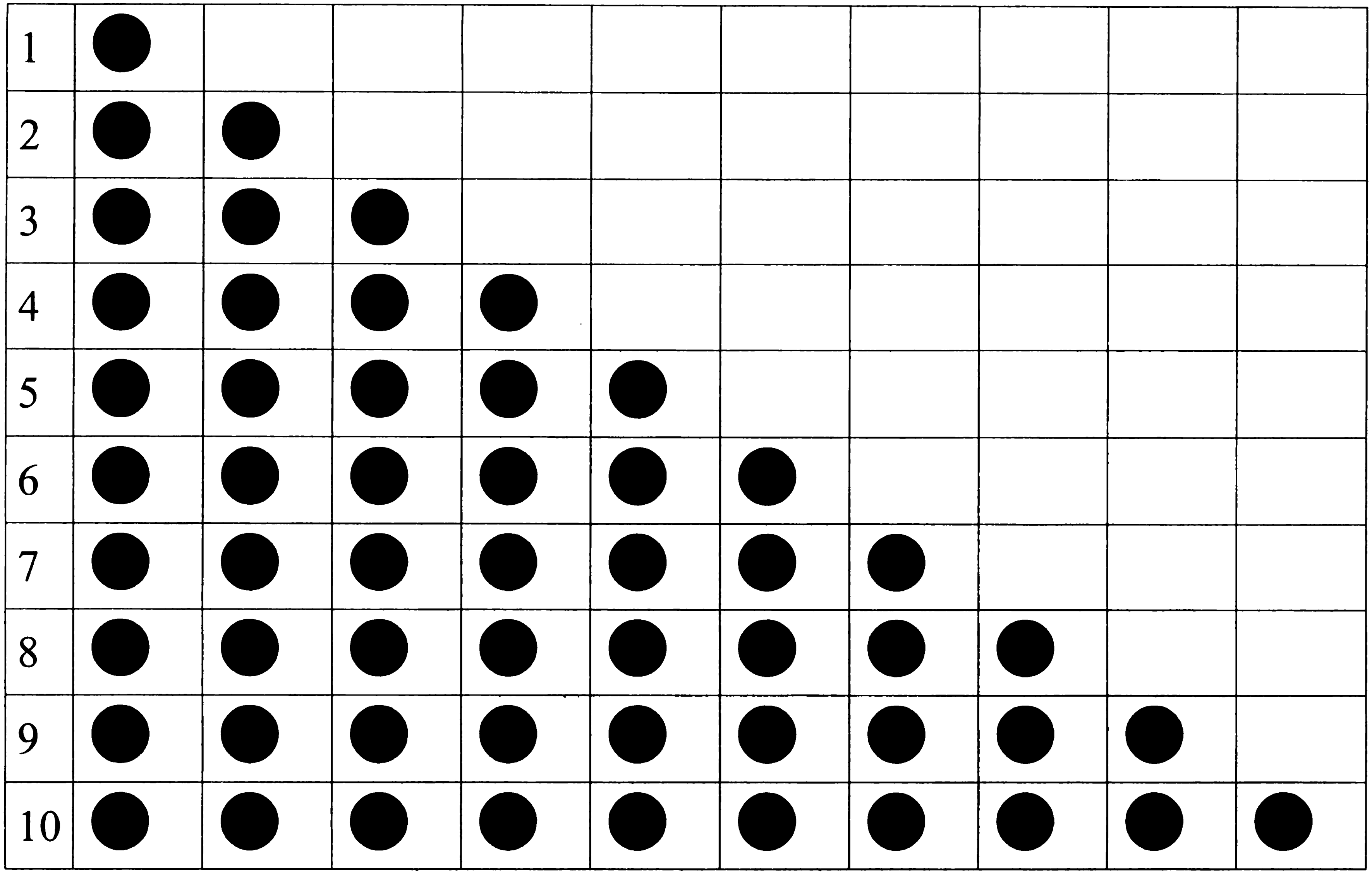


Figure 1. Number Chart

To help with the quantity and Arabic symbols. This chart was also used to help with the concept of the complement of 10.

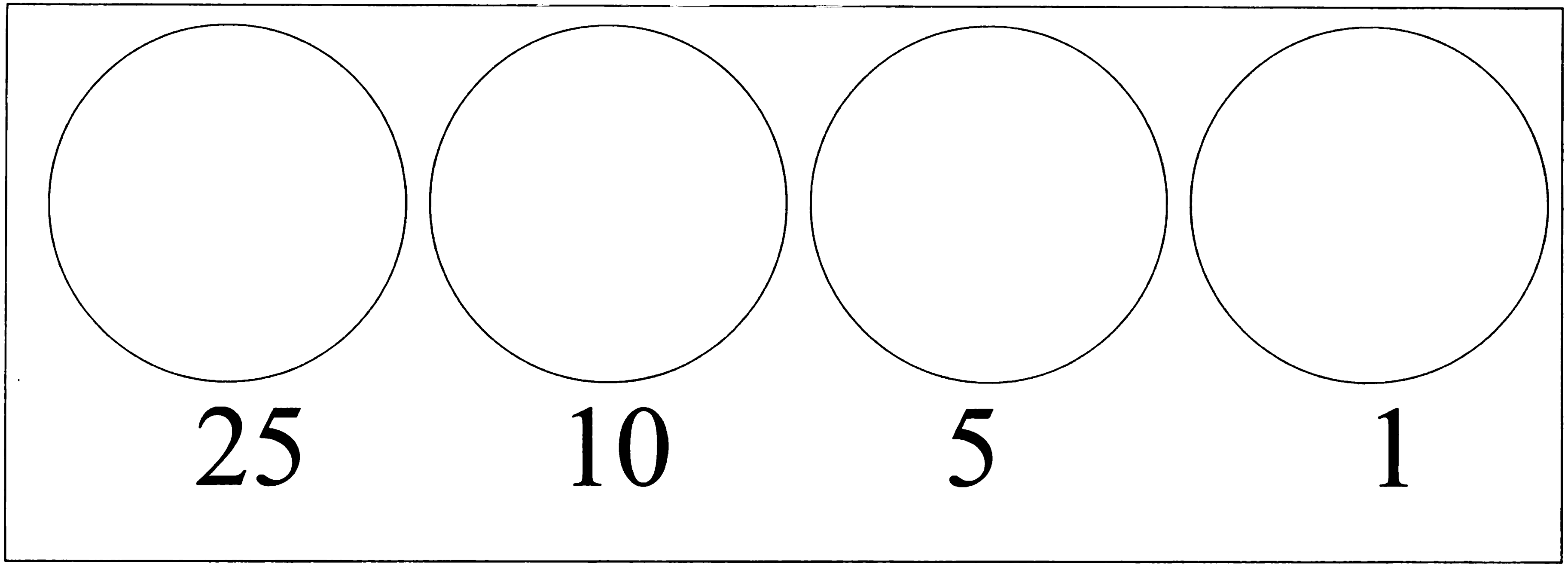


Figure I- 2. Coin classification chart

To help with classification of different coins. The participants were encouraged to put coins in order, and then add from left

