

ABSTRACT

Title of Dissertation: THE EFFECT OF VIOLIN, KEYBOARD, AND
SINGING INSTRUCTION ON THE SPATIAL
ABILITY AND MUSIC APTITUDE OF
YOUNG CHILDREN

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The purpose of the present study was to examine the effect of violin, keyboard, and singing instruction on spatial ability and music aptitude of children ages four to seven years. Specifically, this research attempted to determine: (a) whether formal music learning in the violin, keyboard and singing conditions enhanced children's spatial ability and music aptitude, and (b) whether children's spatial ability and music aptitude differed among these learning conditions. In addition, this study sought to examine the relationships among children's age, their development of spatial ability, and music aptitude in the given music instruction.

A pretest-posttest two by three factorial design was employed in the study. Children ($N=88$) ages four to seven years were randomly assigned to one of three instructional groups (violin, keyboard, or singing) and received 45 minutes of music instruction four times a week for 16 days. Spatial reasoning skills were measured using two subtests, the Object Assembly and the Block Design of the *Wechsler Preschool and Primary Scale of Intelligence-III*, while music aptitude was measured using the *Primary Measures of Music Audiation* or the *Intermediate Measures of Music Audiation*.

An ANOVA with repeated measures was used to analyze children's mean scores on spatial abilities and music aptitude. Using an alpha level of .05, results indicated that the violin and keyboard groups significantly improved on spatial-temporal reasoning over four weeks of music instruction. The spatial-temporal reasoning scores of 4-5 year olds significantly increased from the pretest to posttest while the scores of 6-7 year olds remained statistically constant. Regarding music aptitude, the tonal aptitude scores of 4-5 year olds singing group significantly increased over four weeks of music instruction. No statistically significant differences were found on the spatial recognition and rhythm aptitude scores among the three instructional groups for either age level.

The study concluded that (a) violin and keyboard instruction might influence the spatial-temporal reasoning of young children, (b) younger children's spatial-temporal reasoning ability might be more enhanced by music instruction than those of older children, and (c) singing instruction appears to help young children develop their tonal aptitude. Pedagogical implications for music education were discussed.

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THE SPATIAL ABILITY AND MUSIC APTITUDE
OF YOUNG CHILDREN

By

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Dedication

This dissertation is dedicated to my husband and parents.

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Writing this dissertation has been an exciting and fruitful learning experience for me. The completion of this dissertation was only possible because of many individuals. I wish to express gratitude to the people who have supported me in the journey of conducting this research project.

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Table of Contents

Dedication	ii
Acknowledgements	iii
List of Tables	viii
List of Figures	ix
CHAPTER 1 INTRODUCTION	1
Background of the Study	1
Music Learning and Spatial Ability	3
Music Aptitude of Children	7
Statement of the Problem	10
Purpose of the Study	12
Research Questions	12
Null Hypotheses	12
Spatial Ability	12
Music Aptitude	13
Definition of Terms	15
Limitations of the Study	16
Overview of Remaining Chapters	17
CHAPTER 2 REVIEW OF LITERATURE	18
Music Learning in the Cognitive Development of Young Children	18
Music and Language Ability	22
Music Listening and Spatial-Temporal Reasoning	28
Music Learning and Spatial-Temporal Reasoning	35
Summary	42

Musical Development of Young Children	46
Development of Music Aptitude.....	46
Auditory Discrimination	50
Tonal and Melodic Perception	52
Rhythmic Development	55
Summary	58
CHAPTER 3 METHODOLOGY	61
Restatement of Purpose.....	61
Selection of Sample	61
Research Design.....	63
Internal Validity	64
External Validity.....	66
Independent Variables	66
Dependent Variables and Measurement	68
Spatial Ability	68
Music Aptitude.....	71
Experimental Procedures	73
Pilot Testing	73
Instructor Training	74
Pre-testing Stage	75
Treatment Stage	76
Post-testing Stage.....	79
Methods for Data Analysis	79
Summary	81
CHAPTER 4 RESULTS.....	83

Research Question One: Effects of Music Instruction on Spatial Ability	83
Spatial-Temporal Reasoning.....	84
Spatial Recognition.....	86
Summary for Spatial Ability.....	90
Research Question Two: Effects of Music Instruction on Music Aptitude	91
Tonal Aptitude	91
Rhythm Aptitude.....	94
Null Hypotheses of Music Aptitude	95
Summary for Music Aptitude	98
CHAPTER 5 DISCUSSION OF RESULTS AND CONCLUSIONS.....	99
Summary of the Study	99
Discussion of the Findings.....	100
Spatial-Temporal Reasoning.....	100
Spatial Recognition.....	103
Music Aptitude.....	105
Tonal aptitude.	106
Rhythm aptitude.....	107
Implications for Music Education.....	108
Recommendations for Future Research	111
Conclusions.....	117
APPENDICES	120
Appendix A Letter to Parents	120
Appendix B Parental Consent Form	121
Appendix C Assent Form for Children.....	123
Appendix D Sample Lesson Plan for Violin Instruction	124

Appendix E Sample Lesson Plan for Keyboard Instruction	125
Appendix F Sample Lesson Plan for Singing Instruction.....	126
REFERENCES	127

List of Tables

TABLE 1 SUMMARY OF RELATED LITERATURE: MUSIC LEARNING IN COGNITIVE DEVELOPMENT.....	45
TABLE 2 SUMMARY OF RELATED LITERATURE: MUSICAL DEVELOPMENT OF YOUNG CHILDREN	60
TABLE 3 ILLUSTRATION OF SIX EXPERIMENTAL GROUPS	64
TABLE 4 RELIABILITIES IN SPLIT-HALF COEFFICIENTS FOR TONAL AND RHYTHM	73
TABLE 5 OUTLINE OF CURRICULUM AND LESSON OBJECTIVES.....	78
TABLE 6 RESULTS OF ANOVA WITH REPEATED MEASURES: SPATIAL-TEMPORAL REASONING.....	84
TABLE 7 DESCRIPTIVE DATA: SPATIAL-TEMPORAL REASONING	86
TABLE 8 RESULTS OF ANOVA WITH REPEATED MEASURES: SPATIAL RECOGNITION	87
TABLE 9 DESCRIPTIVE DATA: SPATIAL RECOGNITION.....	88
TABLE 10 RESULTS OF ANOVA WITH REPEAT MEASURES: TONAL APTITUDE	92
TABLE 11 DESCRIPTIVE DATA: TONAL APTITUDE	94
TABLE 12 RESULTS OF ANOVA WITH REPEATED MEASURES: RHYTHM APTITUDE.....	95
TABLE 13 DESCRIPTIVE DATA: RHYTHM APTITUDE	95

List of Figures

FIGURE 1 PERFORMANCE OF SPATIAL-TEMPORAL REASONING UPON GROUP AND TIME ...	85
FIGURE 2 PERFORMANCE OF SPATIAL-TEMPORAL REASONING UPON AGE AND TIME	86
FIGURE 3 PERFORMANCE OF TONAL APTITUDE OF FOUR TO FIVE YEAR OLDS UPON GROUP AND TIME.....	93

CHAPTER 1 INTRODUCTION

Background of the Study

Music can be an integral part of a child's growth. Research has found that musical development begins with prenatal musical influences in the womb and progresses through the mother-child bond to musical experiences in the context of family, school education, and society (Gembris, 2006). Considering music as a type of cognition, Serafine (1988) believes that music is an essential component of knowing and thinking in human beings and describes music as a cognitive activity which employs sounds and temporal phenomena in a culture that shares a specific music style. In her book, *Music as Cognition*, Serafine (1988) writes:

I construe music as the activity of thinking in or with sound and for this reason I favor the term musical "thought" or "cognition" over "music" alone. Music thought may be defined as human aural-cognitive activity that results in the posing of artworks embodying finite and organized sets of temporal events described in sound (p. 69).

Serafine identifies two psychological processes in music cognition: temporal process and non-temporal process. The temporal process involves perception of musical events or ideas in time (e.g., music goes forward with another musical unit succeeding), while the non-temporal process involves perception of general properties of the musical materials (e.g., auditory discrimination and music literacy).

In his theory of multiple intelligences, Gardner (1999) suggests that a child's potential and cognitive development should be considered from multiple perspectives, including linguistic intelligence, musical intelligence, logical-mathematical intelligence,

spatial intelligence, bodily-kinesthetic intelligence, personal intelligence, naturalist intelligence, and existentialist intelligence. Gardner believes that musical intelligence, as one of the multiple intelligences, is not only a unique way of knowing in child development, but has links to properties of other intellectual systems (Gardner, 1983, 1999).

Since music appears to be an important aspect of knowing and understanding during child development, a quality music education should be included in a child's learning environment and educational system. Of course, it is also important to understand the role that music learning plays in a child's growth. The music education profession views the value of music learning for children through both intrinsic and extrinsic merits (Peery & Peery, 1987). Correspondingly, a proliferation of research on early childhood music education has provided insights into the role of music learning in musical development of children, and revealed knowledge on how music instruction affects other areas of child development such as language, creativity, affective development, motor skills, spatial abilities, and social development (Jordan-Decarbo & Nelson, 2002; Wolff, 1978).

The present investigation sought to add to this body of knowledge by focusing on the influences that music learning may have on the development of spatial and musical cognition of young children. In this chapter, I will discuss the roles of spatial ability and music aptitude in the course of child development as well as how music learning relates to these two cognitive areas based on existing research findings. Then, I will address the research problems and the need for conducting this research. Finally, I will describe the purpose of this study and present research questions, hypotheses, definition of terms, as

well as the limitations of the study.

Music Learning and Spatial Ability

Spatial ability is one important aspect of a child's cognitive development. Spatial ability refers to the mental processing of objects, including the skills of recognizing, transforming, generating and recalling symbolic and non-linguistic information (Cohen, 1985). In his theory of multiple intelligences, Gardner (1983) refers to spatial intelligence as the "capacities to perceive the visual world accurately, to perform transformations and modifications upon one's initial perceptions, and to be able to re-create aspects of one's visual experience, even in the absence of relevant physical stimuli" (p. 173). A well-developed spatial ability helps a child reason and think through the processing and transforming of a mental image of an object within the environment (Lin & Peterson, 1985). This understanding is essential for children to be able to recognize the settings of their environments (e.g., the concept of "next to" or "in front of"), interact with physical and environmental factors in their daily life, and further enhance their learning as a whole (Piaget & Inhelder, 1967).

Spatial ability consists of several cognitive skills such as spatial visualization, spatial memory, spatial rotation, and spatial perception (Lin & Peterson, 1985). Although several spatial skills have been categorized and documented in the literature, little consensus regarding the definition of spatial skills exists among psychologists (McGee, 1979). It seems that spatial ability is an amalgamation of several mental processes, relating to objects or non-linguistic information. The following description by Gardner (1983) is in accordance with this point of view:

"Spatial intelligence entails a number of loosely related capacities: the ability to

recognize instances of the same element; the ability to transform or to recognize a transformation of one element into another; the capacity to conjure up mental imagery and then to transform that imagery; the capacity to produce a graphic likeness of spatial information and the like” (p. 176).

In recent years, research exploring the influences of music learning on spatial abilities indicates a dichotomous classification of spatial abilities, comprised of *spatial-temporal reasoning* and *spatial recognition* (Rauscher, 1999).

Spatial-temporal reasoning is a process in which one is able to maintain and transform images without the assistance of a physical model, and then to combine different parts of images into a single whole. For instance, putting jigsaw puzzles together is an example of spatial-temporal reasoning; it requires successive steps in a temporal order to accomplish the spatial-temporal task. Spatial recognition, on the other hand, is the ability for individuals to recognize and classify similarities and differences among spatial objects or mentally organized items according to size, shape, color, and pattern (Bilhartz, Bruhn, & Olson, 2000; Rauscher, 1999).

Rauscher and Shaw (1998) point out that spatial-temporal reasoning requires abilities of transforming and organizing spatial imagery and temporal-ordering of objects; these abilities are essential for proportional reasoning used in mathematics and scientific endeavors. Shaw (2004) mentions that the lack of focus on the development of young children’s spatial-temporal reasoning in school systems may be the reason for the low performance achievement in math and science. In his book, *Keeping Mozart in Mind*, Shaw (2004) states:

“There are two complementary ways that we reason, specifically in math and

science: the spatial-temporal and the language-analytic approaches. The spatial-temporal allows the child to visualize the problem and a solution, which means she understands it conceptually. Understanding the concept allows her to better solve the relevant equations for the quantitative answers in language-analytic approach...the big problem is that the spatial-temporal approach is almost entirely neglected in traditional school systems” (p.17).

In 1993, Rauscher, Shaw, and their colleagues published a scientific report in *Nature*, indicating that listening to Mozart’s Piano Sonata in D major K.448 temporarily enhanced college students’ performance on spatial reasoning tasks as measured by the Stanford-Binet IQ battery (Thorndike, Hagen, & Sattler, 1986). Although the study was focused on college students, the results were popularized by the broadcast media and public press and became known as “the Mozart effect” (Hetland 2000b). While the idea of the Mozart effect was widely disseminated in the general public, the question of whether music really makes children smarter appears to be of substantive interest to many parents and educators.

Over the past 30 years, psychology of music research has shown the positive relationship between music learning and spatial ability in child development. Karma (1979) studied the connections among children’s musical, verbal, and spatial abilities. These studies found a significant correlation between musical and spatial abilities. Hassler et al. (1985) investigated similar research questions and tested children ages 9-14 years old concerning their musical talent and spatial ability. Results also indicated that spatial ability was significantly correlated with musical talent.

Advancement in brain research over the past two decades has allowed

neurologists to observe the activities of the human brain using magnetic resonance imaging (MRI) and the electroencephalogram (EEG), and have provided detailed information about the development of the human brain and its connection to music learning. For instance, magnetic resonance imaging studies have shown that musicians who began keyboard/piano instruction prior to age six or seven had larger corpus callosi compared to non-musicians (Schlaug, Jancke, Huang, & Steinmetz, 1995). Moreover, string players who begin string instruction prior to age 12 display larger cortical representations of the digits of the left hand than non-musicians (Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1995).

Leng and Shaw (1991) have proposed a model of the brain, called the Trion model, which provides a neuro-scientific framework for the relationship between music and spatial ability. The Trion model is a neuronal model, suggesting that the development of neural pathways is related to spatial ability that can be influenced by environmental stimulations. It has been assumed that music can stimulate certain neural firing patterns organized in a complex spatial-temporal code over a large region of cortex in the brain structure (Shaw, 2004). Leng and Shaw (1991) state “ that music can serve as a window to access inherent cortical spatial-temporal firing patterns in the human brain at an early age, in order to enhance and accomplish the spatial-temporal reasoning performance” (p.255).

Recently, several studies exploring the influence of music learning on the development of spatial-temporal reasoning in children have been based on the theory of Trion model. Rauscher et al. (1997) conducted an experimental study where three- and four-year-old children who received group piano instruction scored significantly higher

on spatial-temporal reasoning tasks than children who received instruction in singing, computer, or who received no instruction. Rauscher and Zupan (2000) examined the effect of keyboard instruction on the development of spatial-temporal reasoning of kindergarten children in a school classroom setting. This study also found that children in the keyboard group scored significantly higher on spatial-temporal reasoning tasks than children who received no music instruction.

Costa-Giomi (1999) conducted a longitudinal study, investigating the relationship between piano instruction and cognitive development in 9-year-old children. Her study found that children who received piano instruction scored significantly higher on the performance of spatial tasks than the children who received no piano instruction over the first two years of study. In addition to the research on influences of keyboard/piano instruction on spatial development, other studies have found that general music instruction, including singing, movement, reading music on the musical staff, and playing pitched percussion instruments (xylophones or glockenspiels) also helps children enhance their spatial ability (Bilhartz, Bruhn, & Olson, 2000; Persellin, 2000).

Music Aptitude of Children

Research on musical development has shown the sequence of progressive stages about musical responses and development of musical ability of young children (Campbell, 1991; Davidson & Scripp, 1988; Hargreaves, 1986; Hargreaves & Zimmerman, 1992). Music aptitude is an aspect of musical development in children (Zimmerman, 1993). It refers to the potential or capacity that an individual possesses for learning music and developing musical skills (Boyle, 1992).

Although aptitude has traditionally been defined as a function of natural ability or

capacity for learning, music psychologists have differing points of view to conceptualize the construct. Karma (1985) views music aptitude as a type of cognitive process and mental operation in music. He states: “mental operations or cognitive processes necessarily exist and that musical aptitude can be seen as a set of correlating operations which are needed to analyze music” (p.4). In addition, he challenges the value of traditional approaches to defining and evaluating music aptitude—“researchers often forget that concepts are the results of human perception and thought, and are thus matters of definition rather than objective truth” (p.1).

In his theory of music aptitude, Karma (1985) suggests that music aptitude is a concept that needs to be re-constructed if the aim of scientific research is to make music aptitude measurable, simple, and effective in predicting musical behaviors. Definition of music aptitude may vary based on measurement tools, and different definitions inevitably lead to different point of views about music aptitude. For instance, Karma (1985) examined the possible components of musical aptitude by using general information-processing strategies. At the starting point of his research, music aptitude was referred to as “the ability to structure acoustic material” (p.4).

Boyle and Radocy (1987) recognize music aptitude as natural—“the results of genetic endowment and maturation plus whatever musical skills and sensitivities may develop without formal music education” (p. 139). In other words, music aptitude evolves through the general enculturation process.

Edwin Gordon (1979) proposes a slightly different definition. He defines music aptitude as a product of the nature and nurture process: both processes contribute in unknown proportions to music aptitude. According to Gordon (1979), music aptitude is

not fully developed until the age of nine. A child's music aptitude can be enhanced by engaging in a rich musical environment or any informal or formal music training. Gordon notes that this result does not mean the child should not be involved in music instruction after the age of nine; such instruction will still help children to expand knowledge and skills in music for musical achievement (Gordon, 1979).

Based on Gordon's theory of music aptitude, several researchers examined the relationship between music instruction and development of music aptitude in children. Flohr (1981) conducted an experimental study to determine whether general music instruction consisting of singing, movement, and playing percussion instruments has an effect on music aptitude in five-year-old children. The results indicated that children who received 12 weeks of music instruction scored significantly higher on the test of music aptitude than children who received no music instruction.

Rutkowski (1996) compared the influence of two types of singing instruction (traditional large-group instruction versus small-group/individual instruction) on kindergartners' music aptitude and singing voice. The results indicated that the scores of music aptitude in both groups improved after music instruction although the study found no significant difference between the two instructional groups on music aptitude scores. In terms of effects on the singing voice, the children in the small-group /individual instruction setting scored significantly higher on the test of the singing voice measure than did those in the large-group instruction setting, indicating that small-group/individual singing activities are effective in helping children improve their singing achievement.

Statement of the Problem

Rauscher et al. (1997) suggests that learning keyboard instruments helps children enhance spatial ability because the keyboard provides the linear relationship of spatial distance between the pitches. The aural information from the pitches along with visual information on the instruments may stimulate the brain areas that relate to spatial-temporal development. However, some studies show that general music instruction, including singing, movement, and playing percussion instruments also assists children in development of spatial ability (Bilhartz, Bruhn, & Olson, 2000; Persellin, 2000). Others point out that studying note reading in music lessons may be the factor related to development of spatial ability (Hetland, 2000a). Because music instruction often includes sensory motor activity, visual stimulation and aural memory of space and sound, some researchers note that the combination of these instructional components may be likely to amplify the development of spatial ability (Gromko & Poorman, 1998).

Although a number of aforementioned studies suggest that music learning helps children develop their spatial ability and music aptitude, the issue of whether types of music instruction or pedagogical components are related to enhancement of children's spatial ability is still not clear. The concern whether the enhancement is due to a certain type of instrumental instruction or music learning itself remains unanswered. Thus, it could be valuable to investigate whether type of music instruction (instrumental instruction versus non-instrumental instruction) is an important factor on children's spatial ability.

In recent years, a variety of music programs (e.g., Kindermusik, Music Together) and instrumental lessons (e.g., piano and violin lessons) have become available for young

children outside of school music contexts. While learning violin is popular in young children, no study illustrates whether learning to play violin facilitates development of spatial ability in children. Therefore, it would be valuable to examine whether learning to play violin can help children enhance their spatial ability. Also, since violin is different from piano keyboard in instrumental structures, it could be interesting to compare the effects of these two types of instruction on spatial ability in children.

Furthermore, Hetland (2000a) states that the spatial abilities of younger children (ages 3-5 years) are more enhanced by active music instruction than those of older children (ages 6-12 years). However, no empirical research provides direct evidence in support of this argument. This present study attempted to compare two age groups (4-5 and 6-7 years of age) to further determine whether age is an important factor in the relationship of music learning to spatial ability.

Many researchers have investigated the relationship of music aptitude to children's musical achievement such as singing accuracy or pitch discrimination by using Gordon's Primary Measures of Music Auditation (e.g., Hornbach & Taggart, 2005; Mota, 1997; Phillips & Aitchison, 1997; Phillips, Aitchison, & Nompula, 2002). While some studies found that children's singing achievement is related to tonal aptitude (Aitchison, 1997; Rutkowski, 1996), none of the studies explore the relationship between singing instruction and tonal aptitude. Further, only a few studies examined the influence of music learning on music aptitude (Flohr, 1981; Rutkowski, 1996); none of these studies revealed whether instrumental instruction have effects on development of music aptitude in children.

Purpose of the Study

The purpose of the present study was to examine the effect of violin, keyboard, and singing instruction on 4- to 7-year-old children's spatial ability and music aptitude. Specifically, this research attempted to determine: (a) whether formal music instruction in the violin, keyboard and singing conditions enhanced children's development of spatial ability and music aptitude, and (b) whether children's spatial ability and music aptitude differed among these learning conditions. In addition, this study sought to examine the relationships among children's age, their development of spatial ability, and music aptitude in the given music instruction.

Research Questions

1. What is the effect of music learning conditions (violin, keyboard, and singing) and ages (4-5 years old and 6-7 years old), alone and in combination, on children's spatial-temporal reasoning and spatial recognition over time?
2. What are the effects of music learning conditions (violin, keyboard, and singing) on tonal and rhythm aptitude for children ages 4 to 7 years old over time?

Null Hypotheses

Spatial Ability

- 1a. There is no significant difference among music instructional conditions (violin, keyboard, and singing) on spatial-temporal reasoning.
- 1b. There is no significant difference between two age levels (4-5 years old and 6-7 years old) on spatial-temporal reasoning.
- 1c. There is no significant difference between the pretest and posttest on spatial-temporal reasoning.

- 1d. There is no interaction effect between time (before and after instruction) and music instructional conditions (violin, keyboard, and singing) on spatial-temporal reasoning.
- 1e. There is no interaction effect between time (before and after instruction) and age levels (4-5 years old and 6-7 years old) on spatial-temporal reasoning.
- 1f. There is no interaction effect among time (before and after instruction), music instructional conditions (violin, keyboard, and singing), and age levels (4-5 years old and 6-7 years old) on spatial-temporal reasoning.
- 2a. There is no significant difference among music instructional conditions (violin, keyboard, and singing) on spatial recognition.
- 2b. There is no significant difference between two age levels (4-5 years old and 6-7 years old) on spatial recognition.
- 2c. There is no significant difference between the pretest and posttest on spatial recognition.
- 2d. There is no interaction effect between time (before and after instruction) and music instructional conditions (violin, keyboard, and singing) on spatial recognition.
- 2e. There is no interaction effect between time (before and after instruction) and age levels (4-5 years old and 6-7 years old) on spatial recognition.
- 2f. There is no interaction effect among time (before and after instruction), music instructional conditions (violin, keyboard, and singing), and age levels (4-5 years old and 6-7 years old) on spatial recognition.

Music Aptitude

- 3a. There is no significant difference among music instructional conditions (violin,

- keyboard, and singing) on tonal aptitude of four- to five-year-old children.
- 3b. There is no significant differences between pretest and posttest on tonal aptitude of four-to five-year-old children.
- 3c. There is no interaction effect between time (before and after instruction) and music instructional conditions (violin, keyboard, and singing) on tonal aptitude of four- to five-year-old children.
- 3d. There is no significant difference among music instructional conditions (violin, keyboard, and singing) on rhythm aptitude of four- to five-year-old children.
- 3e. There is no significant differences between pretest and posttest on rhythm aptitude of four- to five-year-old children.
- 3f. There is no interaction effect between time (before and after instruction) and music instructional conditions (violin, keyboard, and singing) on rhythm aptitude of four- to five-year-old children.
- 4a. There is no significant difference among music learning conditions (violin, keyboard, and singing) on tonal aptitude of six- to seven-year-old children.
- 4b. There is no significant differences between pretest and posttest on tonal aptitude of six- to seven-year-old children.
- 4c. There is no interaction effect between time (before and after instruction) and music instructional conditions (violin, keyboard, and singing) on tonal aptitude of six- to seven- year-old children.
- 4d. There is no significant difference among music instructional conditions (violin, keyboard, and singing) on rhythm aptitude of six- to seven-year-old children.
- 4e. There is no significant differences between pretest and posttest on rhythm aptitude of

six- to seven-year-old children.

4f. There is no interaction effect between time (before and after instruction) and music instructional conditions (violin, keyboard, and singing) on rhythm aptitude of six- to seven-year-old children.

Definition of Terms

Spatial Ability: refers to the overall capacity to perceive the visual world accurately, to perform transformations and modifications upon one's initial perceptions, and to be able to re-create aspects of one's visual experience, even in the absence of relevant physical stimuli (Gardner, 1983).

Spatial-Temporal Reasoning: refers to a process in which one is able to visualize, maintain and transform the images, mentally rotate objects without assistance of a physical model, or combine different parts of images into a single whole (Shaw, 2004; Rauscher, 1999).

Spatial-recognition: refers to the ability in which one is able to indicate similarities and differences among objects (Bilhartz, Bruhn, & Olson, 2000; Rauscher, 1999).

Young Children: refers to children from birth to eight years (National Association of Education for Young Children).

Music Aptitude: refers to the capacity that one possesses for learning music and developing musical skills. According to Gordon's definition (1979), music aptitude is not stabilized until nine years of age; therefore, a child's music aptitude can be enhanced by engaging in a rich musical environment or any informal or formal music training (Gordon, 1979, 1997).

Keyboard Instruction: refers to music lessons that focus on techniques for playing piano

keyboard, study of music notation and ability to transfer music notation to the instrument along with other music activities including singing (only used for echo singing for roll call), listening, and movement.

Violin Instruction: refers to music lessons that focus on techniques for playing the violin, study of music notation and ability to transfer music notation to the instrument along with other music activities including singing (only used for echo singing of closing song, and singing letter names of pitches), listening, and movement. The instruction includes the use of finger placement markers approach in which adhesive labels are applied to the fingerboard under the strings to label pitches (Bergonzi, 1997).

Singing Instruction: refers to music lessons that focus on development of aural skills through singing (learning of music notation, sight singing and pitch matching skills). The instruction included visual, aural and kinesthetic musical activities such as music reading, listening, and movement with no instrumental playing.

Limitations of the Study

The present study has the following limitations. First, because the target population of the present study was 4- to 7-year-old children, implications of the present study may not apply to children of different ages. Further, given the circumstance that the participants of this study were drawn from a large metropolitan area in the U.S., results of this study may not be generalized to children in various geographic areas. In addition, the present study explored three types of music instruction; therefore, findings may not shed light on other types of instrumental learning (e.g., recorder, guitar or band instruments) and class settings (e.g., individual lessons).

Another set of limitations is related to the issue of research design. The exclusion

of a non-music control group in the research design restricts the examination of causal effects of music instruction on spatial ability and music aptitude since all participants received some form of music instruction. Also, three teachers provided the three types of music instruction; therefore, the teacher effect should be considered when interpreting the experimental results. Furthermore, other artificial effects such as testing effect, parental involvement, and practice time at home that were outside of the researcher's control may have contributed to the results.

Finally, the use of two different measurement tools between two age groups results in a limitation in data analysis. Because music aptitude of two age groups is measured using the PMMA and IMMA respectively, the music aptitude scores of two age groups were analyzed separately. Thus, results from the data analysis are limited in demonstrating interaction effects among music learning, age and music aptitude.

Overview of Remaining Chapters

The remainder of the present study is structured as follows: Chapter 2 presents a review of the literature focusing on music learning and young children's development of spatial-temporal reasoning and music aptitude. Chapter 3 describes the methodology used in the present study including the research design, selection of participants, instrumentation, data collection, and procedures for data analyses. Chapter 4 reports the results of data analyses for the research questions. Finally, Chapter 5 provides a summary of the study, discussion of the findings, implication of findings for music teaching and learning, recommendations for further research, and conclusions.

CHAPTER 2 REVIEW OF LITERATURE

Over the past 30 years, many researchers have been intrigued with exploring the role of music learning in child development. Some studies focused on the influence of music learning on non-musical outcomes such as cognitive development, academic achievement, and social development (Črnčrec, Wilson and Prior, 2006a; Draper & Gayle, 1987; Wolff, 1978). Some studies emphasized how musical learning experiences and environments affects children's musical development (Peery, Peery, & Draper, 1987; Jordan-Decarbo & Nelson, 2002; Winner & Hetland, 2000). Other research on musical development of young children has shown that music is one aspect of cognitive development in children (Davidson & Scripp, 1988).

This review of literature presents a body of research related to the topic of children's musical and cognitive development. This chapter is organized into the two sections: (1) music learning in the cognitive development of young children, and (2) music instruction and musical development in young children. In the first section, studies that are focused on influence of music learning on general cognitive development, language development, and spatial cognition development are reviewed and analyzed. In the second section, research that emphasizes musical development in the development of music aptitude, auditory discrimination, tonal/melodic perception, and rhythmic skills are discussed. Finally, both sections close with a summary of the studies presented in the literature review.

Music Learning in the Cognitive Development of Young Children

The cognitive development refers to changes in cognitive structure (e.g., the content of a child's mind) and functioning (e.g., how the cognitive system works) that

take place over time (Charlesworth, 2008). In the field of child development, educational theorists have identified various cognitive structures and intelligence systems in a child's mind including linguistic, mathematical, music, spatial, gestural, and other kinds of intelligences and symbolic systems (Gardner, 1983; Gardner & Wolf, 1983).

Based on this framework of cognitive structures in child development, research examining the role of music learning in cognitive development has been focused on whether experiences of musical learning could enhance children's overall cognitive development and specific cognitive domains such as language/reading ability and spatial reasoning (Bultzlaff, 2000; Črnčrec, Wilson and Prior, 2006a; Hetland 2000a, 2000b). Regarding the influence of music on children's overall cognitive development, several researchers investigated the influence of music instruction (e.g., piano instruction and general music instruction) and experiences of music learning (e.g., years of experience) on overall cognitive development (Costa-Giomi, 1999, 2004; Jordan-Decarbo & Galliford 2001; Schellenberg, 2006).

Jordan-Decarbo and Galliford (2001) conducted an experimental study investigating the effects of general music instruction on cognitive, social/emotional, and musical movement abilities of preschool disadvantaged children. Preschoolers ($N=106$) from birth to four years and six months of age were assigned to one of the two groups. The experimental group received 45 minutes of music instruction once a week for 10 weeks; the control group received no additional music instruction besides what was delivered in the regular school music curriculum. The Preschool Evaluation Scale (an assessment tool designed for the early identification of children with developmental delays) and a researcher-designed musical movement test were administered before and

after the music instruction.

Results of this study showed that the experimental group scored significantly higher on the tasks of motor, cognitive, expressive language, and social/emotional abilities than did the control group. In addition, the experimental group scored significantly higher on expressive music movement and overall musicality. The study suggests that music instruction helps children in the developmental cognitive domains as determined by the Preschool Evaluation Scale. Further, the authors recommend that inclusion of music in the curricula of remedial preschool programs is beneficial to prepare children for school readiness.

Costa-Giomi (1999, 2004) conducted a longitudinal study investigating the influence of three-year piano instruction on children's cognitive abilities, academic achievement, and self-esteem. A total of 117 fourth graders from 20 selected schools were assigned to one of the two conditions: piano instruction group and no instruction group. Children ($N=63$) in the piano instruction group received 30 to 45 minutes of private piano lessons once a week for 3 years, while the participants ($N=54$) in the control group received no piano instruction. For data collection, participants were administered tests of self-esteem, academic achievement, cognitive abilities, motor proficiency, and musical abilities at beginning of the study and at the end of the first, second, and third years of instruction. The cognitive ability was measured using the Developing Cognitive Abilities Test (DCAT), which consists of three cognitive domains (language, quantitative, and spatial ability). Because of attrition, a total of 78 children completed all the required research tasks by the end of the study in the third year.

The data analysis revealed that participants in piano instruction group scored

significantly higher than those in the control group on the scores of overall cognitive ability at the second year of the study. In terms of instruction effect on each type of cognitive ability, results of the study showed that the experimental group's spatial scores were higher than those of the control group after the first and second years of instruction; however, no significant differences were found between the experimental and control groups at the third year. Regarding the relationship among piano instruction, academic achievement, and self-esteem, results of the study showed that self-esteem scores of the experimental group tended to increase throughout the three years of music instruction, while those of the control group tended to decrease. The study suggests that piano instruction may produce temporary improvements in children's general cognitive ability and spatial ability. In addition, the music instruction may have positive effect on children's self-esteem.

Schellenberg (2006) conducted an observational research to investigate whether duration of music learning in childhood is associated positively with intellectual abilities, and whether these associations might persist after music lessons ended. This study consisted of two parts based on two populations (children and adults). Participants ($N=147$) in the first part of the study were 6- to 11-year-old children who had varied musical learning experiences. The predictor variable (musical learning experiences) was measured with a questionnaire in which the parents were asked to provide details about their child's history of private or group music lessons taken outside of school. The criterion variables consisted of measures of intelligence, academic abilities, and social adjustment measured by using the entire Wechsler Intelligence Scale for Children (WISC), the Kaufman Test of Educational Achievement (K-TEA), and school grades.