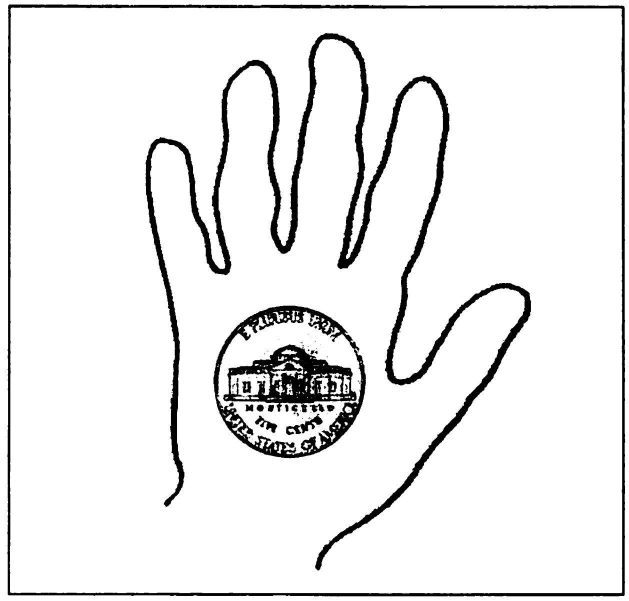


Figure I-3. Nickel Hand Prop

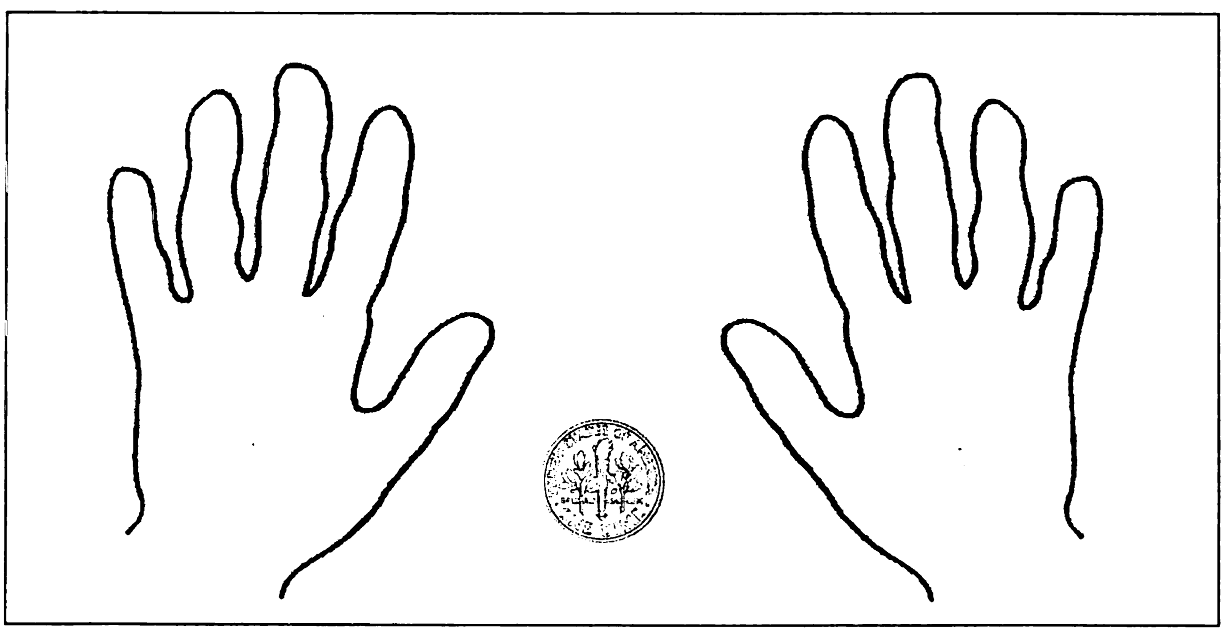


Figure I-4. dime Hand Prop

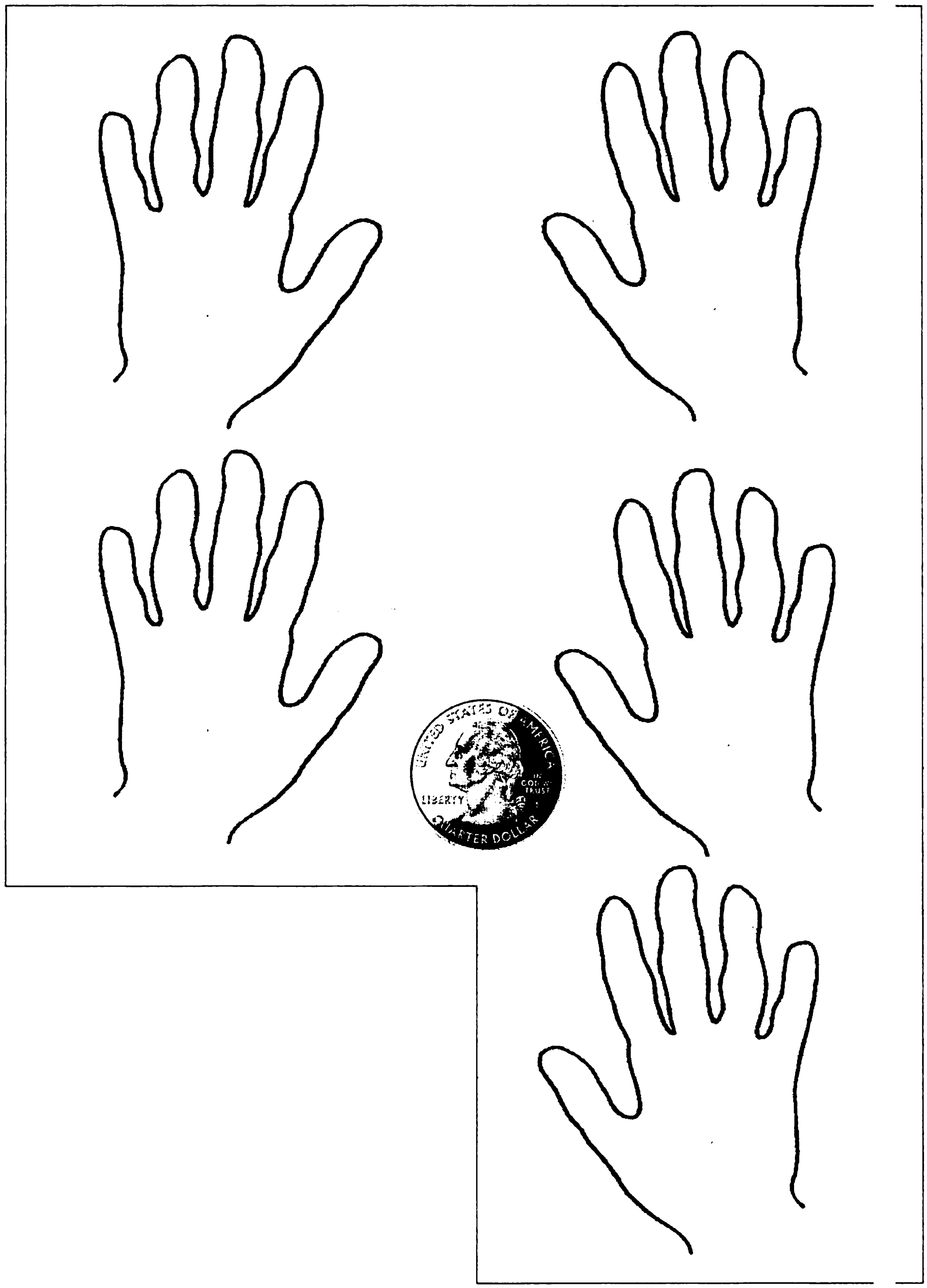


Figure I-5. Quarter Hand Prop Pattern 1

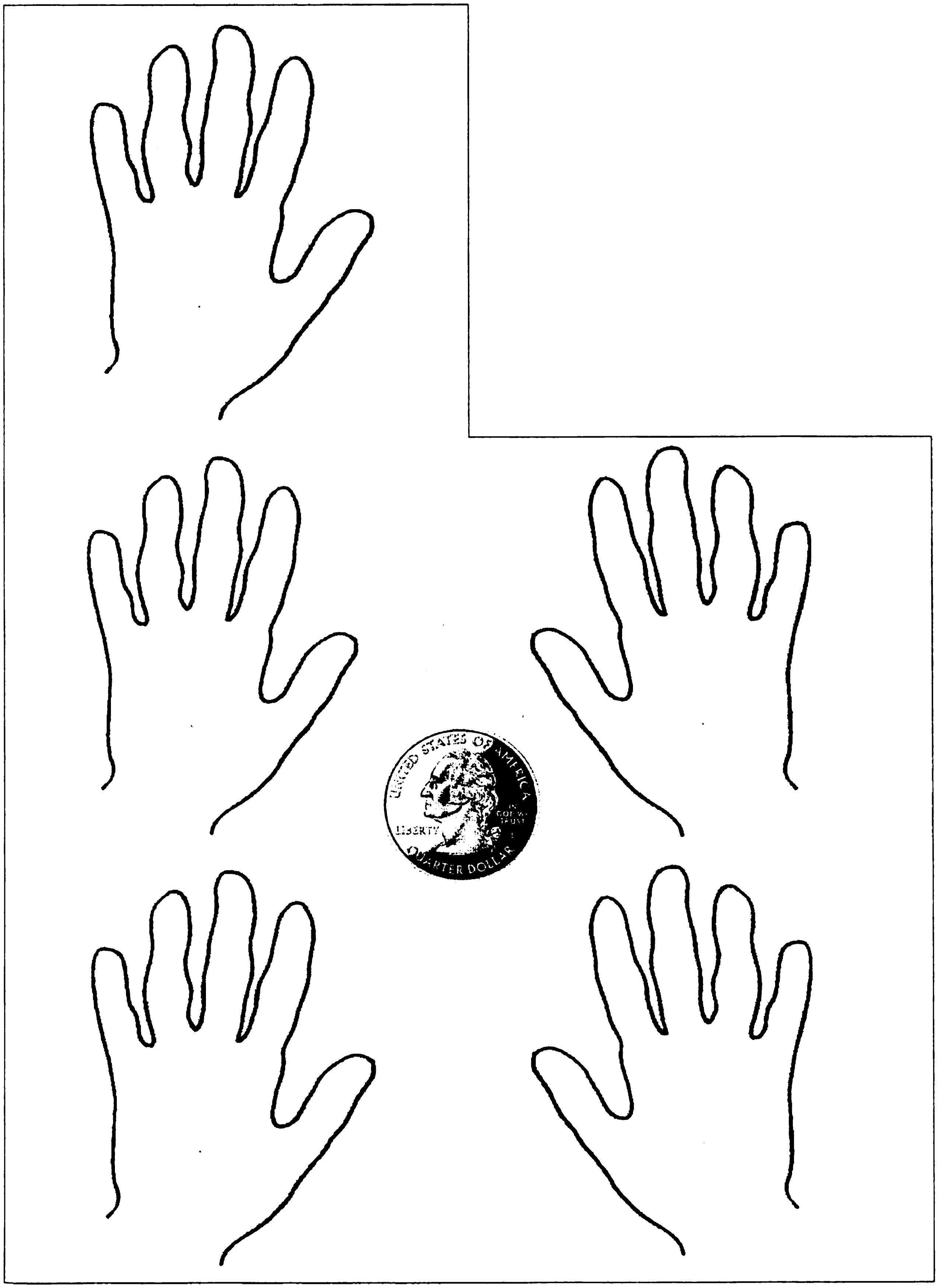


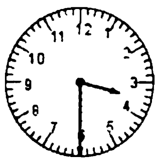
Figure I-6. Quarter Hand Prop II.
To put the pattern 1 and 2 makes 50 cents presentation.

Appendix J

Pre-test of Angela, Roxy, and Big Red

Angela

1. What time is it?



a. 4:30 b. 7:15 c. 6:03 d. 3:30

2. Put these numbers in order, from largest to smallest: 7, 12, 3, 8, 19.

a. 3. 7. 8. 12. 19
b. 12. 19. 3. 7. 8
c. 19. 12. 8. 7. 3
d. 12. 3. 7. 8. 19

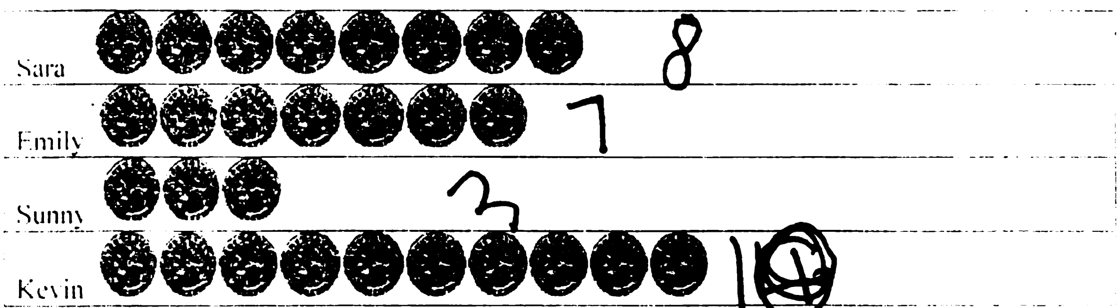
3. You find 3 nickels, 1 quarter, and 2 dimes in your pocket. How much money do you have?

a. 6 cents
b. 30 cents
c. 47 cents
d. 60 cents

4. How do you read the equation 11 = 9 + 2 out loud?

a. Eleven equals nine plus two.
b. Eleven minus nine equals two.
c. Eleven equals nine minus two.
d. Eleven plus nine equals two.

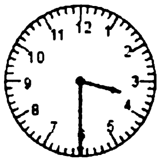
5. Look at the pictograph. Which person has the most coins?



a. Sara b. Emily C. Sunny D. Kevin

Roxy

1. What time is it?



a. 4:30 (b) 7:15 c. 6:03 d. 3:30