Results of this study illustrated that musical learning experiences were correlated positively with each measure of intelligence or academic ability, even when other confounding variables (e.g., family income, parents' education, involvement in nonmusical activities) were accounted for.

The participants in the second part of the study were undergraduates from 16 to 25 years of age. As in the first part of the study, the predictor variable (musical learning experiences) was quantified based on the questionnaire in which the participants provided details about their history of music learning. The criterion variables included intellectual and academic achievement, which was measured using the complete Wechsler Adult Intelligence Scale—Third edition, and report of academic achievement in high schools. Results of the study showed that a longer history of musical learning experiences was positively correlated to intelligence ability and high school average, even when other variables (e.g., parent's education, family income, and gender) were held constant. However, the associations were smaller in magnitude and less consistent than those observed in children. In short, the study suggests that formal music learning experiences in childhood are associated positively with intelligence ability and academic performance; the association may be small but general and long lasting.

Music and Language Ability

Linguistic intelligence is one of the major cognitive domains in child development and school education (Gardner & Hatch, 1989). Music and language are both symbol systems sharing similar information-processing strategies, organization principles, and expressive qualities (Hansen, Bernstorff, & Stuber, 2004). It has been noted that several reading or decoding skills in language and literacy development are

parallel to the aural and visual-information processes in music, such as phonological awareness, phonemic awareness, sight identification, orthographic awareness (e.g., a mental representation of appearance of a word), cueing system awareness, and fluency (Hansen & Bernstorf, 2002). Auditory attention and sound discrimination proficiency are among the first of the sequential skills vital to language development (Piro & Ortiz, 2009).

Research has suggested that phonemic awareness (the ability to recognize that a spoken word consists of individual sounds or phonemes) is an essential predictor for development of reading ability (Ehri et al, 2001). While phonic awareness concerns the word structure in sound, the auditory discrimination ability is vital for awareness at the phoneme level (Gromko, 2005). Interestingly, research has shown that children's test scores of auditory discrimination of pitch were significantly related to their scores on a test of phonemic awareness (Lamb & Gregory, 1993). As auditory ability in music is related to phonemic awareness, Butzlaff (2000) suggests "that there is indeed a strong and reliable association between the study of music and performance on standardized reading/verbal tests" (p.172). Given this relationship, many researchers have investigated the influence of music learning on the development of language/reading ability in children (Anvari, Trainor, Woodside, & Levy 2002; Douglas & Willatts, 1994; Gromko, 2005; Ho, Cheung, & Chan, 2003; Hurwitz, Wolf, Bortnick, & Kolas, 1975; Piro & Ortiz, 2009).

Hurwitz, Wolf, Bortnick, and Kolas (1975) studied the effects of general music instruction on temporal and spatial ability, as well as reading competence by matching two groups of first-grade children ($N=40$). One group received music instruction using a

Kodaly-based curriculum and the other group received no music training. A Kodaly-based curriculum emphasizes the development of music literacy through singing. This method uses the solfege technique, which assigns syllables to notes of the diatonic scale (*Do, Re, Mi, Fa, Sol, La, Ti*). These two groups were matched for age, IQ score, and social class. No significant group differences were found on these selected variables. After the music instruction, the Comprehension and Vocabulary subtests of the Wechsler Intelligence Scale for Children (WISC) were administered to evaluate children's language ability. Results of the study demonstrated that children receiving the Kodaly music instruction performed more effectively on reading tasks than the comparable group of children not receiving this music instruction. The study suggests that the use of visual symbols in music reading along with auditory stimulation in music listening may facilitate children's language development and reading ability.

Douglas and Willatts (1994) conducted an observational study to examine the relationship between musical ability and literacy skills. A total of 78 children in the age range from seven years and five months to eight years and nine months participated in the study. Participants' musical abilities were measured using the Primary Aural Awareness, while the literacy skills were measured using the British Picture Vocabulary Scale and the Schonell Reading and Spelling Test. Results of the study revealed that a positive correlation exists among phonological awareness, rhythm ability, and literary skills. Further, a pilot intervention study was conducted to investigate the effect of music learning on reading ability. Participants in the intervention group received six months of music instruction while the participants in the control group received no music instruction. The same series of language test using in the observational study were

administered before and after the music instruction in this intervention study. Results of the experiment demonstrated that the intervention group scored significantly higher than did the control group. In addition, reading scores for the intervention group increased from the pre-test to the post-test, while scores for the control group did not increase. According to these results, the authors suggest that learning music is a valuable additional strategy for assisting children with reading difficulties.

To study the relationship between music learning and verbal memory, Ho, Cheung, and Chan (2003) examined whether experiences of instrumental music learning and participation in school music ensembles have effects on children's verbal and visual memory. Ninety children ages 6-15 years old in Hong Kong participated in this study. Participants in the experimental group had music training at their schools where they received music lessons on Western instruments (e.g., violin, piano, or flute) for at least one hour per week and participated in the music ensemble programs, while the children in the control group had no experiences of instrumental music learning and participation in music ensemble programs. In the verbal memory test, the child was orally presented a 16 two-character Chinese word list three times and was asked to recall as many words as possible in the three learning trials. The visual memory was measured using the Brief Visuospatial Memory Test—Revised (BVMT-R). Results of the study revealed that the music group demonstrated the better verbal memory ability than did the non-music group; however, no significant differences were found in visual memory between the two groups. A year later, a follow-up study was conducted to re-examine the participants' verbal memory and visual memory. Results showed that participants who continued music training demonstrated significant verbal memory improvement while participants

who discontinued music training after the first evaluation did not show any improvement. In contrast to the differences in verbal memory between the groups, the evaluation of visual memory was not significantly different between the groups. Accordingly, the study suggests that music training systematically affects verbal processing in children.

Anvari, Trainor, Woodside, and Levy (2002) studied the relationship among phonological awareness, music perception skills, and early reading skills of 4- and 5-year-old. A total of 100 children in this study were given a battery of tests (e.g., phonemic awareness, reading, vocabulary, music, digit span, and mathematics) over the course of five sessions; each session lasted approximately 23-30 minutes. Some tasks were standardized tests (e.g., the Rosner Test of Auditory Analytic Skills, the Peabody Picture Vocabulary Test) while other musical tasks were developed by the researchers after extensive pilot testing. Regression data analyses indicated that music perception skills contribute unique variance in predicting phonological awareness, even when other cognitive abilities (mathematics, auditory memory, and vocabulary) were held constant. The study suggests that music perception skill is reliably related to phonological awareness and early reading development.

The effect of music instruction on young children's phonemic awareness is a research focus in another study by Gromko (2005). Kindergarten children ($N=103$) were assigned to the treatment and control groups. Each child in the treatment group received weekly 30 minutes of music instruction weekly for four months while the control group received no music instruction. The three subtests (letter-naming fluency, phoneme-segmentation fluency, and nonsense-word fluency) from the Dynamic Indicators of Basic Early Literacy Skills test (Good, Gruba, & Kaminski, 2002) were administered to assess

children's literacy skills. Results of the study illustrated that the treatment group receiving four months of music instruction had significantly greater gains in the scores of phoneme-segmentation fluency tasks when compared to the control group who received no music instruction. The study suggests that the association of sound with developmentally appropriate symbols and active music learning may assist cognitive processes related to those needed to understand the segmentation of a spoken word in sound.

Examining the relationship of music learning to other language skills, Piro and Ortiz (2009) carried out a study to investigate the effects of piano instruction on vocabulary and verbal sequencing of primary grade students. The experimental group ($n=46$) studied piano formally for three consecutive years, while the control group received no music instruction, either in school programs or private study. The piano curriculum included teaching the children basic music notation, fingering technique, sight-reading, note and rest values, and other related musical topics. The two subtests (Vocabulary and Verbal Sequencing) of the Meeker Structure of Intellect Test were administered to assess children's vocabulary and verbal sequencing skills. The participants were pre- and post-tested at the start and close of a 10-month school year; each child in the experimental group received 40 minutes of piano instruction twice each week. Results of this study revealed that the experimental group scored significantly higher than did the control group on both vocabulary and verbal sequencing scores. This study suggests the role of music study on children's cognitive development and sheds light on the potential question of music to enhance academic performance in language and literacy.

Music Listening and Spatial-Temporal Reasoning

The research exploring the effects of music on ability of spatial-temporal reasoning is focused on two musical aspects: music listening and active music learning. Most studies implemented an experimental research design to investigate whether listening to music affects spatial-temporal reasoning ability. While some researchers found significant effects of music listening on spatial-temporal reasoning (Rauscher, Shaw, & Ky, 1995; Ridout & Taylor, 1997; Rideout, Dougherty, & Wernert, 1998), others remained skeptical about these findings (Carstens, Huskins, & Hounshell, 1995; Nantais & Schellenberg, 1999; Newman et al., 1995; Steele, Ball, & Runk, 1997; Steele, Brown, & Stoecker, 1999; Wilson & Brown, 1997). In addition, several researchers investigated whether listening to music by Mozart enhances children's spatial-temporal reasoning (Črnčrec, Wilson and Prior, 2006a). Some studies focused on children at the elementary school and middle school level (Črnčrec, Wilson and Prior, 2006b; Ivanov & Geake, 2003; McKelvie & Low, 2002), while others focused on children at preschool level (Hui, 2006).

A landmark study regarding the relationship of music listening to spatial-temporal reasoning was conducted by Rauscher, Shaw, and Ky (1993). A total of 36 college students were randomly assigned to one of the following three listening conditions: (1) listening to Mozart Sonata K.448; (2) listening to a relaxation tape; or (3) silence. After receiving one of the treatment conditions, spatial-temporal reasoning of participants was evaluated immediately by using the *Stanford-Binet Intelligence Scale*. Results of the study showed that students who listened to about ten minutes of the Mozart Piano Sonata K.448 increased their spatial-temporal performance. This result known as “Mozart

Effect” was the first report of a causal relationship between music listening and spatial-temporal reasoning.

While findings of this study were popularized by the public media, and labeled as the “Mozart effect,” this demonstration has also led to several replication studies.

Carstens, Huskins, and Hounshell (1995) carried out a study to examine whether listening to Mozart music improves spatial-temporal reasoning. A total of 30 women and 21 men in age from 18 to 38 years participated in this study. While participants in the treatment group listened to Mozart sonata K.448 for 10 minutes, participants in the control group meditated in silence for 10 minutes. After the listening and meditation condition, the spatial-temporal reasoning was measured immediately by the *Revised Minnesota Paper Form Board Test*. Results of this study indicated that the difference in the two group means was not statistically significant. This study concluded that the failure to replicate the Mozart effect might have been caused by administering different outcome measurement tools. Other studies (e.g., Newman et al. 1995, Steele, Ball, & Runk, 1997) did not find that listening to Mozart music enhance spatial-temporal reasoning due to the use of different measurement tools.

In contrast to the findings of aforementioned studies, Rideout and Taylor (1997) found the “Mozart effect” on performance of spatial-temporal reasoning. In this study, sixteen men and sixteen women in age from 18 to 21 years were placed in two conditions: music listening (Mozart Sonata K. 448) and silence. After each participant completed the assigned experimental condition, the Stanford-Binet Scale of Intelligence Test was administered immediately to evaluate the participant’s spatial-temporal reasoning. Analysis of the data showed a small but significant improvement immediately

following presentation of music condition.

In order to further determine whether the selection of music affected spatial-temporal reasoning, Rideout, Dougherty, and Wernert (1998) added the contemporary music similar to the Mozart music in tempo, structure, melodic and harmonic consonance as one the listening conditions in this study (three conditions —Mozart music, contemporary music, and silence conditions). The analysis of the data revealed that the scores on spatial-temporal reasoning tasks significantly increased after listening to both contemporary music and the Mozart sonata. The study suggests that music with a rapid tempo, fairly high melodic complexity, and rhythmic variation seemed to enhance spatial-temporal reasoning ability.

Another study carried out by Wilson and Brown (1997) also found that other types of music (other than the Mozart piano sonata) might also affect spatial-temporal reasoning. In this study, 22 college students were assigned to one of the experimental conditions: (1) Mozart piano concerto K.488, (2) repetitive relaxation music, (3) silence. Different from the landmark “Mozart effect” study (Rauscher, Shaw, Ky, 1993), the performance of spatial-temporal reasoning was measured by completing nine pencil-and-paper mazes with varying complexity. Four measures of maze performance were used as the index for spatial-temporal reasoning of subjects: the number of mazes completed within each condition, the number of path errors, the quality of each maze solution, and the number of times for a recursion in the solution. Results of this study showed that participants who listened to the Mozart sonata improved in their performance of spatial-temporal reasoning tasks. In addition, those who listened to the repetitive relaxation music also enhanced their spatial-temporal reasoning performance as compared with

those who experienced the silence condition.

While various research studies showed mixed results regarding effects of music listening on spatial-temporal reasoning, Rauscher and Shaw (1998) clearly defined the meaning of spatial-temporal reasoning, as well as explained the theoretical rationale and outcome measures for replication studies. The authors defined spatial-temporal reasoning as “the ability to transform mental images in the absence of a physical model” (p.836). In addition, the authors noted that effects of music listening on spatial ability were only found on spatial-temporal tasks. Their study did not show music listening effects on other types of spatial abilities such as spatial recognition. Rauscher and Shaw also stated that the different choices of outcome measures in the replication studies may have been the reason for mixed findings.

After Rauscher and Shaw (1998) provided the definition of spatial-temporal reasoning and a clarification of experimental procedures, Nantais and Schellenberg (1999) followed the suggested experimental procedures and designed two experimental studies to investigate whether listening to music by Mozart enhance spatial-temporal reasoning. In the first experiment, 56 college students were assigned to one of three experimental conditions: (1) Mozart Sonata K.448, (2) Schubert Piano Sonata in F minor, and (3) silence. The spatial-temporal reasoning of subjects was measured by Paper Folding and Cutting tasks (20 items from the *Stanford-Binet Intelligence Scale*, 14 items created by the researchers). After the participants listened to the music and sat in silence, the test was administered immediately to assess performance of spatial-temporal reasoning. The results of this experiment illustrated that participants who listened to music by either Mozart or Schubert scored significantly higher on spatial-temporal

reasoning tasks than did the participants who was sat in the silence condition.

In the second experiment, Nantais and Schellenberg attempted to test whether effects of music listening on spatial-temporal reasoning is actually a consequence of participants' preference for one testing condition over another. The experimental procedure was similar to the procedure of the first experiment, except that the control condition (silence) was replaced by listening to a short narrative story. After the test session, the subjects were asked their preference of each treatment condition. Interestingly, the performance of spatial tasks was significantly better in participants' preferred condition.

Hetland (2000b) conducted a meta-analysis of 31 experimental studies concerning effects of music listening on spatial-temporal reasoning for adults. Her report of the analyses supported Rauscher and Shaw's (1998) argument that "the Mozart effect is limited to a specific type of spatial task that requires mental rotation in the absence of a physical model" (p.136). Also, the report revealed that the enhancing effect on spatial-temporal reasoning is not limited to music by Mozart, but may include other kinds of classical music such as Schubert's Piano Sonata in F minor.

While numerous studies focused on the influence of music listening on spatial-temporal reasoning for adults, several researchers studied whether listening to music by Mozart enhances spatial-temporal reasoning of children. McKelvie and Low (2002) conducted two experiments with school-aged children (approximately 12 years). In the first experiment, fifty-five children were assigned to one of two listening conditions: either Mozart Sonata K. 448 or popular music. The spatial ability was measured using Stanford-Binet Intelligence Scale---Fourth Edition. The tests were given prior to and after

the treatment conditions. Results of the study showed no significant differences on the scores of spatial-temporal reasoning tasks between the Mozart and the popular music groups.

In the second experiment, McKelvie and Low changed the experimental procedure from a control group experimental design to a within-subjects repeated measure design where all the subjects were provided with both treatment conditions. In addition, the design added the relaxation music condition, which has been suggested to inflate the findings from the original Rauscher and Shaw's study (Nantais and Schellenberg, 1999). Given the efforts made to refine the experimental procedure, the data analysis still revealed that both main effects of music conditions and tests were not significant, indicating that children did not improve their spatial-temporal reasoning performance after listening to music by Mozart.

Hui (2006) designed an experimental study to examine whether listening to music by Mozart improves preschool children's spatial-temporal reasoning. A total of 41 preschool children were randomly assigned to six groups of approximately seven individuals each. Each group was presented the three conditions in the same order: Mozart Piano Concerto K.488, age-appropriate popular music, and silence. This cross-sectional research design was intended to balance learning effects and reduce variance and design flaws discussed by Rauscher and Shaw (1998). The spatial-temporal reasoning was measured by a series of pencil-and-paper maze tests based on Wechsler Preschool and Primary Scale of Intelligence-Revised. The analysis of mean scores revealed no significant differences among three treatment conditions while controlling for the children's age. However, the data analysis indicated that the increase of spatial-

temporal scores for younger children was significantly greater than the scores for older children after listening to Mozart.