2. Put these numbers in order, from largest to smallest: 7, 12, 3, 8, 19. I Dont know

a. 3, 7, 8, 12, 19
b. 12, 19, 3, 7, 8
c. 19, 12, 8, 7, 3
d. 12, 3, 7, 8, 19

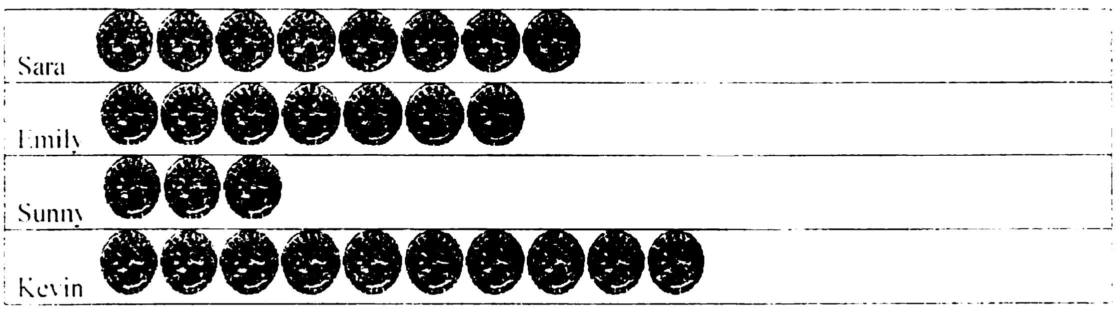
3. You find 3 nickels, 1 quarter, and 2 dimes in your pocket. How much money do you have?

(a) 6 cents
b. 30 cents
c. 47 cents
d. 60 cents

4. How do you read the equation 11 = 9 + 2 out loud?

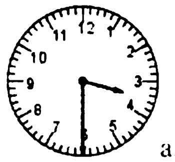
(a) Eleven equals nine plus two.
b. Eleven minus nine equals two.
c. Eleven equals nine minus two.
d. Eleven plus nine equals two.

5. Look at the pictograph. Which person has the most coins?



a. Sara b. Emily C. Sunny (D). Kevin

1. What time is it?



a. 4:30   b. 7:15   c. 6:03   d. 3:30

2. Put these numbers in order, from largest to smallest: 7, 12, 3, 8, 19.

a. 3, 7, 8, 12, 19
b. 12, 19, 3, 7, 8
c. 19, 12, 8, 7, 3
d. 12, 3, 7, 8, 19

19 12 8 7 3
19 7 3 12
19 8 7 3 12

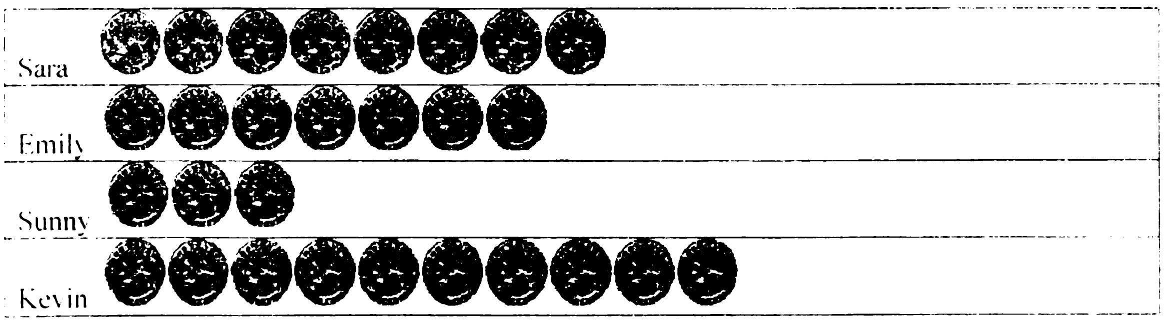
3. You find 3 nickels, 1 quarter, and 2 dimes in your pocket. How much money do you have?

a. 6 cents
b. 30 cents
c. 47 cents
d. 60 cents

4. How do you read the equation 11 = 9 + 2 out loud?

a. Eleven equals nine plus two.
b. Eleven minus nine equals two.
c. Eleven equals nine minus two.
d. Eleven plus nine equals two.