Črnčrec, Wilson and Prior (2006b) conducted an experimental study to determine whether listening to music enhances children's spatial-temporal reasoning. One hundred and thirty six fifth graders were assigned to one of three experimental listening conditions: (1) Mozart Sonata K.448, (2) popular music, and (3) silence. The Fitzgerald Paper-Folding Test was administered immediately after the participant listened to the music or sat in silence. In accordance with the findings of other cited studies, results of this study showed that the scores of spatial-temporal reasoning tasks were not significantly different among the three experimental conditions, indicating that children listening to music by Mozart may not affect children's spatial-temporal reasoning.

In contrast to the findings of aforementioned studies, Ivanov and Geake (2003) found that listening to music by Mozart improves performance in spatial-temporal reasoning tasks for upper-primary school-aged children in a school setting. In this study, grade five and six students ($N=76$) were randomly assigned to one of the three listening conditions: (1) Mozart Sonata K.448, (2) Bach Toccata in G Major, and (3) background noise condition. The spatial-temporal reasoning was measured using the Fitzgerald Paper-Folding Test. While most experimental procedures were similar to other Mozart effect studies, one difference in this experimental procedure was that children in both music groups listened to music throughout the testing process while the instructions of the task were being explained. Interestingly, the results of this study indicated a significant difference between music and the control group. In addition, the mean score of the Bach group was also significantly higher than the control group. In other words,

listening to the Bach Toccata had a similar effect as listening to the Mozart sonata on the performance of spatial-temporal tasks for upper primary school-aged children.

Music Learning and Spatial-Temporal Reasoning

While some researchers have conducted studies to determine the relationship between listening to Mozart and children's spatial-temporal reasoning, many studies have emphasized the effect of active music learning on children's spatial-temporal abilities. However, the findings of these studies are mixed; some studies showed that music instruction has significant effects on performance of spatial-temporal reasoning (Bilhartz, Bruhn, & Olson, 2000; Hurwitz, Wolff, Bortnick, & Kokas, 1975; Rauscher, et al., 1997; Rauscher & Rupan, 2000; Persellin, 2000; Zafranas; 2004), others did not demonstrate significant music effects on spatial-temporal reasoning (Gromko & Poorman, 1998; Hanson, 2003). All these studies were conducted using an experimental research design; the music instruction examined in these studies included piano keyboard instruction and general music instruction (e.g., Kindermusik, Orff-based or Kodaly-based music instruction).

Hurwitz, Wolff, Bortnick, and Kokas (1975) first conducted an experimental study to examine the influence of music instruction on spatial and temporal ability. A total of 40 first graders participated in this study were assigned to one of the two groups. Twenty children in the experimental group received approximately 40 minutes of music instruction based in the Kodaly method five days a week for approximately seven months, while another 20 children in the control group received no Kodaly music instruction.

The spatial- temporal ability and sequencing skills were measured using a series

of tests (e.g., the Block Design and Object Assembly of the Wechsler Intelligence Scale for Children, Raven Progressive Matrices, and Visual Motor Integration Test). Results of the study indicated that children in the music group performed significantly better in the spatial-temporal tasks than children of the control group. In addition, the boys in the music group scored significantly higher in spatial abilities than ones in the control group, while the girls in both groups did not show significantly difference in their spatial-temporal reasoning scores.

Based on their theory of the Trion model (Leng and Shaw, 1991), Rauscher et al. (1997) designed an experimental study to determine the causal relationship between piano instruction and development of spatial-temporal reasoning of young children. In this study, seventy eight children in age from three to four years were assigned to one of four groups including piano instruction, singing instruction, computer instruction, and no instruction groups. Children in the piano instruction group received 10 minutes of piano lesson once a week for six months. The lesson materials included pitch intervals, fine motor coordination, fingering technique, sight-reading, music notation, and playing from memory. While children in the piano group received piano lessons, other children received singing, computer lessons or no lessons respectively.

All children's spatial abilities were measured by the four subtests of the *Wechsler Preschool and Primary Scale of Intelligence-Revised* (Wechsler, 1989). While the Object Assembly task was used to measure children's spatial-temporal ability, the other tasks including the Geometric Design, Block Design and Animal Pegs were implemented to test children's spatial-cognition. The data analysis demonstrated that the piano group's scores significantly increased on performance of spatial-temporal reasoning, while other

groups did not show the significant improvement. More surprisingly, the post hoc analysis showed that children in the piano instruction group scored significantly higher than children in other three groups on the Object Assembly task. On the other hand, the piano group did not show significant difference on the spatial-recognition tasks. The study concluded that piano instruction enhances young children's spatial-temporal reasoning, but not spatial-recognition abilities.

Rauscher and Zupan (2000) examined the influence of piano instruction on spatial-temporal reasoning in a public school classroom setting. Sixty-two kindergarten children (36 boys and 26 girls) from four kindergarten classes at two public elementary schools participated in this study. Participants were assigned to one of two conditions: keyboard instruction and no instruction. The keyboard group received 20-minute keyboard lessons twice a week for eight months. The keyboard instruction was given in a small group of approximately 10 children. Meanwhile, children in the control group were involved in journaling with their classroom teacher during the lesson time. Prior to the commencement of the study, children were pretested with two spatial-temporal reasoning tasks and one pictorial memory task taken from the McCarthy Scales of Children's Abilities and Learning Accomplishment Profile Standardized Assessment test. The children were given the same tests again after four and eight months of keyboard instruction.

Results of the study revealed that the keyboard group scored significantly higher than children in the control group on the two spatial-temporal reasoning tasks, while no significant difference found between the two groups on the pictorial memory task after the four months of instruction. Furthermore, the data from the study showed the greater

significant difference between the two groups in the spatial-temporal reasoning scores after the eight months of lesson period. The study suggested that piano instruction may enhance children's spatial-temporal reasoning in a school classroom setting.

Bilhartz, Bruhn and Olson (2000) investigated whether the Kindermusik instruction has an effect on young children's music and other cognitive abilities such as language, spatial ability, quantitative reasoning. Children ($N=71$) in age from four to six years were assigned to the Kindermusik instruction group or the control group. Children in the instruction group received 75 minutes of Kindermusik instruction once a week for 30 weeks, while the control group received no music instruction. Before and after the music instruction, a series of subtests from the Stanford-Binet Intelligence Scale and the researcher-designed Music Skills Assessment were administered to evaluate children's musical skills and selected cognitive abilities.

Results of the study showed that the experimental group scored significantly higher than the control group in the spatial-temporal reasoning tasks. There were no significant differences between the experimental and control groups in vocabulary tests for the combined sample; however, experimental group children from high income households showed greater improvement on vocabulary improvement during the test period than control group children from high income households. Also, no significant differences were found between the experimental and control groups in other cognitive tasks (e.g., quantitative reasoning and memory for sentences). In terms of musical skills, the experimental group scored significantly higher than the control group in three subareas of the Music Skills Assessment, including steady beat subtest, rhythmic pattern subtest, and vocal pitch test. Nevertheless, in the aural discrimination subtest designed to

identify the development of perfect pitch, the experimental group was not significantly different from the control group.

Zafranas (2004) designed an experimental study to investigate the relationship of keyboard learning to spatial-temporal reasoning of kindergarten children. Kindergarten children ($N=61$) ranging in age approximately five to six years were divided into 12 groups; each group received a 30-minute piano lesson once a week for six months. No control group was assigned in this study. All children were pre- and post-tested by completing the six subtests of Kaufman Assessment Battery for Children (K-ABC), including the hand movement task, the gestalt closure task, the triangles task, the spatial memory task, the arithmetic task, and the matrix analogies task. Results of this study indicated that the scores significantly increased in Hand Movements (visual-motor sequencing tasks), Gestalt Closure (visual-vocal communication tasks), Triangles (spatial-visualization tasks), Spatial Memory (spatial-localization tasks), and Arithmetic (mathematical concept and computational skill tasks) but not in Matrix Analogies (analogical thinking tasks). In addition, boys had significantly better gain scores than girls in Triangles.

Gromko and Poorman (1998) investigated the effects of general music instruction on preschoolers' spatial-temporal reasoning performance. Three- and four-years-old children ($N=30$) were assigned to either the experimental group or the control group. The experimental group received an extra 30 minutes of general music instruction (class activities include singing, musical movement, and playing percussion instrument) outside of school music curriculum once a week for approximately six months, while the control group did not received the extra music instruction. Children's spatial abilities were

measured by administering five subtests of the Wechsler Preschool and Primary Scale of Intelligence-Revised, including the Object Assembly, Geometric Design, Block Design, Picture Completion, and Animal Pegs. Results of the study revealed that the two groups were not significantly different when using scaled scores (standardized scores) in the analysis ($p = .059$). However, the results indicated that the experimental group scored significantly higher than did the control group when using raw scores in the analysis ($p = .049$). Overall, the authors believed that music training could have a positive effect on the development of spatial intelligence in preschool children. Given the non-significant findings in the analysis of scaled scores, however, the interpretation of findings should be made with caution.

Persellin (2000) examined whether general music instruction based on the Orff method has an effect on young children's spatial-temporal task performance. A total of 12 kindergarten children participated in this study. The participants in the experimental group received 45-minute music instruction three times a week for six weeks, while children in the control group participated in regular kindergarten classroom activities. The music instruction included singing activity, full-body movement, and playing Orff percussion instruments. Before and after the music instruction, the Object Assembly of the Wechsler Preschool and Primary Scale of Intelligence-Revised was administered to evaluate participants' spatial-temporal reasoning. Six weeks later from the completion of music instruction, the Object Assembly was administered again to evaluate participants' spatial-temporal reasoning. The analysis indicated that music group scored significantly higher than did the control group over six weeks of the music instruction. Nevertheless, children's second post-test scores were not significantly different from the pre-test scores.

The findings of the study supported the point of view that music instruction has significant effects on children's spatial-temporal reasoning. However, it might be just a short-term effect if music instruction is no longer provided.

Hanson (2003) investigated whether music instruction based on the Kodaly method is able to enrich young children's spatial abilities. Three groups (Kodaly music instruction, computer instruction, and control groups) were included in the research design; a total of 54 kindergarten children were assigned to one of three groups. The Kodaly music instruction group and computer group received 30 minutes of computer and Kodaly music instruction twice a week for 31 weeks respectively, while the control group was engaging in informal musical activities lead by their classroom teachers during the study. In the Kodaly music instruction, participants learned introductory music concepts (e.g., beat, fast/slow, high/low, and same/different), and basic literacy concepts (e.g., rhythm, quarter note, eighth notes, rest sign, bar line, and five-line staff). In the computer group, participants were introduced basic computer keyboard skills including how to use a mouse. The Object Assembly of the *Wechsler Preschool and Primary Scale of Intelligence-Revised*, the Visual Closure Test of the *Woodcock-Johnson Psycho-Educational Battery-Revised* and the Absurdities Test of the *Stanford-Binet Intelligence Scale* were administered to evaluate children's spatial-temporal reasoning, spatial recognition, as well as the verbal ability. Results of this study showed that the scores were not significantly different among the three groups for spatial-temporal reasoning, spatial recognition, as well as the verbal ability.

Hetland (2000b) conducted a meta-analysis of 15 experimental studies investigating the relationship of music learning to spatial reasoning of children. Hetland

found that the research on music learning and spatial ability was usually constructed in an experimental research design in which the participants in age from three to seven years were assigned to one of two to four experimental conditions. The treatment groups usually received 10 to 60 minutes of active music instruction, one to five times per week for four weeks to three years in duration, while the control groups received an alternative treatment or no instruction. The music instruction often included the following activities: singing, listening, playing percussion instruments, and moving responsively to music. The piano instruction focused on music reading and playing techniques in conjunction with some general music activities (e.g., singing and moving). Music knowledge taught in these music classes included simplified notations, discrimination of melody, rhythm and timbre.

The report of Hetland's meta-analysis indicated that active music instruction had an influence on children's spatial-temporal reasoning although the mean effect size was not large ($r = .39$) in the analysis. Specifically, the analysis revealed that music instruction that included standard notation resulted in greater spatial-temporal improvement than the instruction that did not include music notation. However, further investigations are still needed to determine whether the enhancement of spatial-temporal reasoning takes place when learning music notation in combination with the keyboard/piano instruction.

Summary

In summary, research reviewed in this section focused on the influence of music learning on the development of children's overall cognitive ability, language ability, and spatial-temporal reasoning (See Table 1 for a summary of the reviewed studies). Several

studies found that learning music may facilitate children's language ability, including phonemic awareness, verbal memory, and literacy skills (Anvari, Trainor, Woodside & Levy, 2002; Douglas & Willatts, 1994; Gromko, 2005; Ho, Cheung, and Chan, 2003; Piro & Ortiz, 2009).

A number of studies have been focused on the influence of music listening or music instruction on spatial-temporal reasoning. The relationship between music listening and spatial-temporal reasoning has been known as the "Mozart effect" in which the research found listening to the Mozart Piano Sonata K.448 may enhance performance of spatial-temporal reasoning (Rauscher, Shaw, & Ky, 1993). However, several replication studies on the "Mozart effect" showed inconsistent research results (Carsten, Huskin & Hounshell, 1995; Rauscher & Shaw, 1998; Ridout & Taylor, 1997; Steele, Temara, & Runk, 1997). In addition, no research findings support the "Mozart effect" on children (Črnčrec, Wilson and Prior, 2006b; Hui, 2006; McKelvie & Low, 2002).

Although Ivanov and Geake (2003) found that listening to classical music may enhance children's spatial-temporal reasoning, others researchers questioned this finding because of the experimental procedures of the study (Črnčrec, Wilson and Prior, 2006a). These researchers argue that the results of Ivanov and Geake's (2003) study are difficult to interpret since "the study required children to listen to music continuously while performing a spatial-temporal task, significantly changing the experimental paradigm from other Mozart effect studies" (Črnčrec, Wilson and Prior, 2006a, p.581).

In addition, Hetland (2000b) also suggests that the report for the Mozart effect has "primarily scientific rather than educational implications, which does not lead to the conclusion that exposing children to classical music will raise their intelligence or their

academic achievement of even their long term spatial skills” (p.137). Hence, it is assumed that mere exposure to music without active learning seems not to impact on children’s spatial-temporal reasoning.

Many studies that focused on the relationship between music instruction and spatial ability of children found that music instruction helps children develop their spatial-temporal reasoning ability (Bilhartz, Bruhn and Olson, 2000; Costa-Giomi, 1999; Hurwitz, Wolff, Bortnick & Kokas, 1975; Persellin, 2000; Rauscher et al, 1997; Rauscher & Zupan, 2000). In contrast, few studies did not find significant effects of music instruction on spatial-temporal reasoning in children (Gromko & Poorman, 1998; Hanson, 2003). Further, some studies revealed that music effects may not be observed once the music instruction is discontinued, and the enhancement of spatial ability may not be sustained after two years of instructional period (Costa-Giomi, 1999; Persellin, 2000). Therefore, Hetland (2000b) conjectured that “it is possible that music simply speeds up a universal developmental process in spatial ability, rather than providing a lasting advantage” (p.223).

Table 1 Summary of Related Literature: Music Learning in Cognitive Development

Purpose of Investigation/Authors/Participants	Research Design	Dependent Variables /Measurements	Findings
Music and Cognitive Development <ul style="list-style-type: none"> Costa-Giomi (1999) <i>N</i>=63 children (ages 9-12 years) Jordan-Decarbo and Galliford (2001), <i>N</i>=106, preschoolers Schellenberg (2006) <i>N</i>=147, children (ages 6-11 years) and adults (ages 16-25 years) 	<p>Experimental Design</p> <p>Experimental Design</p> <p>Correlation Research Design</p>	<p>Overall cognitive ability and Self-esteem /DCAT* and the self-esteem test</p> <p>Overall cognitive ability/DCAT*</p> <p>Cognitive ability/WISC*</p>	<p>Music instruction has significant effects on overall cognitive ability and self-esteem of children.</p>
Music and Language Ability <ul style="list-style-type: none"> Anvari et al. (2002) <i>N</i>=100 children ages 4-15 Douglas and Willatts (1994) <i>N</i>=78 (ages 7-8 years) Gromko (2005) <i>N</i>=103 kindergarten children Ho, Cheung and Chan (2003) <i>N</i>=90 children ages 6-15 Piro and Ortiz (2009) <i>N</i>= 46 children in primary grades 	<p>Experimental Design</p>	<p>Literacy skills, verbal memory/BVMT-R*, phonological, phonemic awareness, and vocabulary sequencing /MSIT*</p>	<p>Early music instruction has a positive effect on phonological and phonemic awareness, verbal memory, and verbal and vocabulary sequencing</p>
Music Listening and Spatial Reasoning <ul style="list-style-type: none"> Rauscher et al. (1995); Ridout and Taylor (1997); Newman et al. (1995); Wilson and Brown (1997) <i>N</i>=16-32 adults McKelvie and Low (2002); Nantais and Schellenberg (1999); Hui (2006); Črnčrec, Wilson and Prior, (2006) <i>N</i>=41-136 children ages 3 to 12 years 	<p>Experimental Design with repeated measures</p>	<ul style="list-style-type: none"> Spatial reasoning / SBIS* and researcher-designed tasks Spatial reasoning/SBIS* WPPSI-R* 	<ul style="list-style-type: none"> The studies found mixed results regarding effects of music listening on spatial-temporal reasoning for adults. No significant effects were found for children.
Music Instruction and Spatial Reasoning <ul style="list-style-type: none"> Karma (1985); Rauscher et al. (1997, 2000); Gromko and Poorman (1998); Bilhartz, Bruhn and Olson (2000); Persellin (2000); Hanson (2003); Zafranias (2004) 	<p>Correlation Research Design</p> <p>Experimental Design</p>	<p>Spatial reasoning ability/ subtests of the WPPSI-R*, K-ABC*, and SBIS*.</p>	<ul style="list-style-type: none"> Significant correlation was found between music learning and spatial ability (Karma, 1985). Effects of music instruction were found on spatial ability, except Hanson's (2003) study.