5. Look at the pictograph. Which person has the most coins?



a. Sara   b. Emily   C. Sunny   D. Kevin

Appendix K

Mathematical Mistakes and Interesting Incidents

Some of interesting and thought-provoking episodes are presented in this section. Some of them are already mentioned in the case studies as well as analysis, and interpretation sections.

In the conversation, Emily is identified by the dialogue without a line, and the participants dialogue has lines.

Big Red

Episode	Conversation
Big Red 1	Give me a nickel Normal
Big Red 2	Let's make 25 pennies here. 1, 2,3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25 (Did not use any strategies for faster process such as counting by 2's or 5's)
Big Red 3	__________A Nickel… is a nickel smaller or bigger? You need to think about it. __________I think normal nickels are little bigger.
Big Red 4	Dime has the tingly feeling. (singing *Give Me a Nickel)* ________ Normal (singing *Give Me a Nickel e)* ________tiny so tiny
Big Red 5	Give me a dime. ________ Dime is worth 5 cents Uh-huh ________ Dime is worth 25 cents. Uh-huh __________ 10
Big Red 6	(Asked him to find a quarter within a two count) Quarter, one - two __________Oh!!! (cannot finishes the task within a time frame, he was frustrated and he touched forehead) Dime, one - two __________One and two Nickel, one - two __________One and two One and two (cannot fine a nickel, anxiously rubs his hands together, has agitated body posture, fine motor difficulty is presented)

Big Red 7	(He supposed pick two quarters; he picks a quarter and a nickel) Look at this __________That's not good. This is right. This is wrong. (Rubs his hands together)
Big Red 8	Five pennies same as (expect him to answer a nickel) __________Five nickel
Big Red 9	__________(sings *Five Pennies Make a Nickel*) Two dimes and a quarter make a quarter every time.
Big Red 10	__________(sings *Five Pennies Make a Nickel*) Two nickels, Two nickels (supposed to be a dime; growls; rubs his forehead)
Big Red 11	(work on finding nickel, dime, and quarter) 14:10 Nickel, dime, and quarter __________A nickel... A dime... and a quarter... There we go. Mm-hmm __________This is nickel. Because this is tiny. No, a nickel is normal. __________It's the original size.
Big Red 12	How many? (points out a nickel) __________10 (he examines my facial expression for the hidden message.) That's 5. (add one more nickel) __________10 (add one more nickel) __________15. No way! (he thinks he got the wrong answer) 15! Yeah! you are right! you are right! (add one more nickel) __________OK (point two nickels) __________10 (add one more nickel) __________20, No, 10, 15, 20 (It is supposed to be 5, 10, 20) 10, 15, 20. No!!!
Big Red 13	OK, How many hands are there? __________1, 2, 3, 4, 4! How many fingers are there? __________.................. 5, 10, 15, 20 Good. This is (show my one hand) __________5 (show one more hand) makes? __________10 Put your 5 fingers and __________5 (I expect him to say 15) And all together __________10 (I expect him to say 20) Your ten and my ten makes

Big Red 13 (cont.)	_________10, 15. No! No, No Think about it your hands have 10 fingers. My fingers are 10. All together? _________25 Think about it. Your hands have ten fingers. Like this one and this one (point the nickel hand prop). Let's count together. _________5, 10, 15, 20, there we go OK. 10 and your ten. Makes? __________10, 15, 20, 25 (count my first hand as a 10) Ah-ha. I got you. I think I know why you think that way. OK. 5, 10, 15, 20 (show him to one hand by one hand) _________5, 10, 15, 20 Let's do it. _________5, 10, 15, 20 _________5, 10, 15, 20 (he points each hand one by one).
Big Red 14	(show a dime hand prop) ___________10, right? (show the second dime hand prop) ___________25 (examines Emily's facial expression) ___________10, 20. There we go. (show the third dime hand prop) ___________25 (examines Emily's facial expression) ___________30, there we go. (put down a dime hand prop and a nickel hand prop) ___________10. (points a dime hand prop) Just 10. Ah-ha, this is 10. ___________(points a nickel hand prop) 25 Before you tell me, think about it. ●● (a dime hand prop) ● (a nickel hand prop) 5, 10, 15 ___________5, 10, 15 There we go. (switch to a dime hand prop) ●● (a dime hand prop) ●● (a dime hand prop) ___________5, 10 ___________This gotta be 5. This is 5. ___________5, 10, 15, 20 Good, OK (switch to a nickel hand prop) ●● (a dime hand prop) ● (a nickel hand prop) ___________(points the top line dime hand prop) 5

Big Red 14 (cont.)	___________(points the second line nickel prop)10 ___________(examines Emily's facial expression; points the second line nickel prop again) 15 ___________(points the left hand from the dime hand prop) 5, ___________(points the right hand from the dime hand prop) 10, ___________(points the second line nickel prop) 20, No (touches his forehead) (show approval facial expression; points one hand by one hand) _________5, 10, 15 Good.
Big Red 15	●● 5 ●10 ● 15 ●● 30
Big Red 16	_________Five pennies make a nickel. _________Two pennies make a dime.
Big Red 17	_________Five pennies make a nickel. _________Two dimes make a dime. _________Two dimes and a quarter make a nickel.
Big Red 18	_________That's gotta be a quarter. Can you tell me how many fingers are there? _________1, 2, 3, 4, 5 That's how many hands. How many fingers are there? _________1, 2, 3, 4, 5 There are more fingers, isn't it? _________1, 2, 3, 4, 5 _________1, 2, 3, 4, 5 _________1, 2, 3, 4, 5 _________1, 2, 3, 4, 5 (laugh) Good How can you count that? We practice that one, 5. _________5, 10, 15, 20, 25 Yeah!!! How many fingers are there? _________5 (shows his one hand) Here… how many fingers? _________10, No way. 1, 2, 3, 4, 5 That's how many hands. How many fingers are there? _________1, 2, 3, 4, 5 How many fingers are here? _________1, 2, 3, 4, 5 (points one finger by one finger in one hand) 5, 10,fingers 15 fingers 20 fingers _________25 fingers (a phone is ringing and looks away) (sing *How Many Pennies in a Quarter*) _________(sings the answer) 25. This one is? (show a quarter hand prop) _________25 How many fingers are there? (show another a quarter hand prop)

Big Red 18 (Cont.)	_________5, 10, 15, 20, 25. 25 again, Wow Quarter? _________25 Quarter 25 (sing *Nickel five, Dime 10, Quarter 25* song) _________(Answers the song) 10, 25 _________(A phone is ringing again, and tries to focus and to not look away. Was not successful) We ignore the phone.

Roxy

Episode	Conversation

Roxy 1	(Works on 5 pennies same as a nickel, 10 pennies same as a dime, and 25 pennies same as a quarter)
	It is same as a quarter (points out 5 pennies in 5 rows), and five pennies same as a nickel.
	How many pennies?
	        35
	Why
	        Because there is 35 pennies.
	35 pennies? This is 25 and this is 5.
	25 plus 5 equals
	        35
	Nope-Nope

Roxy 2	Roxy, you have 10, and take away 5. How much you have?
	        (manipulates her fingers, but could not do it)
	(shows her 10 fingers and take away 5)
	        5

Roxy 3	(previously we work on coin hand props; showed her nickel hand prop and worked on counting by 5; showed her dime hand prop and worked on counting by 10)
	(presents 4 nickel hand props)
	        5, 10, 15, 20
	(presents dime hand prop)
	        25
	No, just this (covers the 4 nickel hand props and points dime hand prop)
	        10
	Mm-hmm (adds nickel hand prop)
	        15
	(adds one more nickel hand prop)
	        16
	(shakes my head) 10
	        20
	Yeah! (takes out one nickel hand prop). This is 10
	        5
	10 and 5
	        15
	(add one more nickel hand prop)
	        Er!!!!!!!!!!!!! (manipulates her fingers) 16?
	How many fingers (points a hand by a hand)? Count from here.
	        5, 10, 15, 20. Now I got it.
	I think you got it. This is one hand, but how many fingers?
	        5 (holds a hand in a air and adds another hand) and this is
	                10

	(hold up my right hand) all together ...15 Give me your 10. Give me your 10 fingers (hold up my right hand) 20, This is 15 (add my left hand) 10 Yeah! I have 10 and you have 10 Together 25 10 and 10 20
Roxy 4	(work on mixed dimes and nickels) (two dimes) 10, 20 (add a nickel) 5 Twenty...five 25 10, 20 (add a nickel) 5 Twenty-five hohum, 25 (present a dime) 10 (add one more dime) 20 (add a nickel) 25 (add a nickel) 30 (add a nickel) 35 (add a nickel) 40 (take away a nickel) 30. (looks at my facial expression; growls; thrusts her hand downward) I always messed up. No. (Sing *You Can Do It*; stop after the lyric "if you") try (laughs and changes her mode)

Roxy 5	(show her a nickel) ________5 (add a penny) ________15 No, if I this one (put the dime), it is 15. But this is? ________6 Yes (add more pennies). ________7, 8, 9, 10 (add a dime) ________20 (high five; add a penny) ________25 How much? ________One. Messed up every time. Yai yai ya (throw herself into her lap) No (singing, *You Can Do It song*: You can do it, you can do it, you can do it, if you…) _______I always messed up on those one with the dime and nickel (roles her eyes and throw herself backward toward to the couch)

Angela

Session 1	
Episode	Conversation
Angela 1	How many pennies in a quarter? 52 pennies?
Angela 2	(Working on counting by 5) 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 10 I mean 60.
Angela 3	(holds up 8 fingers: 3 fingers in right hand and 5 in left hand: In her view, I hold up 3 in her left side and 5 in her right side) 1, 2, 3 (counting fingers in my left side and then) 4, 5, 6, 7, 8 [Better strategy is counting 5 and 6, 7, 8 for the faster process]
Angela 4	(puts down two nickels) How much is it? And, 5 and…. 25…. (Thinks with tapping her chin)… 29 29! No, No, No. This is 5. OK. Nickel five, (Sings *nickel, dime, quarter)* (finishes the stanza for quarter) 25 (Sings *Nickel, Dime, Quarter)* Nickel five. How much is it? 10 (read my Emily's facial expression) (points a nickel) This is??? 25 No, nickel is 5. 10!!!!!!!
Angela 5	(points the quarter finger chart) How many fingers? 1, 2, 3, 4, 5, No, No, No. (points a quarter in the middle of the quarter finger chart) That's? 25 Look at this (points out each fingers). 5, 10, 15, 20, 25 (high five)
Angela 6	(points a quarter) This is how much? 25. This is 25. And this is? (points a nickel) A nickel? Nickel and 25 plus 5 equals. 29! 29 90… wait. I am confused
Angela 7	(presents 4 dimes and a nickel) 10 10, 20, 30, 40, 50… 55 (Gives her surprised facial expression; sings *Think Before You Answer*) 10, 20 (together) 30, 40 40 plus 5 equals 45 Together: (high five)
Angela 8	10 plus 5 equals

	holds up fingers one by one) 11 is 1, 12 is 2, 13 is 3, 14 is 4, 15 is 5.
Angela 9	(presents in verbal format) 25 + 10 equals 30 (presents in a written format) 25 + 10 equals (works on the 25 + 10) Yes, you need to write down 5 there. 35!
Angela 10	(Sings *How Much is it Bum, Bum, Bum?*) ____________ (a dime, a nickel, and a penny) 1, 11, 25 I mean, I mean… 19… Let's me share the secret with you. Put the most valuable first (points out coin classification chart). 10 + 5 equals ………… Um 10 + 5 equals (shouts) 10 10 + 5 equals ? (points coin hand props with a dime and a nickel) (counts coin hand props) 5, 10, 15 This one (points a penny) 21 (in singing voice) This is … One (penny) …. 15, what is the next number? 20 (very careful voice) 15… 16
Angela 11	(Sings *How Much is it Bum, Bum, Bum?;* 3 quarters) 25……ah…. 75 (in singing voice) I mean 25 (in singing voice). 70 (in singing voice) 25 (shows quarter hand prop pattern 1 and 2 together) 5, 10, 15, 20, 25, 30, 35! (with exited voice) Uh-oh 75 wait… (covering her face with her hand) OK, you can do it. How much? (shows one hand) 5 (shows two hands) 10 (points two hands in the quarter hand props) 10, 20, 30, 40, 50
Angela 12	(Ⓢ *How Much is it Bum, Bum, Bum?*; three nickels) 10, 20, 35? (Ⓢ Think before you answer) How much is it? (Ⓢ nickel five)
Angela 13	(Ⓢ *How Much is it Bum, Bum, Bum?*; a dime & two nickels) 75 (nervously nods)… 5

	Is it same size? 10, 20.... 25 (shows her "No" facial expression) I mean (covers her face with her hands) (Ⓢ *nickel five*) (lets her feel the smooth edge of a nickel) 10 + 5 equals 20, 15 Plus 5 is 15 and 20
Angela 14	(points to 9:30) What time is it? 10 But clock goes this way, so 7... No 6 (Angela reads the number where the big hand points) No, Uh-uh (no). It passes 9 but does not pass 10. That's why you need to say 9 o'clock This is? 6 o'clock (it supposed to be 30 minutes) No Big hand goes like. 5, 10, 15, 20, 30 I mean 25, 30 Yes! 9:30.
Angela 15	Clock goes which way? That way. Pass 4, but not pass 5 Which means? 30... Uh-oh !!! (sing *Think Before You Answer*)

REFERENCES

Adler, R. F. (2006). Goals and treatment objectives, settings, and service delivery models for the school age years. In M. E. Humpal & C. M. Colwell (Eds.), *AMTA Monograph series: Effective clinical practice in music therapy: Early childhood and school age educational settings* (pp. 68-81). Silver Spring, MD: American Music Therapy Association

Aldridge, D. (1996). *Music therapy research and practice in medicine: from out of the silence*. London; Bristol, PA: J. Kingsley.

Ansari, D., Donlan, C., Thomas, M. S. C., Ewing, S. A., Peen, T., & Karmiloff-Smith, A. (2003). What makes counting count? Verbal and visuo-spatial contributions to typical and atypical number development. *Journal of Experimental Child Psychology, 85*(1), 50-62.

Ansari, D., & Karmiloff-Smith, A. (2002). Atypical trajectories of number development: a neuroconstructivist perspective. *Trends in Cognitive Sciences, 6*(12), 511-516.

Aunio, P. (2008). Early numeracy in low-performing young children. *British Educational Research Journal, 99999*(1), 1-22.

Bachot, J., Gevers, W., Fias, W., & Roeyers, H. (2005). Number sense in children with visuospatial disabilities: orientation of the mental number line. *Psychology Science, 47*(1), 172-183.

Baharloo, S., Johnston, P. A., Service, S. K., Gitschier, J., & Freimer, N. B. (1998). Absolute pitch: An approach for identification of genetic and nongenetic components. *The American Journal of Human Genetics, 62*(2), 224-231.

Bellugi, U., Lichtenberger, L., Jones, W., Z., L., & St. George, M. (2001). The neurocognitive profile of Williams Syndrome: A complex pattern of strengths and weakness. In U. Bellugi, M. St. George & A. M. Galaburda (Eds.), *Journey from cognition to brain to gene: perspectives from Williams Syndrome* (pp. 1-41). Cambridge, MA: MIT Press.

Bellugi, U., Marks, A. B., Bihrle, A., & Sabo, H. (1988). Dissociation between language and cognitive functions in Williams syndrome. In D. Bishop & K. Mogford (Eds.), *Language Development in Exceptional Circumstances* (pp. 177-189). London: Churchill Livingstone.