*Developing Cognitive Abilities Test; *Wechsler Intelligence Scale for Children, *; Brief Visuospatial Memory Test-R; *Meeker Structure of Intellect Test; *Stanford-Binet Intelligence Scale; *Preschool and Primary Scale of Intelligence-R; *Kaufman Assessment Battery for Children.

Musical Development of Young Children

Music educators and researchers have explored a variety of developmental theories in music learning and development of musical abilities in young children (Gembris, 2006; Hargreaves & Zimmerman, 1992; Zimmerman, 1993). This review of research focuses on the following musical abilities: development of music aptitude, auditory discrimination ability, tonal/melodic perception, and rhythmic ability.

Development of Music Aptitude

As music aptitude is an essential component in musical development, several studies focused on how formal music learning relates to development of music aptitude. Some researchers examined whether formal music instruction helps children develop their music aptitude (DeYarman, 1975; Flohr, 1981; Rutkowski, 1996; Stamou, 1998), while others studied the relationship between musical achievement and music aptitude (Mota, 1997; Hornbach & Taggart, 2005).

DeYarman (1975) conducted a longitudinal study to examine the influence of formal music learning on development of music aptitude and music aptitude stability among primary school children. The participants ($N=2980$) received music instruction from their kindergarten teacher for a year, and were exposed to the new music curriculum taught by a music specialist for the following three years. The Musical Aptitude Profile (MAP) was administered to evaluate children's music aptitude at the end of each school year for four years. Results of the study revealed that type of music instruction had effect on music aptitude prior to the fourth grade and that music aptitude may be stabilized by age six or earlier.

Another study focused on the influence of music instruction on development of

music aptitude was conducted by Flohr (1981). Participants ($N=29$) were five-year-old children who were randomly assigned to one of three groups: the Music-I, the Music-II, and the control groups. The Music-I group received 25 minutes of music instruction for 12 weeks; the class emphasized instrumental improvisation. The same amount of music instruction in the Music-II group consisted of singing, playing percussion instruments, and movement, while the control group received no instruction. Prior to and after the music instruction, the Primary Measures of Music Audiation (PMMA) was administered to assess children's music aptitude. Results of the study showed statistically significant difference between the groups receiving music instruction and the control group. The combined mean score of the Music-I and Music-II on the PMMA was significantly higher than the scores of the control group. The study suggests that a short-term music instruction (12 weeks) can have a positive impact on development of music aptitude for 5-year-old children.

Rutkowski (1996) examined the effects of singing instruction on young children's development of music aptitude and singing voice. In this experimental study, kindergartens ($N=99$) were assigned to one of two instructional conditions: large-singing group and individual/small-singing group. The music aptitude was measured using the Primary Measures of Music Audiation (PMMA). The test was administered three times (a pretest, a test midway through the instruction period, and a posttest) over 9 months of instructional period. Children in both groups received 30 minutes of music instruction once a week. The instruction for the treatment group focused on small-group and individual singing activity, while the control group emphasized large-group singing activities and rhythmic/ movement activities. Songs and games were the same for both

the treatment and control groups. Results of the study illustrated that the two groups were not significantly different on the scores of music aptitude although the mean scores increased for both groups during the period of music instruction. As for development of singing voice, children in the small-group/individual singing instruction scored significantly higher than those in the large-group singing instruction. The study suggests that singing instruction in a small-group setting affects development of children's singing voice.

Examining the relationship between instrumental instruction and development of aptitude, Stamou (1998) studied whether Suzuki violin instruction has an effect on development of music aptitude in children. Forty-three beginning Suzuki string students assigned to the treatment group received 20 to 30 minutes of individual lesson and 45 minutes of group class once a week respectively while seventy-six students assigned to the control group received general music instruction in school music classes, but no Suzuki violin instruction. The age range of the participants in this study was 5 to 8 years old. Gordon's Primary Measures of Music Audiation (PMMA) was administered to measure children's music aptitude. Results indicated that although the Suzuki instruction groups mean score was higher than the control group, the statistical test showed no significant difference between the two groups.

In addition to examining the effects of music learning on development of music aptitude, some researchers investigated the relationship between development of music aptitude and musical achievement. Mota (1997) studied the relationship between children's music aptitude and their performances on three specific musical tasks: singing a song, reproducing a short tune, and keeping meter in instrumental play. Six-year-old

children ($N=106$) from three local schools in northern Portugal participated in this study. The Primary Measure of Music Audiation (PMMA) was administered to evaluate children's music aptitude. A set of individual musical tasks was administered to evaluate musical skills, including singing, reproducing a short tune, and maintaining beats while playing a percussion instrument. Results of the study suggest that the PMMA tasks were not significantly related to the three musical skills, except for the ability to sing a song of the child's own choice.

Another study examining the relationship between musical achievement and music aptitude was conducted by Hornbach and Taggart (2005). The research focus was to determine how tonal aptitude relates to singing achievement, whether the relationship between tonal aptitude and singing achievement changes with age, and whether school setting and age affect children's singing achievement. Children ($N=168$) in grade levels ranging from kindergarten to third grade were randomly selected from the two schools to participate in this study. Children's tonal aptitude was measured using the tonal test in the Primary Measure of Music Audiation (PMMA), while the singing achievement was measured using the researcher-designed Singing Achievement Rating Scales. All the participants received four class periods of music instruction to learn a traditional folk song. After the instruction, the Singing Achievement Rating Scales was used to evaluate children's singing skills; each participant sang the song individually and the performance was audio recorded for subsequent rating. Results of the study demonstrated that there was no significant relationship between tonal aptitude and singing achievement among children.

Auditory Discrimination

Auditory discrimination is an essential component in the musical development of young children. Research on auditory discrimination skills emphasizes children's aural perception and the ability to recognize different auditory patterns of sound stimuli. Some researchers investigated effects of music instruction on discrimination ability in tonality (Costa-Giomi, 1996); other researchers examined children's ability in discriminating different rhythmic patterns and sound stimuli (Arms, 1997; Sims, 1991).

Sims (1991) examined the effects of music instruction on preschool children's ability in music concept discrimination. The experimental variable was the music instruction designed to help children discriminate two music characteristics at the same time, including contrasting characteristics in tempo (slow/fast) and style of articulation (smooth/choppy). Thirty children were randomly assigned to a treatment group or a control group ($n=15$ per group); the average age of the children in each group was four years and six months. Participants in the treatment group were divided into small groups of three or four and received four 20-minute instructional sessions while the control group did not receive the instruction. The instruction provided participants a variety of experiences with each sound characteristics (slow, fast, smooth, choppy) and opportunities for these characteristics to be labeled verbally. All characteristics and their combinations were presented through speech, singing, movement, and listening activities.

The ability of music concept discrimination was measured by a researcher-designed test including the listening and movement response components. Results of the study indicated that the experimental group scored significantly higher than the control group in both music discrimination abilities, whereas all children scored significantly

higher on single discrimination items than the double discrimination items in the tests. The study suggests that preschoolers can easily learn and identify single discrimination through active music instruction. However, young children may not be ready for listening tasks requiring attention to more than one element at a time.

Costa-Giomi (1996) investigated young children's ability to perceive mode changes in music and to identify major and minor stimuli. Participants ($N=32$) in this study were children in age from four to five years receiving brief music instruction (four 10 minute of group lessons) on mode discrimination. Participants learned the terms "major" and "minor," and applied them in music listening activities. After completion of the music instruction, each participant took an individual listening test. The edited version of "Twinkle Twinkle Little Star" and an unfamiliar song to children were used as the stimuli in the test. Each song was played two times. Participants were asked to listen for mode change (major to minor mode) in one of songs, to response to the change with movements of their choice whenever they heard a change, and to apply the term major or minor to the corresponding fragments of the stimuli during the second listening. Results of the study revealed that kindergarten children were able to discriminate major mode from minor mode if they are provided music instruction that directs their attention to the changing aspect of the music. In addition, results demonstrated that children performed better in the test when responding verbally than when responding nonverbally. The author noted that since young children might prefer to use verbal to non-verbal responses if provided with adequate instruction, teaching young children accurate musical terminology is recommended in early childhood music lessons.

Arms (1997) compared the effects of computer-assisted keyboard instruction and

general music instruction on fourth, fifth and sixth graders' musical ability in meter and rhythm discrimination. The experimental variable was computer-assisted keyboard instruction, and the outcome measures were meter and rhythm discrimination skills. Six intact classes with 136 students were randomly assigned to one of two treatment groups: (1) computer-assisted keyboard group; and (2) general music group. The meter and rhythm discrimination skills were measured by the subtests of Meter Discrimination and Auditory-Visual Discrimination in the *Music Achievement Test I & II* (Colwell, 1969). The computer –assisted keyboard instruction included computer programs focused on recognizing and manipulating note values and rhythmic patterns. In addition, participants used the keyboards for creating music that followed teacher-assigned rhythmic patterns. The general music instruction taught children concepts of meter values and rhythmic patterns through movement activities, and through playing these rhythmic patterns on various percussion instruments.

The data analysis indicated that children in general music group scored significantly higher than ones in the computer-assisted keyboard group. The study showed that children received general music instruction had greater meter and rhythmic discrimination skills from children received computer-assistant keyboard instruction.

Tonal and Melodic Perception

According to Hargreaves & Zimmerman (1992), melodic processing begins as early as in infancy stage. Children by the age of 6 months are capable of discriminating short melodies with the melodic contour as the most important distinguishing feature (Trehub, Bull, and Thorpe, 1984). Research on development of melody perception in children has focused on aural perception in melodic contours, intervals, and tonality

(Apfelstadt, 1984; Ramsey, 1983).

In a landmark study, Trehub, Bull, and Thorpe (1984) studied infants' sensitivity to a variety of changes in melodic contours. The researchers attempted to determine whether infants are capable of discriminating transposition of melodic sequence or other melodic transformations from the original melody. In the experiment, a total of 92 healthy infants in age ranging from 8 to 11 months were exposed to one six-tone melody sequence paired with one of the following conditions: transposition and change in pitch height of whole melody (e.g., from Key of C to E flat), change in pitch within a melody (e.g., octave alteration of some pitches), and change in melodic contour. The researchers measured the responses to a variety of change by recording head turning in infants. Results of the study showed that infants were able to discriminate all the transformation conditions from the original melody. However, when the researchers increased the difficulty by adding change in duration of the tones in the transformation of original melody, the infant only responded to gross changes in the pitch height of single notes and change in melodic contours. The study suggests that melodic contour is a critically essential feature of melodies for infants.

Ramsey (1983) investigated the effects of age, singing ability, and instrumental experiences on preschool children's auditory perception of five melodic components including absolute pitch level, melodic rhythm, melodic contour, tonal center, and melodic interval. A total of 91 children in age ranging from three to five years participated in this study. Participants were assigned to one of the music instructional conditions: instrumental and non-instrumental groups. Prior to the commencement of treatment, the researcher-designed Preschooler Singing Ability Level Test (PSALT) was

administered individually to participants to determine each participant's initial signing ability level.

Participants received 30 minutes of music instruction for six sessions to learn the three songs selected for this study. In the instrumental group, participants learned to sing the songs as well as play the songs on pitched instruments (e.g., tone bells), while the non-instrumental group learn the songs through echo-singing games. After the treatment, each participant was asked to sing the three songs individually for evaluation of his or her auditory perception in the five melodic components. Results of data analysis revealed that 4- and 5-year-old children scored significantly higher than the 3-year-old children on melodic rhythm, melodic contour, and melodic interval. In addition, children with high-level singing ability scored significantly higher than children with low-level singing ability on melodic rhythm, melodic contour, tonal center, and melodic interval. However, no significant differences were found between instrumental and non-instrumental groups on all the melodic perception components.

Apfelstadt (1984) compared effects of three types of vocal instruction in general music class on kindergarten children's pitch discrimination and vocal accuracy. Three intact classes with 61 children were assigned to one of three treatment conditions: (1) vocal instruction that focused on development of perception through visual and kinesthetic means such as the use physical movement; (2) vocal instruction that consisted primarily of imitation; (3) traditional instruction with no particular emphasis on perceptual or conceptual development. The treatment condition lasted for 11 weeks; each experimental group received two 30 minutes of classes per week. Children's pitch discrimination ability was measured using the tonal portion of the Primary Measures of

Music Audiation (PMMA), while the vocal accuracy was measured using the Boardman Test of Vocal Accuracy, and a rote-singing test developed by the researcher. In the posttest data analysis for pitch discrimination, the results indicated that children among three types of music instruction did not show significant differences. As for vocal accuracy, however, data revealed that the mean score of children's vocal accuracy in the instruction group focused on the perceptual development were significantly higher than the children in the control group.

Rhythmic Development

Research on children's rhythmic development has shown that rhythmic ability could be influenced by several factors such as physical/mental development, musical features, types of rhythmic skills, and music literacy skills (Davidson & Colley, 1987). Similar to the development of tonal/melody perception, infants about age of five to six months in age could recognize changes of simple rhythmic patterns (e.g., long-short or short-long) (Shuter-Dyson & Gabriel, 1981). Several studies focused on the issue of how the chronological stages of mental and physical development of children relate to rhythmic perception and performance (Davidson & Colley, 1987; Persellin, 1992; Rainbow & Owen, 1979; Rainbow, 1980).

Rainbow (1980), and Rainbow and Owen (1979) observed rhythmic development of preschool children over a period of three years. Participants in this study were three-year-old children ($N=27$), and four-year-old children ($N=25$). Rhythmic instruction was taught as part of the regular musical lesson in which the participants learned the rhythmic concepts through movement activities. The researcher-designed rhythmic tests were administered to participants in the classroom during the course of music lessons. The

tasks included motor tasks that used large muscles, vocal sounds and simple instruments for rhythmic response. Participants' rhythm performances were video recorded for subsequent analysis.

Results of this study showed that children at age three and four years may hardly be able to imitate someone's clapping, synchronized clapping or marching to the beat of the music precisely. However, they still can perceive rhythms that they cannot reproduce themselves though movement. It is more easily for children to verbalize a rhythmic pattern before precisely clapping the rhythmic pattern. The authors noted that children in age of three and four years usually have fewer difficulties understanding the rhythm through the use of their voice. Thus, verbalizing rhythmic patterns is a developmentally appropriate approach to teach rhythm to young children.

Davidson and Colley (1987) conducted a longitudinal study to investigate children's rhythmic development from age five to seven years. The research questions in this study focused on the role of the inherent contextual features of a rhythmic example in children's perception, as well as the relationship of music literacy skills to development of rhythmic perception. Data were collected in a four-week period over three years; children were tested individually for their rhythm performance. In the testing, the child was presented rhythmic patterns through visual and aural presentation in symbol and text, and was asked to recall and clap the rhythmic patterns that had been presented. Each child received a set of four rhythmic patterns in the testing. The rhythmic tasks included quarter notes and eighth notes. To get the child's best performance, the example pattern could be played for three times. After performing the rhythmic patterns, the child was directed to notate the rhythmic patterns he/she just performed on the construction paper.

The children were allowed as much time as they needed to write the notation on the papers. After writing the rhythmic patterns, the child was asked to perform the rhythmic patterns from their invented notations. The performance was video recorded for further analysis. A total of 51 children at age of five years participated in this study; because of attrition, 46 children remained for the second year, and 39 children remained for the third year.

Results of the study showed that older children were better able to separate a text from its rhythm than the younger children. Regarding the notation of rhythmic pattern, items without a text were notated more accurately than those with text for 5- and 6-year-olds; however, the 7-year-olds tended to use the words of the song in their notations. Further, recalling rhythmic patterns seemed to be easy tasks for 7-year-olds. While the older children were able to recall multiple rhythmic features (e.g., pulse and on-going patterns), the younger children seemed to only capture single rhythmic feature. Finally, the length of patterns may affect children's accuracy of rhythmic performance. The study showed that the accuracy of rhythmic perception decreased as the length of patterns increased.