Bellugi, U., & St. George, M. (2001). *Journey from cognition to brain to gene: Perspectives from Williams Syndrome.* Cambridge, Mass.: MIT Press.

Bellugi, U., Wang, P. P., & Jernigan, T. L. (1994). Williams syndrome: An unusual neuropsychological profile. In S. H. Broman & J. Grafman (Eds.), *Atypical cognitive deficits in developmental disorders: Implications for brain function* (Vol. 23). Hillsdale, NJ: Lawrence Erlbaum Associates.

Benner, G. J., Nelson, J. R., Allor, J. H., Mooney, P., & Dai, T. (2008). Academic processing speed mediates the influence of both externalizing behavior and language skills on the academic skills of students with emotional disturbance. *Journal of Behavioral Education, 17*(1), 63-78.

Benson, H. S. (2003). Glossary of math terms. Retrieved 05-31, 2008, from http://journal.naeyc.org/btj/200301/MathGlossary.pdf

Bertrand, J. (1997). Drawing by children with Williams Syndrome: A developmental perspective. *Developmental Neuropsychology, 13*(1), 41-67.

Bertrand, J., & Mervis, C. B. (1996). Longitudinal analysis of drawings by children with Williams Syndrome: Preliminary results. *Visual Arts Research, 22*(44), 19-34.

Booth, J. L., & Siegler, R. S. (2006). Developmental and individual differences in pure numerical estimation. *Developmental Psychology, 41*(6), 189-201.

Brock, J. O. N. (2007). Language abilities in Williams syndrome: A critical review. *Development and Psychopathology, 19*(01), 97-127.

Brooks, D. M. (2003) D. Brooks, A history of music therapy journal articles published in the English language, *Journal of Music Therapy* 40 (2), pp. 151–168

Bruscia, K. E. (1998). Standards of integrity for qualitative music therapy research. *Journal of Music Therapy, 35*(3), 176-200.

Bull, R., Espy, K. A., & Wiebe, S. A. (2008). Short-Term Memory, Working Memory, and Executive Functioning in Preschoolers: Longitudinal Predictors of Mathematical Achievement at Age 7 Years. *Developmental Neuropsychology, 33*(3), 205 - 228.

Carpenter, T. P., Fennema, E., Franke, M., Levi, L., & Empson, S. B. (1999). *Children's mathematics: Cognitively guided instruction*. Portsmouth, NH: Heinemann.

CBS (1997). A very special brain *60 Minutes [Television series]*: CBS: Available at www.williams-syndrome.org/media/wstv.html.

Clements, D. H. (2004). Major themes and recommendations In D. H. Clements & J. Sarama (Eds.), *Engaging young children in mathematics: Standards for early childhood mathematics education* (pp. xv, 474 p.). Mahwah, NJ: Lawrence Erlbaum Associates.

Clements, D. H., & Sarama, J. (2004). *Engaging young children in mathematics: Standards for early childhood mathematics education*. Mahwah, N.J.: Lawrence Erlbaum Associates.

Cooper, R. G (1984). Early number development: Discovering number space with addition and subtraction. *Origins of cognitive skills*, 157-192.

Creswell, J. (1998). *Qualitative inquiry and research design: Choosing among five traditions*: Sage Publications.

Davis, W. B. (1999). Music therapy for mentally retarded children and adults In W. B. Davis, K. E. Gfeller & M. H. Thaut (Eds.), *An introduction to music therapy: Theory and practice* (2nd ed., pp. xiv, 370 p.). Boston, MA: McGraw-Hill.

Dehaene, S., Bossini, S., & Giraux, P. (1993). The mental representation of parity and number magnitude. *Journal of Experimental Psychology: General, 122*(3), 371-396.

Dehaene, S., Dupoux, E., & Mehler, J. (1990). Is numerical comparison digital? Analogical and symbolic effects in two-digit number comparison. *Journal of Experimental Psychology: Human Perception and Performance, 16*(3), 626-641.

Deruelle, C., Sch, D., Rondan, C., & Mancini, J. (2005). Global and local music perception in children with Williams syndrome. *Neuroreport, 16*(6), 631-634.

Dirckx, J. H. (2005). *Stedman's concise medical dictionary for the health professions and nursing: indexed (Stedman's Concise Medical Dictionary)*: Lippincott Williams & Wilkins.

Don, A. J., Schellenberg, G. E., & Rourke, B. P. (1999). Music and language skills of children with Williams Syndrome. *Child Neuropsychology, 5*(3), 154-170.

Donnai, D., & Karmiloff-Smith, A. (2000). Williams syndrome: From genotype through to the cognitive phenotype. *American Journal of Medical Genetics, 97*(2), 164-171.

Dowker, A. (2003). Interventions in numeracy: Individualized approaches. In I. Thompson (Ed.), *Enhancing Primary Mathematics Teaching*. London: Open University Press.

Dowling, W. J. (1991). Rhythm and tonality in children's recognition of intact and distorted melodies. Unpublished paper presented at the Biennial Meeting of the Society for Research ni Child Development (Seattle, WA, April 18-20, 1991) from http://eric.ed.gov/ERICDocs/data/ericdocs2sql/content_storage_01/0000019b/80/24/22/3f.pdf.

Dowling, W. J. (1993). Procedural and declarative knowledge in music cognition and education. In T. J. Tighe & W. J. Dowling (Eds.), *Psychology and music: The understanding of melody and rhythm.* (pp. 5-18). Hilsdale, NJ: Lawrence Erlbaum Association

Dowling, W. J., & Fujitani, D. S. (1971). Contour, Interval, and Pitch Recognition in Memory for Melodies. *The Journal of the Acoustical Society of America, 49*, 524.

Duerksen, G. L. (1968). The Research Process. In E. T. Gaston (Ed.), *Music in Therapy* (pp. 409-424). New York,: Macmillan.

Dykens, E. M., & Rosner, B. A. (1999). Refining behavioral phenotypes: personality-motivation in Williams and Prader-Willi syndromes. *Am J Ment Retard, 104*(2), 158-169.

Dykens, E. M., & Rosner, B. A. (2006). Psychopathology in Persons with Williams-Beuren Syndrome. In C. A. Morris, H. M. Lenhoff & P. P. Wang (Eds.), *Williams-Beuren Syndrome: Research, Evaluation, and Treatment* (pp. 274-293). Baltimore: Johns Hopkins University Press.

Elliott, D. J. (1995). *Music matters: A new philosophy of music education*. New York: Oxford University Press.

Epstein, D. (1985). Tempo Relations: A Cross-Cultural Study. *Music Theory Spectrum, 7*(1), 34-71.

Fanconi, G, Giradet, P., Schlesinger, B., Butler, N., & Blade, J. S. (1952). Chronische Hy percalcaemie kombiniert mit Osteosklerose, Hyperazotaemie, Minderwuchs, und kongenitalen Missbildungen. *Helvetica Paediatrica Acta* 7: 314-334.

Fidler, D. J., Lawson, J. E., & Hodapp, R. M. (2003). What do parents want? An analysis of education-related comments made by parents of children with different genetic syndromes. *Journal of Intellectual & Developmental Disability, 28*(2), 196-204.

Frangiskakis, J. M., Ewart, A. K., Morris, C. A., Mervis, C. B., Bertrand, J., Robinson, B. F., et al. (1996). LIM-kinase1 hemizygosity implicated in impaired visuospatial constructive cognition. *Cell, 86*(1), 59-69.

Fuson, K. C. (2004). Pre-K to Grade 2 goals and standards: Achieving 21st-century mastery for all. In D. H. Clements & J. Sarama (Eds.), *Engaging young children in mathematics: Standards for early childhood mathematics education* (pp. 105-148). Mahwah, N.J.: Lawrence Erlbaum Associates.

Gaston, E. T. (1968). Man and music. In E. T. Gaston (Ed.), *Music in Therapy* (pp. 7-29). New York,: Macmillan.

Geary, D. C. (2004). Mathematics and learning disabilities. *JOurnal of Learning Disabilities, 37*(1), 4-15.

Getty, D. J. (1975). Discrimination of short temporal intervals: A comparison of two models. *Perception & psychophysics, 18*(1), 1-8.

Gfeller, K. E. (1999). Music therapy in the schools. In W. B. Davis, K. E. Gfeller & M. H. Thaut (Eds.), *An introduction to music therapy: Theory and practice* (2nd ed., pp. 259-272). Boston, Mass: McGraw-Hill.

Gordon, E. (1997). *A music learning theory for newborn and young children* (1997 ed.). Chicago: GIA Publications.

Gothelf, D., Farber, N., Raveh, E., Apter, A., & Attias, J. (2006). Hyperacusis in Williams syndrome Characteristics and associated neuroaudiologic abnormalities. *Neurology, 66*(3), 390-395.

Hackett, P. (1998). *The Melody Book: 300 Selections from the World of Music for Autoharp, Guitar, Piano, Recorder, and Voice* (3rd ed.): Prentice-Hall.

Hallahan, D. P., & Kauffman, J. M. (2003). *Exceptional Learners: Introduction to special education* (9th ed.): Allyn & Bacon.

Holmes, J., & Adams, J. W. (2006). Working memory and children's mathematical skills: Implications for mathematical development and mathematics curricula. *Educational Psychology, 26*(3), 339-366.

Hopyan, T., Dennis, M., Weksberg, R., & Cytrynbaum, C. (2001). Music Skills and the expressive interpretation of music in children with Williams-Beuren Syndrome: Pitch, rhythm, melodic imagery, phrasing, and musical affect. *Child Neuropsychology, 7*(1), 42-53.

Howlin, P., Davies, M., & Udwin, O. (1998). Cognitive functioning in adults with Williams Syndrome. *The Journal of Child Psychology and Psychiatry and Allied Disciplines, 39*(02), 183-189.

Jarrold, C., Baddeley, A. D., & Hewes, A. K. (1999). Genetically dissociated components of working memory: Evidence from Down's and Williams syndrome. *Neuropsychologia, 37*(6), 637-651.

Jarvis, H. L., & Gathercole, S. E. (2003). Verbal and non-verbal working memory and achievements on national curriculum tests at 11 and 14 years of age. *Educational and Child Psychology, 20*(3), 123-140.

Jordan, N. C., Hanich, L. B., & Kaplan, D. (2003). A longitudinal study of mathematical competencies in children with specific mathematics difficulties versus children with comorbid mathematics and reading difficulties *Child Development, 74*(3), 834-850.

Karmiloff-Smith, A., Ansari, D., Campbell, L., Scerif, G., & Thomas, M. (2006). Theoretical implications of studying cognitive development in genetic disorders. In C. A. Morris, H. M. Lenhoff & P. P. Wang (Eds.), *Williams-Beuren Syndrome: Research, Evaluation, and Treatment* (pp. 274-293).

Kilpatrick, J., Swafford, J., & Findell, B. (2001). *Adding it up: Helping children learn mathematics*: National Academy Press.

Klein, B. P., & Mervis, C. B. (1999). Contrasting patterns of cognitive abilities of 9- and 10-year-olds With Williams Syndrome or Down Syndrome. *Developmental Neuropsychology, 16*(2), 177-196.

Lacro, R. V., & Smoot, L. B. (2006). Cardiovascular Disease in Williams-Beuren Syndrome. In C. A. Morris, H. M. Lenhoff & P. P. Wang (Eds.), *Williams-Beuren syndrome : research, evaluation, and treatment* (pp. 107-124). Baltimore: Johns Hopkins University Press.

Lenhoff, H. M., Perales, O., & Hickok, G. (2001). Absolute pitch in Williams Syndrome. *Music Perception, 18*(4), 491-503.

Lenhoff, H. M., Wang, P. P., Greenberg, F., & Bellugi, U. (1997). Williams Syndrome and the brain. *Scientific American, 277*, 68-73.

Levitin, D. J., & Bellugi, U. (2006). Rhythm, timbre, and hyperacusis in Williams-Beuren Syndrome. In C. A. Morris, H. M. Lenhoff & P. P. Wang (Eds.), *Williams-Beuren Syndrome: Research, Evaluation, and Treatment* (pp. 343-358). Baltimore: Johns Hopkins University Press.

Levitin, D. J., Cole, K., Lincoln, A., & Bellugi, U. (2005). Aversion, awareness, and attraction: investigating claims of hyperacusis in the Williams syndrome phenotype. *Journal of Child Psychology and Psychiatry, 46*(5), 514-523.

Levitin, D. J., Menon, V., Schmitt, J. E., Eliez, S., White, C. D., Glover, G. H., et al. (2003). Neural correlates of auditory perception in Williams syndrome: an fMRI study. *NeuroImage, 18*(1), 74-82.

Levitin, D. J., & Rogers, S. E. (2005). Absolute pitch: perception, coding, and controversies. *Trends in Cognitive Sciences, 9*(1), 26-33.

Lionni, L. (1970). *Fish is fish*: Scholastic Press.

Lopez, R., & Marx, J. (2004). *Avenue Q: the musical.* Milwaukee, WI: Hal Leonard Corp.

Martens, M. A., Wilson, S. J., & Reutens, D. C. (2008). Research Review: Williams syndrome: a critical review of the cognitive, behavioral, and neuroanatomical phenotype. *Journal of Child Psychology and Psychiatry, 49*(6), 576-608.

Mazzocco, M., Singh Bhatia, N., & Lesniak-Karpiak, K. (2006). Visuospatial skills and their association with math performance in girls with Fragile X or Turner Syndrome. *Child Neuropsychology (Neuropsychology, Development and Cognition: Section C), 12*(2), 87-110.

McBurney, D., & Collings, V. (1977). *Introduction to sensation/perception*: Prentice-Hall.

Mervis, C. B., & Becerra, A. M. (2007). Language and communicative development in Williams syndrome. *Mental Retardation and Developmental Disabilities Research Reviews, 13*(1), 3-15.

Mervis, C. B., & Klein-Tasman, B. P. (2000). Williams syndrome: Cognition, personality, and adaptive behavior. *Mental Retardation, and Developmental Disabilities Research Reviews, 6*(2), 148-158.

Mervis, C. B., & Morris, C. A. (2007). Williams Syndrome In M. M. M. Mazzocco & J. L. Ross (Eds.), *Neurogenetic developmental disorders: Variation of manifestation in childhood*: MIT Press.

Mervis, C. B., Morris, C. A., Bertrand, J., & Robinson, B. F. (1999). Williams syndrome: Findings from an integrated program of research. In H. Tager-Flusberg (Ed.), *Neurodevelopmental disorders: Contributions to a new framework from the cognitive neurosciences* (pp. 65-110). Cambridge, MA: MIT Press.

Mervis, C. B., Robinson, B. F., Bertrand, J., Morris, C. A., Klein-Tasman, B. P., & Armstrong, S. C. (2000). The Williams Syndrome cognitive profile. *Brain and Cognition, 44*(3), 604-628.

Meyer-Lindenberg, A., Hariri, A. R., Munoz, K. E., Mervis, C. B., Mattay, V. S., Morris, C. A., et al. (2005). Neural correlates of genetically abnormal social cognition in Williams syndrome. *Nature Neuroscience, 8*(8), 991-993.

Meyer-Lindenberg, A., Kohn, P., Mervis, C. B., Kippenhan, J. S., Olsen, R. K., Morris, C. A., et al. (2004). Neural basis of genetically determined visuospatial construction deficit in Williams syndrome. *Neuron, 43*(5), 623-631.

Meyer-Lindenberg, A., Mervis, C. B., & Berman, K. F. (2006). Neural mechanisms in Williams syndrome: a unique window to genetic influences on cognition and behavior. *Nature reviews. Neuroscience, 7*(5), 380-393.

Michie, J., & Lord, J. V. (1989). *Aesop's fables*. London: J. Cape.

Mills, D. L., Alvarez, T. D., St. George, M., Appelbaum, L. G, Bellugi, U., & Neville, H. (2000). III. Electrophysiological studies of face processing in Williams syndrome. *Journal of Cognitive Neuroscience, 12*(1), 47-64.

Miyazaki, K., & Rakowski, A. (2002). Recognition of notated melodies by possessors and nonpossessors of absolute pitch. *Perception & psychophysics, 64*(8), 1337-1345.