Persellin (1992) examined the effects of three modalities (auditory, visual, and kinesthetic modality) on the recall of rhythmic patterns. For data collection, children ($N=210$) in first, third and fifth grade, were asked to memorize and clap rhythmic patterns, which were provided either through iconic presentations (visual modality), by hearing resonator bell (auditory modality), by patting a child's hand (kinesthetic modality), or combinations of these modalities. In testing procedures, each child was randomly assigned to one of the rhythm presentation modalities, and was asked to clap a

set of six rhythmic tasks presented in the assigned modalities. The six rhythmic tasks consisted of quarter, eighth, and half notes. All children were presented the same six rhythmic tasks in the same order. Results of the study showed that the first graders in visual modality scored significantly lower than did other children; however, the scores were much improved when visual modality was coupled with auditory or kinesthetic modality. For older children (third and fifth graders), the scores were not statistically significant among the learning modalities. The study suggested to incorporate multiple learning modalities might help young children (first graders) effectively develop rhythmic skills.

Summary

In summary, research reviewed in musical development of young children includes the following topics: development of music aptitude, auditory discrimination, tonal/melodic perception, and rhythmic development (See table 2 for a summary of related literature). Corresponding to Gordon's theory of music aptitude (Gordon, 1979), several studies showed that formal music learning might enhance development of music aptitude (DeYarman, 1975; Flohr, 1981; Rutkowski, 1996). Other studies found that performance achievement in music may not be significantly related to music aptitude (Hornbach & Taggart, 2005; Mota, 1997; Rutkowski, 1996). Research on auditory discrimination skills in children often focuses on children's ability to recognize auditory patterns in tonal, melodic, and rhythmic sound stimuli. Several studies suggest that young children in age ranging from four to six years are able to comprehend a variety of musical concepts, including rhythm, tonality, melody, and other sound characteristics (smooth/choppy) through music instruction (Arms, 1997; Costa-Giomi, 1996; Sims, 1991).

Research also shows that tonal and rhythmic perceptions begin to develop during infancy. By five or six months of age, children are capable of focusing on their aural perception on melodic contours and changes of rhythmic patterns (Dowling, 1988; Shuter-Dyson & Gabriel, 1981; Trehub, Bull & Thorpe, 1984). Studies reveal that active music learning and singing ability are important factors in development of tonal/ melodic perception (Apfelstadt 1984; Ramsey, 1983). Children at ages of three and four years may not be able to precisely imitate the rhythmic patterns presented through movements; however, music instruction still helps them develop sense of rhythmic perception (Rainbow, 1980). In addition, the rhythmic features, the length of rhythmic patterns, and types of rhythmic presentation used in the instruction may affect children's development of rhythmic skills (Davidson & Colley, 1987; Persellin, 1992).

Table 2 Summary of Related Literature: Musical Development of Young Children

Purpose of the investigations/ participants	Research Design/ Independent Variables	Dependent Variables/Measures	Findings
<p>Development of Music Aptitude</p> <ul style="list-style-type: none"> Flohr (1981) <i>N</i>=29 children ages 5 years; Rutkowski (1996) <i>N</i>=99 kindergarten children; Mota (1997) <i>N</i>=106 children ages 6 years; Stamou (1998) <i>N</i>= 116 children ages 5-8 years; Hornbach and Taggart (2005) <i>N</i>=168 children from kindergarten to third grade 	<p>Experimental research design /general music instruction, singing instruction, and Suzuki violin instruction</p>	<p>Music aptitude and music tasks (singing achievement and maintaining steady beats)/the PMMA*, a researcher-designed singing test</p>	<ul style="list-style-type: none"> Music instruction enhances children’s music aptitude (Flohr, 1981). The musical achievement may not be significantly related to music aptitude No significant differences were found among the music instructional groups on music aptitude.
<p>Auditory Discrimination</p> <ul style="list-style-type: none"> Sims (1991) <i>N</i>=30 children ages 4 years; Costa-Giomi (1996) <i>N</i>=32 children ages 4-5 years; Arms (1997) <i>N</i>=136 children in four to six grades 	<p>Experimental research design/general music instruction, ear training activities, and computer-assisted keyboard instruction</p>	<p>Music concept discrimination, major and minor mode discrimination, and rhythmic discrimination/a researcher-designed test and the PMMA*</p>	<ul style="list-style-type: none"> Music instruction may improve young children’s auditory discrimination skills (Sims,1991; Costa-Giomi,1996). No significant differences were found among the music instructional groups on rhythmic discrimination.
<p>Tonal and Melodic Perception</p> <ul style="list-style-type: none"> Ramsey (1983) <i>N</i>=91 children ages 3to 5 years; Adfelstadt (1984) <i>N</i>=61 kindergarten children 	<p>Experimental research design/ instrumental instruction (pitched percussion instruments), vocal instruction, and general music instruction</p>	<ul style="list-style-type: none"> Auditory perception of five melodic components/a researcher-designed test Pitch discrimination and vocal accuracy/the PMMA* and BTVA* 	<ul style="list-style-type: none"> No significant differences were found between the two instructional groups for both studies. Singing instruction that focused on perceptual development enhanced children’s vocal accuracy.
<p>Rhythmic Development</p> <ul style="list-style-type: none"> Rainbow and Owen (1979, 1980) <i>N</i>=52 children ages 3-4 years; Davidson and Colley (1987) <i>N</i>=51 children ages 5 years; Persellin (1992) <i>N</i>=210 children in first, third and fifth grades 	<ul style="list-style-type: none"> Observational research design Experimental research design/types of rhythmic presentation (Persellin, 1992) 	<p>Rhythmic Ability/a researcher-designed test</p>	<ul style="list-style-type: none"> Verbalizing rhythmic patterns and integrating multiple rhythmic presentations are appropriate approaches for children in development of rhythmic skills. The complexity and length of rhythmic patterns affect children’s rhythmic performance.

*Primary Measures of Music Audiation; *Boardman Test of Vocal Accuracy.

CHAPTER 3 METHODOLOGY

Restatement of Purpose

The purpose of the present study was to examine the effect of violin, keyboard, and singing instruction on the spatial ability and music aptitude of young children.

Specifically, this study investigated the following research questions:

(a) What are the effects of music learning conditions (violin, keyboard, or singing) and age level (4-5 years old and 6-7 years old), alone and in combination, on children's spatial-temporal reasoning and spatial recognition over time?

(b) What are the effects of music learning conditions (violin, keyboard, and singing) on tonal and rhythm aptitude for children ages 4 to 7 years old over time?

The focus of this chapter is to address the research methods employed to investigate these research questions. The contents include the selection of the sample, research design, independent variables, dependent variables and measurement, experimental procedures, and methods for data analysis.

Selection of Sample

Participants ($N=88$) were children ages four to seven years old. A stratified sampling was used to divide the participants into two age groups: four to five years old ($n= 42$) and six to seven years old ($n= 46$). Within each age group, the participants were randomly assigned to one of the three music instructional conditions: violin ($n=30$), keyboard ($n=29$), or singing ($n=29$). The sample size estimation (the effect size $\eta^2 = .40$, $N= 78$, group $=6$) was used to determine the appropriate sample size for the present study. This statistical procedure is necessary since an adequate sample size provides enough statistical power to accurately detect the differences among the experimental groups.

Participants were recruited from a large metropolitan area in the United States. To recruit children to participate in this study, a recruiting team organized by the researcher distributed flyers during a university-wide open house that attracted approximately 77,500 visitors from the local communities, and described the purpose of this present research project to parents or families who were interested in participation. In addition, the researcher also visited one local public school and two private schools in the local community to distribute research flyers. Prior to recruiting children for participation, the research protocol for human-subject rights was approved by the Institutional Review Board at the University of Maryland (See Appendix A).

The researcher created a website for recruiting purposes, which included the rationale of the present study, detailed research procedures for activities in which the children would be involved during treatment and data collection. Adults who expressed interest in having a child participate were directed to the website in order to submit an on-line application. Information requested included contact information, availability for attending music classes and testing sessions on specific dates, flexibility in having students randomly assigned to a treatment group, and participants' previous music learning experiences on the application form. Two hundred eight applications were collected by the end of a 45-day recruiting period.

A sample was selected from this target population. The selection criteria for the sample were based on children's availability to complete at least 80 percent of class participation and all testing tasks. In addition, only children with no formal violin or keyboard experience qualified for participation, as did only those who were not planning to enroll in other music classes/lessons during the study. A total of 107 children were

selected for participation. Participants were asked for information concerning their previous music learning experience. All participants had a certain type of musical learning experiences outside of school contexts. Experiences ranged from formal class instruction to informal music activities at home. With exception of students who were homeschooled, all children had received general music classes in their local elementary school once or twice each week during the school year. In order to control confound findings, the researcher control participants' previous music learning experiences by selecting children with no formal violin or keyboard learning experience. A stratified random-sampling approach was used to assign participants to one of three instructional conditions (violin, keyboard, or singing group). An e-mail was sent to adult caregivers notifying them of selection. It included group assignment and other details concerning the location and time of the study.

After receiving the invitation e-mail, two children decided to drop out of the study because they were not assigned to the music group they preferred. The remaining 105 adult caregivers who confirmed participation in the study were directed to schedule appointments with the researcher for the pretest. During the course of the research investigation, 17 children withdrew because of time conflicts, lack of interest, or other personal issues. A total of 88 children completed all the required tests and research activities.

Research Design

A two by three factorial design was employed for this research. The factorial design is an experimental research design in which the researcher examines the effects of two or more independent treatment variables on one or more dependent variables. These

independent variables are examined singly and in interaction with each other. The effect of a single independent variable on the dependent variable is called a main effect while the interaction of the effect of two or more independent variables on the dependent variable is called an interaction effect (Gall, Gall, & Berg, 2007).

Two independent variables and two dependent variables were investigated in the research design. The types of music instruction (violin, keyboard, and singing---three levels) and ages of children (4-5 years old and 6-7 years old---two levels) were independent variables. The outcome measures of spatial reasoning and music aptitude were dependent variables. Table 3 illustrates the six treatment groups in a two by three factorial design.

Table 3 Illustration of Six Experimental Groups

	Violin	Keyboard	Singing
Age (4 to 5 year olds)	Group A (n= 14)	Group B (n=14)	Group C (n=14)
Age (6 to 7 year olds)	Group D (n=16)	Group E (n=15)	Group F (n=15)

Internal Validity

In the social sciences, threats to internal and external validity in an experimental research are inevitable. Typical threats to internal validity include selection, history, maturation, regression artifacts, attrition, testing, and instrumentation. In the current study, the pretest and posttest comparison group design with random assignment should minimize the threats to selection, maturation, history, instrumentation, and regression artifact validity. Nevertheless, other internal validity issues such as testing and attrition should be of concern.

As for testing validity, taking a test may influence the score of the subsequent test if the same test has been taken again. This “testing effect” can be confounded with

treatment effects. One way to minimize this threat is to use different tests that yield equivalent ability of estimates in measurement (Shadish, Cook & Campbell, 2002). Given that the same measurement was used for pre- and post-test in this present research, the testing effect may be confounded with treatment effect. Therefore, results of this study should be interpreted with this internal validity issue in mind. Attrition (experimental modality) refers to the participants who withdraw from an experimental study for any number of reasons (Creswell, 2002). A high attrition rate may invalidate the results of the data analysis and threaten the internal validity. While attrition is nearly impossible to prevent, the researcher used several strategies in order to minimize the attrition rate.

First, the researcher provided several incentives to the participants and their parents to make their involvement rewarding and interesting. For instance, the children received free music classes four days a week for one month during the summer. Each child also received a small gift such as candy, pencils, or stickers after completing each class or research testing. Given the fact that parents were very interested in knowing how their children performed in the tests, the reports of testing results were given to the parents as incentive.

Second, the researcher planned the administrative and organizational aspects of the study so that they were “friendly” to participants and caregivers. For example, the researcher provided an on-line scheduling system, which gave the parents a convenient way to schedule or cancel and re-schedule their test appointments. A reminder was sent via email to each of the parents one day before their testing appointments, which also may have helped to minimize the attrition rate. In addition, the researcher established informal relationships with the parents and participants to encourage and motivate their

music learning during the study.

Initially, a total of 107 children participated in this study. Two children dropped out after participants were randomly assigned to the treatment conditions, eleven children withdrew from the study due to the incompleteness of pre-test assignments, and six children decided not to participate in the study during the music instruction period due to time conflicts with other activities or illness. The attrition rate was 17.75%.

External Validity

External validity involves making inferences from the current sample data to populations, settings, and treatment variations (Shadish, Cook & Campbell, 2002). The target population of this study was 4- to 7-year-old children drawn from a metropolitan area in the United States; therefore, generalization of these study results to children of different ages in other geographic locations may not be warranted. In addition, treatment in the present study included one of three types of music instruction (violin, keyboard, or singing) implemented in groups consisting of 14 to 16 children. Thus, results may not be able to apply to other types of music instruction (e.g., guitar instruction) or other instructional settings (e.g., individual or small group lessons).

Independent Variables

The primary independent variable examined was music instruction—violin, keyboard, and singing. The second independent variable was age of children—4-5 years old and 6-7 years old. The instructional activities for both the violin and keyboard groups focused on learning music notation on the staff, associating the printed notes with the correct location on the instruments, and playing music excerpts from notation and memory, while the singing group focused on music notation and sight singing with no

instruments involved. The class activities for all three instructional groups were integrated with ear training, rhythmic exercises, movement, and singing.

The instrumental groups were involved in singing, movement, and listening activities without playing the instruments during the first 10 minutes of each lesson. Children clapped and marched to steady beats, engaged in listening games, and sang the instrumental compositions that they would learn in the lessons. Then, children were directed to sit individually with their instruments to study playing techniques (e.g., instrument holding and establishing hand position), notations, and pitch intervals. During piano lessons, the children learned to associate the notes they read on both treble and bass clef to the keys on the piano keyboard with the numerical fingerings

In the violin treatment group, finger placement markers were used to assist the children in placing fingers correctly on the violin and establishing the left hand position. The finger placement markers (FPMs) were adhesive tapes or labels applied to the fingerboard under the strings to label pitches and provide a visual reference for finger placement (Bergonzi, 1997; Smith, 1985). With this visual reference for finger placement, children were able to visualize the spatial relationship (e.g., whole step and half step) between pitches. Several string educators suggested that the use of FPMs was an effective pedagogical strategy that aids beginning string players in the formation of left hand position and intonation accuracy (Behrend, 1985; Bergonzi, 1997; Kohut, 1973; Young, 1978).

The lesson procedure for singing instruction was divided into two sections; each section was approximately 20-25 minutes of the lesson time. The class activities in the first section usually included ear training (e.g., aural discrimination exercises), rhythmic

movement, listening games, echo singing, improvisation and composition. Then, the children studied music notation with Kodály hand signs and solfège, and engaged in sight singing during the second section of the class. Pitch matching skills (ability for students to match their pitches to that of the teacher) was a primary focus for the singing group. In addition, the singing group did not include any music instruments or percussion instruments that represent the relationships between pitches during music instruction.

The second independent variable designed for the present study was age of children (4-5 years old and 6-7 years old). These two age levels were determined based on Hetland's (2000a) hypothesis that spatial abilities of young children (3-5 year olds) may be more enhanced by active music instruction than those of older children (6-7 year olds). One purpose of this present was to investigate whether age is an important factor in relationships of music learning to spatial abilities of children. The younger group in the sample population ranged from 3 years/8 months to 5 years/6 months while the older group ranged from 5 years/7 months to 7 years/3 months.

Dependent Variables and Measurement

Spatial Ability

The two dependent variables, spatial-temporal reasoning and spatial recognition, were measured respectively using the Object Assembly and Block Design subtests of the *Wechsler Preschool and Primary Scale of Intelligence-Third [(WPPSI-III)]* (Wechsler, 2002). The WPPSI-III is a standardized measure of intelligences for children ages two years six months to seven years three months. It consists of 14 subtests, which are used to evaluate three cognitive domains of young children: Verbal, Performance, and Processing Speed. The Object Assembly and the Block Design are subtests of the performance

domain.

Normative data were gathered based a on national standardization sample representative of the U.S. population of children ages two years and six months to seven years and three months. The sample included 1700 children located in four major geographic regions (Northeast, South, Midwest, and West) with diverse ethnic backgrounds and social-economic statuses across the United States. Each age group consisted of an equal number of female and male children. The reliability of subtests is ranged from .83 to .95 in Split-Half coefficients. In addition to this high reliability coefficient, the research indicated adequate validity present in the WPPSI-III subtests to measure the domains of intellectual functioning of children (Wechsler, 2002).

The Object Assembly and the Block Design are designed to evaluate young children's nonverbal reasoning. The tasks of these two subtests involve spatial ability, visual-motor coordination, visual perception and organization, and nonverbal concept formation (Wechsler, 2002). The Object Assembly is used to evaluate spatial-temporal reasoning of children for the present study. In the testing, each participant was presented with pieces of a puzzle laid out in a specific arrangement, and was required to arrange the pieces to create a meaningful whole within a specified time. Without a physical model or image to guide the child, this task required the cognitive process of visual organization, mental transformation, and synthesis of part-whole relationship.

The Block Design is used to measure the children's spatial recognition for the present study. In the testing, each participant was required to view an example of a constructed model or picture in the Stimulus Book, and use one- or two-color blocks to match and reconstruct the design observed in the model within a specified time limit.