Gerrard, M & Nevil, R (2006). Nobody's Perfect. On *Hannah Montana -Meet Miley Cyrus* [CD]: Walt Disney/Hollywood Records

Morris, C. A. (2006). The dysmorphology, genetics, and natural history of Williams - Beuren Syndrome In C. A. Morris, H. M. Lenhoff & P. P. Wang (Eds.), *Williams-Beuren Syndrome: Research, Evaluation, and Treatment* (pp. 3-17). Baltimore: Johns Hopkins University Press.

National Research Council (U.S.). (2000). *How people learn: brain, mind, experience, and school* (Expanded ed.). Washington, D.C.: National Academy Press.

National Council of Teachers of Mathematics (NCTM) (2005). Retrieved 8/25/2008 3:29:30 PM PST, from http://www.nctm.org/standards/default.aspx?id=58

Nickson, M. (2004). *Teaching and learning mathematics: A guide to recent research and its applications* (2nd ed.): Continuum International Publishing Group.

Nigam, A., & Samuel, P. R. (2007). Hyperacusis and Williams syndrome. *The Journal of Laryngology and Otology, 108*(06), 494-496.

O'Hearn, K., & Landau, B. (2007). Mathematical skill in individuals with Williams syndrome: Evidence from a standardized mathematics battery. *Brain and Cognition, 64*(3), 238-246.

O'Shea, L. J., O'Shea, D. J., & Algozzine, R. (1998). *Learning disabilities: From theory toward practice*. Upper Saddle River, N.J.: Merrill.

Ormrod, J. E. (2003). *Human learning (4th ed.).* Merrill Upper Saddle River, NJ: Prentice-Hall, Inc.

Overy, K. (2000). Dyslexia, Temporal Processing and Music: The Potential of Music as an Early Learning Aid for Dyslexic Children. *Psychology of Music, 28*(2), 218.

Overy, K. (2003). Dyslexia and music: From timing deficits to musical intervention. *Annals of the New York Academy of Sciences, 999*, 497-505.

Overy, K., Nicolson, R. I., Fawcett, A. J., & Clarke, E. F. (2003). Dyslexia and music: Measuring musical timing skills. *Dyslexia, 9*(1), 18-36.

Paltsev, Y. I., & Elner, A. M. (1967). Change in the functional state of the segmental apparatus of the spinal cord under the influence of sound stimuli and its role in voluntary movement. *Biophysics, 12*, 1219?1226.

Partsch, C. J., Dreyer, G., Gosch, A., Winter, M., Schneppenheim, R., Wessel, A., et al. (1999). Longitudinal evaluation of growth, puberty, and bone maturation in children with Williams syndrome. *Journal of Pediatrics, 134*(1), 82-89.

Paterson, S. J., Girelli, L., Butterworth, B., & Karmiloff-Smith, A. (2006). Are numerical impairments syndrome specific? Evidence from Williams syndrome and Down's syndrome. *Journal of Child Psychology and Psychiatry, 47*(2), 190-204.

Peregrine, E., Rowe, M. L., & Mervis, C. B. (2006). *Grammatical abilities of individuals with Williams syndrome: Acquisition of finiteness marking.* Paper presented at the International Williams Syndrome Association Professional Conference, Richmond, VA.

Peretz, I., & Hyde, K. L. (2003). What is specific to music processing? Insights from congenital amusia. *Trends in Cognitive Sciences, 7*(8), 362-367.

Peters, J. S. (1987). *Music therapy : an introduction.* Springfield, IL: C.C. Thomas.

Peters, J. S. (2000). *Music therapy: an introduction* (2nd ed.). Springfield, IL: C.C. Thomas.

Reid, R., & Lienemann, T. O. (2006). *Strategy instruction for students with learning disabilities*. New York: Guilford Press.

Reiss, A. L., Eliex, S., Schmitt, E. J., Straus, E., Lai, Z., Jones, W., et al. (2001). Neuroanatomy of Williams Syndrome: A high-resolution MRI study. In U. Bellugi, M. St. George & A. M. Galaburda (Eds.), *Journey from cognition to brain to gene : perspectives from Williams Syndrome* (pp. 105-122). Cambridge, MA: MIT Press.

Rice, M. L., Warren, S. F., & Betz, S. K. (2005). Language symptoms of developmental language disorders: An overview of autism, Down syndrome, Fragile X, specific language impairment, and Williams syndrome. *Applied Psycholinguistics, 26*(01), 7-27.

Rossignol, S., & Melvill Jones, G. (1976). Audio-spinal influence in man studied by the H-reflex and its possible role on rhythmic movements synchronized to sound. *Electroencephalography and Clinical Neurophysiology, 41*(1), 83-92.

Scheiber, B. (2002). *Fulfilling dreams: A handbook for parents of people with Williams Syndrome*: Williams Syndrome Association.

Schmitt, J. E., Eliez, S., Bellugi, U., & Reiss, A. L. (2001). Analysis of Cerebral Shape in Williams Syndrome (Vol. 58, pp. 283-287): Am Med Assoc.

Sears, W. W. (1968). Processes in music therapy. In E. T. Gaston (Ed.), *Music in Therapy* (pp. 30-44).

Semel, E., & Rosner, S. R. (1991). The behavioral characteristics of children with Williams syndrome: Analysis of the Utah survey: Report presented to a meeting of the Laboratory for Language and Cognition, Salk Institute, La Jolla, CA.

Semel, E., & Rosner, S. R. (2003). *Understanding Williams Syndrome: Behavioral Patterns and Interventions*. Mahwah, New Jersey: Lawrence Erlbaum Associates, Publishers.

Sforza, T. L. H. L. S. (2006). *The strangest song: One father's quest to help his daughter find her voice : the compelling story of the link between a rare genetic disorder and musical talent*: Prometheus Books.

Shanahan, M. A., Pennington, B. F., Yerys, B. E., Scott, A., Boada, R., Willcutt, E. G., et al. (2006). Processing speed deficits in attention deficit/hyperactivity disorder and reading disability. *Journal of Abnormal Child Psychology, 34*(5), 584-601.

Smeijsters, H., & Aasgaard, T. (2005). Qualitative case study research In B. L. Wheeler (Ed.), *Music therapy research: Quantitative and qualitative perspectives* (2nd ed., pp. 440-457). Gilsum, NH: Barcelona Publishers.

Stake, R. E. (1995). *The Art of Case Study Research*: Sage Publications Inc.

Strauss, A. L., & Corbin, J. M. (1998). *Basics of qualitative research: techniques and procedures for developing grounded theory* (2nd ed.). Thousand Oaks: Sage Publications.

Thaut, M. H. (1999). Music therapy in neurological rehabilitation. In W. B. Davis, K. E. Gfeller & M. H. Thaut (Eds.), *An introduction to music therapy: theory and practice* (2nd ed., pp. 221-258). Boston, Mass: McGraw-Hill.

Thaut, M. H. (2005). *Rhythm, music, and the brain: scientific foundations and clinical applications*. New York: Routledge.

Udwin, O. (1990). A survey of adults with Williams syndrome and idiopathic infantile hypercalcaemia. *Developmental Medicine and Child Neurology, 32*(2), 129-141.

Udwin, O., & Yule, W. (1990). Expressive language of children with Williams syndrome. *American Journal of Medical Genetics Supplement, 6*, 108-114.

Venes, D. (2005). *Taber's Cyclopedic Medical Dictionary - 20th Ed.* Retrieved 8/25/2008 2:29:54 PM PST, from http://online.statref.com.pRoxie2.cl.msu.edu:2047/document.aspx?fxid=57&docid=15899.

Wheeler, B. L. (2005). Overview of music therapy research. In B. L. Wheeler (Ed.), *Music therapy research: Quantitative and qualitative perspectives* (2nd ed., pp. 3-19). Gilsum, NH: Barcelona Publishers.

Zager, M. (2003). *Writing music for television and radio commercials: a manual for composers and students*. Lanham, MD: Scarecrow Press.

Zatorre, R. J. (2003). Absolute pitch: a model for understanding the influence of genes and development on neural and cognitive function. *Nature Neuroscience, 6*(7), 692-695.

Zorzi, M., Priftis, K., & Umilt, C. (2002). Neglect disrupts the mental number line. *Nature, 417*, 138.