This process of spatial recognition and visual organization required the ability of classifying, matching, synthesizing and abstract visual stimuli (Wechsler, 2002).

According to the normative data of the WPPSI-III by age group, the average reliability coefficients for both the Object Assembly and Block Design is .84, calculated using Fischer's z transformation. Additionally, WPPSI-III scores possess adequate stability across time for all age levels. The test-retest reliabilities for the Object Assembly and the Block Design were reported as .74 and .76 respectively. Raw scores from the two subtests were calculated from the total correct responses given by each student. Because the standardized scale scores in the WPPSI-III are based on normative data of age levels, the scaled scores may not appropriately represent the difference between the two age groups. Thus the researcher decided to use raw scores for data analysis.

The Object Assembly consists of 14 items; the Block Design consists of 20 items. Administration of each subtest begins at the age-specific starting point designated in the Test Manual. Both subtests include Practice items that are administered to participants immediately prior to the scored items. Completing the practice items in the testing procedures familiarizes participants with the tasks, helps to ensure the understanding of task requirements, and assists participants in performing as well as possible on the test (Wechsler, 2002).

Both subtests have reverse rules and discontinue rules. The test is started at a predetermined question based on the age of the child. If the child is not able to obtain the full score on the starting point question, a reverse item (the question prior to the initial item) is administered. The discontinue rules indicate criteria for determining when to cease the administration of the subtests. For both subtests, the test administration is

discontinued after the child obtains a score of zero on three consecutive questions.

The WPPSI-III is usually administered by a licensed psychologist for clinical purposes. In the present study, the tests were administered by the researcher for the purpose of research. The researcher received training in administration of the Object Assembly and the Block Design from a licensed psychologist. Because the two subtests were not administered by a licensed psychologist, the data obtained from these tests are not meaningful for any clinical judgments of children. The parents of the participants were informed about this condition.

Music Aptitude

Music aptitude was measured using the *Primary Measures of Music Audiation* [PMMA] (Gordon, 1979) and *Intermediate Measures of Music Audiation* [IMMA] (Gordon, 1986). The PMMA and the IMMA are standardized instruments designed to measure music aptitude of children. Gordon (1986) indicated that although the design of these two instruments is identical, the content of the IMMA is more advanced than that of the PMMA. Typically, the PMMA is used with children in kindergarten to third grade, while the IMMA is used with children in first grade to sixth grade. Regardless of the grade level, the IMMA should be used when children score above 80th percentile on the *Tonal* test, the *Rhythm* test, or both on the PMMA.

Both the PMMA and the IMMA include two subtests: *Tonal* and *Rhythm*. Each subtest includes 40 questions and is approximately 12 minutes in length. Gordon (1986) states that for both the PMMA and the IMMA, neither short term nor long term memory skills for aural discrimination were required. Instead, the child is to react to the immediate impressions of what is aurally perceived with intuitive responses. In addition,

the child does not need reading skills in languages, music notation or numbers in order to use the answer sheet for the tests. No formal music learning experiences are needed to take the tests. Instead of labeling the test item by numbers, the child-friendly pictures (e.g., cups, shoes, or apples) are used to identify each test item. In the present study, each participant was required to aurally discriminate whether the two tonal or rhythmic patterns were the same or different. If the two patterns sounded the same, the participant was to respond by circling a pair of same faces on an answer sheet, or by circling a pair of different faces if the two patterns sounded different.

Based on the normative data of the PMMA and IMMA, the reliability for both the PMMA and IMMA are adequate. Table 4 presents the reliability coefficients and test-retest reliability for both the PMMA in kindergarten level and IMMA in first-grade level. In terms of content validity, the PMMA and the IMMA include only tonal and rhythm dimensions in the test. Gordon (1986) notes that there may be more dimensions of music aptitude (e.g., expressive and constructional dimensions of music); however, measures for these dimensions have not yet been developed. Until additional research supports other aspects of music aptitude, the tonal and rhythm dimensions are fundamental for measurement of music aptitude development.

Table 4 Reliabilities in Split-Half Coefficients for Tonal and Rhythm Aptitude

	PMMA		IMMA	
	Tonal	Rhythm	Tonal	Rhythm Aptitude
Reliability Coefficients	.85	.72	.76	.70
Test-retest Reliability	.73	.60	.88	.84

Both the PMMA and the IMMA are designed to be administered to groups. However, Gordon (1979, 1986) states that these two tests may be administered with individual testing if desired. In addition, the tests could be administered by a classroom teacher or a music specialist if the standardized testing procedures are followed. Two types of scores: raw scores and percentile ranks are provided for each subtest of both the PMMA and the IMMA. The raw scores are obtained by calculating the number of correct responses and then were converted to percentile ranks. Since percentile ranks may not precisely represent how the child performs differently between the pretest and posttest, the raw scores of tonal and rhythm tests were used for the execution of data analysis.

Experimental Procedures

Pilot Testing

The study was conducted between May and August 2009 over a period of nine weeks at a large mid-Atlantic university. The experimental procedures consisted of three stages: pre-testing (3 weeks), treatment /music instruction (4 weeks), and post-testing (2 weeks). Prior to the commencement of the study, a pilot test was conducted to determine which test (either the PMMA or the IMMA) was most appropriate for 6-to 7-year-old participants. In addition, the pilot test was administered to assist the researcher in becoming familiar with the testing procedures such as seating arrangement, provision of

test directions, and use of test materials in both spatial and music aptitude tests.

During the pilot test, seven children (three 4-5 years old and four 6-7 years old) were tested with the Object Assembly and the Block Design of the WPPSI-III (Wechsler, 2002) and the PMMA (Gordon, 1979). Based on the testing procedures specified in the test Manual, the Tonal and Rhythm subtests were administered in a group setting while the Object Assembly and the Block Design were administered individually. During the pilot testing, the researcher found that the 6-7 year olds were able to follow the testing procedures and complete both tonal and rhythm tests within the specified time. Also, test results indicated that the 6-7 year olds scored at the 95th percentile or above for both tonal and rhythm tests. In contrast, it was challenging for 4-5 years old to complete both the Tonal and Rhythm tests in a group testing conditions due to short attention spans and other distractions around the classroom.

Based on the results of the pilot test, the researcher decided to use the IMMA to measure music aptitude of 6-7 year olds in order to minimize any ceiling effect. In an effort to make the testing environment more feasible and age-appropriate for 4-5 year olds, the researcher decided to administer the PMMA individually to participants at that age level.

Instructor Training

Three pre-professional music teachers who specialized in one of the three instructional areas (violin, keyboard, and singing) in the music teacher education program at a large mid-Atlantic university served as music instructors. Before instruction began, the teachers met with the researcher to discuss the rationale of this study, lesson objectives, teaching procedures, and class materials for each type of music instruction.

The purposes of the study and treatment protocols were explained.

In addition, the teachers and the researcher met after each lesson to review and discuss the participants' learning, pacing of the lesson, the use of class activities, and class management. The discussion included teachers' needs to modify the lesson plans based on students' progress and learning needs, while still following the guidelines of the given curriculum. To ensure the fidelity of treatment, the researcher video recorded and reviewed all the music lessons and verified the lesson objectives and teaching procedures followed the outline of weekly curriculum designed by the researcher.

Pre-testing Stage

The study began with three weeks of pre-testing. Prior to receiving music instruction, all the participants took the Object Assembly and the Block Design subtests from the WPPSI-III (Wechsler, 2002), and the PMMA or the IMMA (Gordon, 1979, 1986) for the assessment of spatial reasoning and music aptitude. Except for the IMMA, all the tests were administered to the participants individually. The IMMA was administered to 6- to 7-year-old participants in a group setting; each testing group consisted of eight children.

Each participant scheduled two test appointments for pre-testing on different days with the researcher. During the first testing appointment, the participants took the Object Assembly and the Block Design subtests, which took approximately 20 to 30 minutes. Before the testing started, the researcher read the child assent form to each of the participants and explained the research activities involved in this study (See Appendix C). In addition, the parents of each participant were asked to sign the parental consent form to agree to their children's participation in this study (See Appendix B).

In the next two test appointments, the participants took the PMMA or IMMA (Gordon, 1979, 1986). The time for the complete administration of each subtest (the *Tonal* or *Rhythm*) was approximately 20 to 30 minutes, depending on the level of maturity of the child. The practice examples were also included on each subtest. The PMMA was administered by the researcher while the IMMA was administered by either the researcher (eight groups) or an experienced music teacher (two groups). Although the IMMA was administered by two test administrators, all standardized testing both followed procedures.

During the administration of the individual tests, parents had an option to leave or to be presented in the test room. If the parents choose to stay in the test room, they were informed not to give answers or interrupt the test in any way. Violating this request would invalidate the test results and render it unusable for data analysis. In order to encourage the participant to complete each required task, incentives (e.g., sticker books and candy) were provided for the participants who completed all the required tests.

Treatment Stage

After the completion of all pretest components, the participants were randomly assigned to one type of music instruction ---violin, keyboard or singing. Instruction took place at facilities located at a mid-Atlantic university. Each participant received four 45-minute lessons for four weeks of instruction. All instruments and class materials were provided by the researcher and university. A piano lab consisting of 15 keyboards was used for the keyboard instruction while two classrooms were used, one for the violin group and another for the singing group. Because class participation was important to validate results of this study, the researcher monitored the participants' attendance during

the treatment period. If the participant was absent, the researcher contacted the parents and informed them about the importance of class participation. Once a participant missed three lessons, they were withdrawn from the study and their test scores were excluded from the data analysis.

Table 5 presents the outline of the weekly lesson objectives and plans for the music instruction. All participants experienced the concept of steady beat, long and short tone, upward and downward melodic direction, and the study of music notation. Participants in each instrumental group explored sound on the instrument, and established playing skills while the singing group practiced Kodaly hand signs and sight singing. The class activities were developed to be in alignment with the National Music Education Standards for young children. The four standards are (a) singing and playing instruments, (b) creating music, (3) responding to music, and (4) understanding music (Music Educators National Conference, 1994).

Table 5 Outline of Curriculum and Lesson Objectives

		Day 1	Day 2	Day 3	Day 4
Week 1	Violin	<ul style="list-style-type: none"> • Introduction of instrument • Instrument holding exercise • Steady beat 	<ul style="list-style-type: none"> • Low and high tones on the violin • Instrument holding 	<ul style="list-style-type: none"> • Short and long tones • Notes naming on the violin (open strings E & A) 	<ul style="list-style-type: none"> • Quarter note • Note naming on the violin (open strings D&G)
	Keyboa	<ul style="list-style-type: none"> • Introduction of instrument • Steady beat 	<ul style="list-style-type: none"> • Low and high tones on the keyboard 	<ul style="list-style-type: none"> • Short and long tone • Notes naming on the keyboard (Note C) 	<ul style="list-style-type: none"> • Quarter note • C position (Right hand)
	Singing	<ul style="list-style-type: none"> • Steady beat 	<ul style="list-style-type: none"> • Low and high tones • Upward and downward melodic direction 	<ul style="list-style-type: none"> • Quarter note • Short and long tones • Echo singing 	<ul style="list-style-type: none"> • Identify one and two sounds to a beat
Week 2	Violi	Week 1 Review	<ul style="list-style-type: none"> • Notes A and B • Introduction to the bow 	<ul style="list-style-type: none"> • Notes A, B, C#, and D • Plucking and left hand exercise 	<ul style="list-style-type: none"> • Half note • <i>Hot Cross Buns</i> (Plucking)
	Keyboa	Week 1 Review	<ul style="list-style-type: none"> • Notes C,D, and E in treble clef 	<ul style="list-style-type: none"> • Notes C, D, E, F, and G in treble clef • Half note 	<ul style="list-style-type: none"> • <i>Hot Cross Buns</i>
	Singin	Week 1 Review	<ul style="list-style-type: none"> • Notes <i>Sol</i> and <i>Mi</i> (hand sign) • Half note 	<ul style="list-style-type: none"> • Note <i>Sol</i>, <i>Mi</i>, and <i>La</i> (hand sign) 	<ul style="list-style-type: none"> • Singing songs with notes <i>Sol</i>, <i>Mi</i>, and <i>La</i> • Sight singing
Week 3	Violin	Weeks 1&2 Review	<ul style="list-style-type: none"> • Notes A, B, C#, and D • Eighth note 	<ul style="list-style-type: none"> • Up bow and down bow • <i>Twinkle, Twinkle Little Stars</i> (Plucking) 	<ul style="list-style-type: none"> • Note reading and plucking (A, B, C#, D, and E)
	Keyboar	Weeks 1&2 Review	<ul style="list-style-type: none"> • Notes C, and B in bass clef • Eighth note 	<ul style="list-style-type: none"> • Notes C, B, A, in bass clef 	<ul style="list-style-type: none"> • <i>It Takes the Cakes</i>
	Singing	Weeks 1&2 Review	<ul style="list-style-type: none"> • Notes <i>Do</i> and <i>Re</i> (hand sign) 	<ul style="list-style-type: none"> • Eighth note • Notes <i>Do</i>, <i>Re</i>, and <i>Mi</i> (hand sigh) 	<ul style="list-style-type: none"> • Singing songs with note <i>Do</i>, <i>Re</i>, <i>Mi</i>, <i>Sol</i>, and <i>La</i> • Sight Singing
Week 4	Violin	Review	<ul style="list-style-type: none"> • Notes E and F# • Bow holding (air bow exercise) 	<ul style="list-style-type: none"> • Whole note • Quarter rest • Note reading and plucking (A, B, C#, D, E, F#) 	<ul style="list-style-type: none"> • <i>Hot Cross Buns</i> • <i>Twinkle, Twinkle Little Stars</i> • Performance
	Keyboar	Review	<ul style="list-style-type: none"> • Quarter rest • Left hand C position 	<ul style="list-style-type: none"> • Whole note • Notes C, D, and E 	<ul style="list-style-type: none"> • <i>Hot Cross Buns</i> • <i>It Takes the Cakes</i> • Performance
	Singin	Review	<ul style="list-style-type: none"> • Whole note 	<ul style="list-style-type: none"> • Quarter rest 	<ul style="list-style-type: none"> • a variety of children songs • Performance

Post-testing Stage

After completing the 16 music lessons, each participant took the spatial reasoning and music aptitude tests a second time. The procedures were similar to the pre-testing procedure in which each participant scheduled two test appointments to complete the spatial and music aptitude tests. All tests were administered to the participants individually except for the IMMA (Gordon, 1986), which was administered in a group setting. The post-testing period lasted for two weeks.

Methods for Data Analysis

Raw scores obtained from the spatial ability and music aptitude measurements were used for statistical analysis using SPSS 16.0 software. A General Linear Model (GLM) with repeated measures was performed for data analysis. Although the MANOVA is designed to test the significance of group differences with multiple dependent variables, Foster, Barkus, and Yavorsky (2006) suggested using the MANOVA for statistical analysis when the dependent variables are not highly correlated. If the variables are highly correlated, errors in the data analysis can be highly compounded in the MANOVA. In addition, the correlation between the variables can reduce the power of the test. This loss in power can be considered a trade –off for the reduction of a Type-I error.

To determine the use of statistical tests for data analysis, a test of the Pearson correlation was performed to examine the correlation between the two outcome measures of spatial reasoning and music aptitude. Analysis indicated that the scores of the Object Assembly and the Block Design were significantly correlated ($r = .46, p < .01$). The scores of the Tonal and Rhythm aptitude were also significantly correlated ($r = .53, p <$

.01; $r = .72$, $p < .01$) for both the IMMA and the PMMA. Given that the outcome measures of each dependent variable were significantly correlated, the researcher decided to conduct a separate ANOVA for each dependent. The significance level of the statistical analyses for this study was established at $\alpha = .05$, which indicates that the risk of incorrectly rejecting the null hypotheses was five percent.

Three assumptions are usually discussed for the test of ANOVA: independent observation, normality, and homogeneity of variance (Lomax, 2007). Because the outcome measure of each dependent variable for each participant was completed independently without being affected by other participants, the independence of observations was assumed. In an effort to examine the assumption of normality, all the pretest and posttest scores were examined using the Kolmogorov-Smirnov normality test. For music aptitude, the analysis indicated that the deviations from the normality were found in the tonal scores of the PMMA for the singing group and in the rhythm scores of the IMMA for the violin group. For spatial reasoning, deviations from normality were found in the scores of spatial-temporal reasoning for the piano group.

The Levene's test was performed to examine the assumption of homogeneity of variance. The results showed that all of the groups were similar in variance, indicating that the assumption of homogeneous variance was met. In general, the three assumptions of ANOVA were met except the normality of two treatment groups on two subtests. However, the assumption of normality was met in most cases of data analyses. Lomax (2007) stated that the ANOVA is relatively robust to moderate violations of normality assumption with an adequate sample size.

To test the first set of null hypotheses, the first step of data analysis was to

perform two ANOVAs for measures of spatial-temporal reasoning and spatial recognition; each analysis included the factors of group, age, and time. The analysis was focused on the examination of interaction effects among these three factors. Where interaction effects were found, post hoc comparisons were conducted to determine the effect of each factor separately.

The next step of data analysis was to run ANOVAs to test the null hypotheses regarding the measures of tonal and rhythm aptitude. Gordon (1986) indicated that because the score distributions for the PMMA and IMMA are purposely designed to be different, the tasks in the IMMA are much more difficult than the tasks in the PMMA. Therefore, comparisons of the scores between the PMMA and the IMMA should not be made. Given that, the scores of the PMMA and the IMMA were analyzed respectively; each analysis included the factors of group and time. The analysis was focused on the examination of interaction effects between the factors of group and time. Similar to the analysis for the scores of spatial reasoning, the post hoc comparisons were performed to examine the effect of each factor independently when the interaction effects were found.

Summary

This chapter restated the purpose of the study and research questions and presented the experimental research methods used during the present study. The purpose of the present experimental study is to investigate the effect of three instructional conditions (violin, keyboard, and singing) on children's development of spatial reasoning and music aptitude. A two by three factorial design was used. The issues of external and internal validity for this research design were discussed. The participants were children ages four to seven years old recruited from a metropolitan area in the United States. The

procedures of sample selection and the participants' music learning background were addressed.

The two independent variables examined were the type of music instruction and age of children; the two dependent variables were the outcome measures of spatial reasoning and music aptitude. Participants ($N=88$) in each age level were randomly assigned to one of three instructional groups, and received four 45 minutes of music instruction for four weeks. Before and after music instruction, tests of spatial reasoning and music aptitude were administered to participants. The reliability and validity of the measurement tools were presented. Finally, the statistical methods for data analysis for each set of null hypotheses and the assumptions of the statistical test were also discussed. Results are presented in the following chapter.

CHAPTER 4 RESULTS

The purpose of the present study was to examine the effect of violin, keyboard, and singing instruction on 4- to 7-year-old children's spatial ability and music aptitude. Specifically, this research attempted to determine: (a) whether formal music instruction in the violin, keyboard and singing conditions enhanced children's development of spatial ability and music aptitude, and (b) whether children's spatial ability and music aptitude differed among these learning conditions. In addition, this study sought to examine the relationships among children's age, their development of spatial ability, and music aptitude in the given music instruction.

This chapter comprises the results of the data analyses for this study. The presentation of these results is arranged based on the two stated research questions and the related null hypotheses. The descriptive data and the analysis of pretest scores are presented followed by the inferential statistical testing results on the two dependent variables of spatial ability and music aptitude. The significance alpha level was set at .05 for all statistical tests.

Research Question One: Effects of Music Instruction on Spatial Ability

One of the dependent variables in this study was spatial ability. Participants' performances of spatial-temporal reasoning and spatial recognition were measured using the Object Assembly and the Block Design in *The Wechsler Preschool and Primary Scale of Intelligence-Third* (Wechsler, 2002). The following research question was examined: what are the effects of music learning conditions (violin, keyboard, and singing) and age (4-5 years old and 6-7 years old), alone and in combination, on children's spatial-temporal reasoning and spatial recognition over time?

Spatial-Temporal Reasoning

A mixed design ANOVA was performed to investigate whether the total sample of posttest mean scores were significantly different from the pretest mean scores, and whether the scores of spatial-temporal reasoning were significantly different among the instructional groups for both age levels over four weeks of instruction. Between-subject factors were the instructional groups and age levels, while the within-subject factor was time (pretest and posttest). The results of the ANOVA for spatial-temporal reasoning are presented in Table 6.

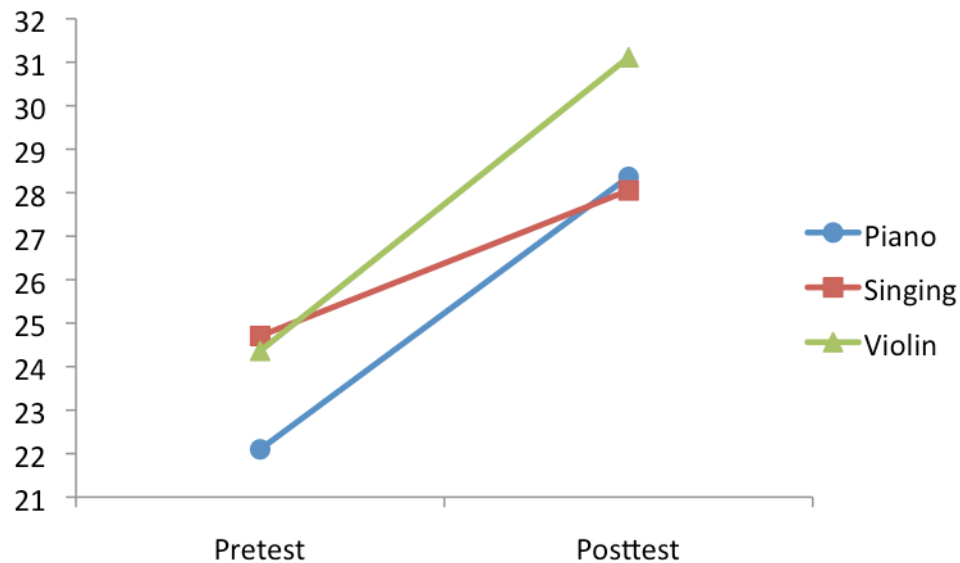
Table 6 Results of ANOVA with Repeated Measures: Spatial-Temporal Reasoning

Source	df	F	Sig	Eta ²
Between-Subject				
Group	(2, 82)	2.22	.116	.05
Age	(1, 82)	31.94**	< .001	.28
Group× Age	(2, 82)	.06	.936	.01
Within-Subject				
Time	(1, 82)	112.95**	< .001	.58
Time× Group	(2, 82)	4.28*	.017	.09
Time× Age	(1, 82)	15.51*	< .001	.16
Time× Group× Age	(2, 82)	2.02	.140	.05

Note: * $p < .05$, ** $p < .001$

Results indicated a statistically significant interaction effect on spatial-temporal reasoning between group and time, $F(2, 82) = 4.28$ $p = .017$ $\eta^2 = .09$, meaning that scores of spatial-temporal are significantly different among the three instructional groups over time. The analysis showed that the violin and keyboard groups had a statistically significant increase on the score of spatial-temporal reasoning. However, the scores of the singing group did not increase significantly over four weeks of music instruction (See Figure 1).

Figure 1 Performance of Spatial-Temporal Reasoning upon Group and Time



Another significant interaction effect was found between time and age, $F(1, 82) = 15.51$, $p < .001$, $\eta^2 = .16$, indicating that there was a significant difference between the two age groups on spatial-temporal reasoning over time. Results showed that the younger group's spatial-temporal reasoning scores significantly increased from the pretest to posttest while the older group remained statistically constant over time (See Figure 2).

Two main effects were found for time and age respectively on spatial-temporal reasoning. Results indicated that pretest and posttest scores were significantly different, $F(1, 82) = 112.95$, $p < .001$, $\eta^2 = .58$. The analysis of mean scores showed that the posttest scores were significantly higher than the pretest scores in the total sample. Results showed that the older groups scored significantly higher than the younger group, $F(1, 82) = 31.94$, $p < .001$, $\eta^2 = .28$. Since the between-subject factors were analyzed using the combination of the pretest and posttest scores, the results provided little meaning for this study. Therefore, no further analysis was conducted for the between-subject factors. Table 7 presents the means, standard deviations, 95% of confidence intervals of the

pretest and posttest for spatial-temporal reasoning.

Figure 2 Performance of Spatial-Temporal Reasoning upon Age and Time

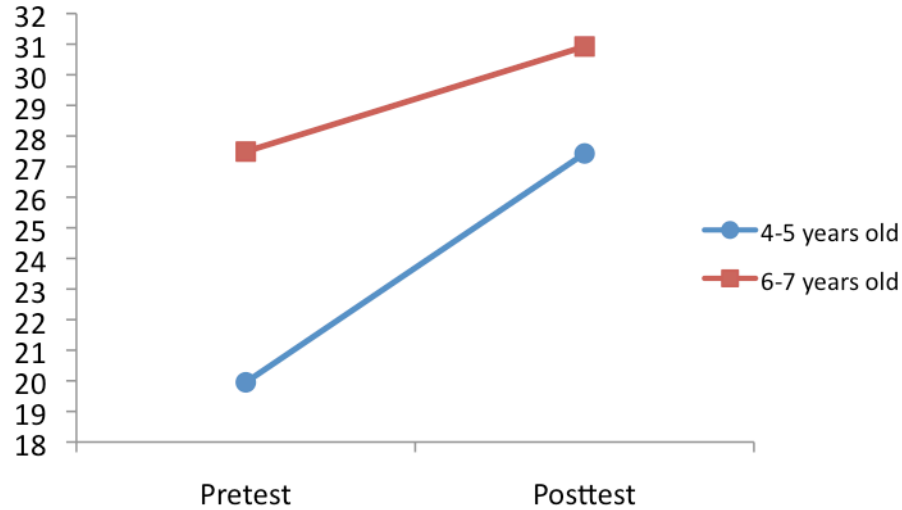


Table 7 Descriptive Data: Spatial-Temporal Reasoning

Group	Age 4-5					Age 6-7				
	n	M	SD	95% CI		n	M	SD	95% CI	
				UL	LL				UL	LL
Pre-test										
Violin	14	19.79	7.13	16.85	22.72	15	28.94	3.66	26.19	31.68
Keyboard	14	18.93	7.79	16.00	21.86	15	25.27	5.12	22.43	28.10
Singing	14	21.14	4.75	18.21	24.08	16	28.27	3.63	25.43	31.10
Post-test										
Violin	14	29.79	3.95	27.24	32.33	15	32.44	3.78	30.06	34.82
Keyboard	14	25.93	6.07	23.38	28.48	15	30.80	6.07	28.34	33.26
Singing	14	26.57	5.56	24.03	29.12	16	29.53	4.16	27.07	31.99

Note: CI= confidence interval; LL = lower limit, UL = upper limit

Spatial Recognition

A mixed design ANOVA was performed to examine the significant differences of mean scores between the pretest and posttest in the total sample, the age levels, as well as among the instructional groups. Between-subject factors were the instructional groups

and age levels, while the within-subject factor was time (pretest and posttest). Table 8 presents the results of the ANOVA for spatial recognition.

Table 8 Results of ANOVA with Repeated Measures: Spatial Recognition

Source	df	F	Sig	Eta ²
Between-Subject				
Group	(2, 82)	1.93	.152	.04
Age	(1, 82)	29.32**	< .001	.26
Group× Age	(2, 82)	2.11	.128	.05
Within-Subject				
Time	(1, 82)	103.69**	< .001	.59
Time× Group	(2, 82)	.23	.792	.01
Time× Age	(1, 82)	1.29	.260	.02
Time× Group× Age	(2, 82)	.69	.531	.02

Note: * $p < .05$, ** $p < .001$

No statistically significant interaction effects were found on spatial recognition between time and group, $F(2, 82) = .23, p = .792, \eta^2 = .01$, time and age, $F(2, 82) = 1.29, p = .260, \eta^2 = .02$, or the combination of time, group, and age $F(2, 82) = .69, p = .531, \eta^2 = .02$. This result indicated that there were no statistically significant differences among the three instructional conditions for either age group over time. However, two main effects were found for time and age respectively on spatial recognition. The mean spatial recognition posttest scores were significantly higher than the mean pretest scores in the total sample, $F(1, 82) = 103.69, p < .001, \eta^2 = .59$. The older group scored significantly higher than the younger group on spatial recognition, $F(1, 82) = 29.32, p < .001, \eta^2 = .26$. Since the between-subject factors were analyzed using the combination of the pretest and posttest scores, the results provided little meaning for this study. Therefore, no further analysis was conducted for the between-subject factors. Table 9 presents the means, standard deviations, and 95% of confidence

intervals for all the experimental groups on spatial recognition.

Table 9 Descriptive Data: Spatial Recognition

Group	Age 4-5					Age 6-7				
	n	M	SD	95% CI		n	M	SD	95% CI	
				UL	LL				UL	LL
Pre-test										
Violin	14	21.79	2.99	19.53	24.05	15	27.06	5.03	24.95	29.18
Keyboard	14	20.86	4.37	18.60	23.12	15	23.93	4.33	21.75	26.12
Singing	14	21.57	4.78	19.31	23.83	16	23.93	3.56	21.77	26.13
Post-test										
Violin	14	25.00	2.80	22.87	27.13	15	32.25	4.31	30.26	34.24
Keyboard	14	25.86	3.18	23.73	27.99	15	28.53	5.15	26.48	30.59
Singing	14	25.71	2.81	23.58	27.84	16	29.60	4.82	27.54	31.66

Note: CI= confidence interval; LL = lower limit, UL = upper limit

Null Hypotheses of Spatial Ability

The results of the null hypotheses for spatial-temporal reasoning and spatial recognition are presented below:

- 1a. There is no significant difference among music instructional conditions (violin, keyboard, and singing) on spatial-temporal reasoning. This null hypothesis was retained. There was no significant difference among the three instructional groups on spatial-temporal reasoning.
- 1b. There is no significant difference between two age levels (4-5 years old and 6-7 years old) on spatial-temporal reasoning. This null hypothesis was rejected. The scores of the older group were significantly higher than the scores of the younger group on spatial-temporal reasoning.
- 1c. There is no significant difference between the pretest and posttest on spatial-temporal reasoning in the total sample. This null hypothesis was rejected. The posttest scores were significantly higher than the pretest scores on spatial-temporal

reasoning in the total sample.

- 1d. There is no interaction effect between time (before and after instruction) and music instructional conditions (violin, keyboard, and singing) on spatial-temporal reasoning. This null hypothesis was rejected. Significant differences were found among the three instructional groups on spatial-temporal reasoning over time. While the scores of the violin and piano groups increased significantly from the pretest to posttest the scores of the singing group remained constant over time.
- 1e. There is no interaction effect between time (before and after instruction) and age levels (4-5 years old and 6-7 years old) on spatial-temporal reasoning. This null hypothesis was rejected. Significant differences were found between the two age groups. While the younger group's scores increased from the pretest to posttest, the older group's scores remained statistically constant over time.
- 1f. There is no interaction effect among time (before and after instruction), music instructional conditions (violin, keyboard, and singing), and age levels (4-5 years old and 6-7 years old) on spatial-temporal reasoning. This null hypothesis was retained. No statistically significant difference was found between the two age groups and three instructional groups on spatial-temporal reasoning over time.
- 2a. There is no significant difference among music instructional conditions (violin, keyboard, and singing) on spatial recognition. This null hypothesis was retained. There was no significant difference among the three instructional groups on spatial recognition.
- 2b. There is no significant difference between two age levels (4-5 years old and 6-7 years old) on spatial recognition. This null hypothesis was rejected. The scores of the

older group were significantly higher than the scores of the younger group on spatial recognition.

2c. There is no significant difference between the pretest and posttest on spatial recognition in the total sample. This null hypothesis was rejected. The posttest scores were significantly higher than the pretest scores on spatial recognition in the total sample.

2d. There is no interaction effect between time (before and after instruction) and music instructional conditions (violin, keyboard, and singing) on spatial recognition. This null hypothesis was retained. No significant differences were found among the three instructional groups on spatial recognition over time.

2e. There is no interaction effect between time (before and after instruction) and age levels (4-5 years old and 6-7 years old) on spatial recognition. This null hypothesis was retained. No significant differences were found between the two age groups on spatial recognition.

2f. There is no interaction effect among time (before and after instruction), music learning conditions (violin, keyboard, and singing), and age levels (4-5 years old and 6-7 years old) on spatial recognition. This null hypothesis was retained. No interaction effect was found between music instructional conditions and age levels on spatial recognition over time.

Summary for Spatial Ability

Data from this study indicated that the posttest mean scores were significantly higher than the pretest mean scores over four weeks of music instruction on the performance of spatial-temporal reasoning and spatial recognition. The violin and the

piano groups had a statistically significant increase on spatial-temporal reasoning scores over four weeks of music instruction. However, the scores of singing group did not increase significantly. Further, data showed that the spatial-temporal reasoning scores of 4-5 year olds significantly increased from the pretest to posttest, while the scores of 6-7 year olds remained statistically constant. With regard to spatial recognition, no significant differences were found among the three instructional groups for either age group.

Research Question Two: Effects of Music Instruction on Music Aptitude

Another dependent variable in this study was the outcome measure of music aptitude. The tonal and rhythm aptitude were measured using the *Primary Measures of Music Audiation* (PMMA) or the *Intermediate Measures of Music Audiation* (IMMA) (Gordon, 1979, 1986). The following research question was examined: what are the effects of music learning conditions (violin, keyboard, and singing) on tonal and rhythm aptitude for children ages 4 to 7 years old over time? The 4-to 5-year-old children's music aptitude was measured using the PMMA, while the 6- to 7- year- old children's was measured using the IMMA.

Tonal Aptitude

A mixed design ANOVA was performed to compare the mean score of the pretests and posttests in the total sample, as well as the group mean differences among the three instructional groups over four weeks of music instruction. The within-subject factor was time (pretest and posttest), while the between-subject factor was the instructional group. Table 10 presents the results of the ANOVA for tonal aptitude.

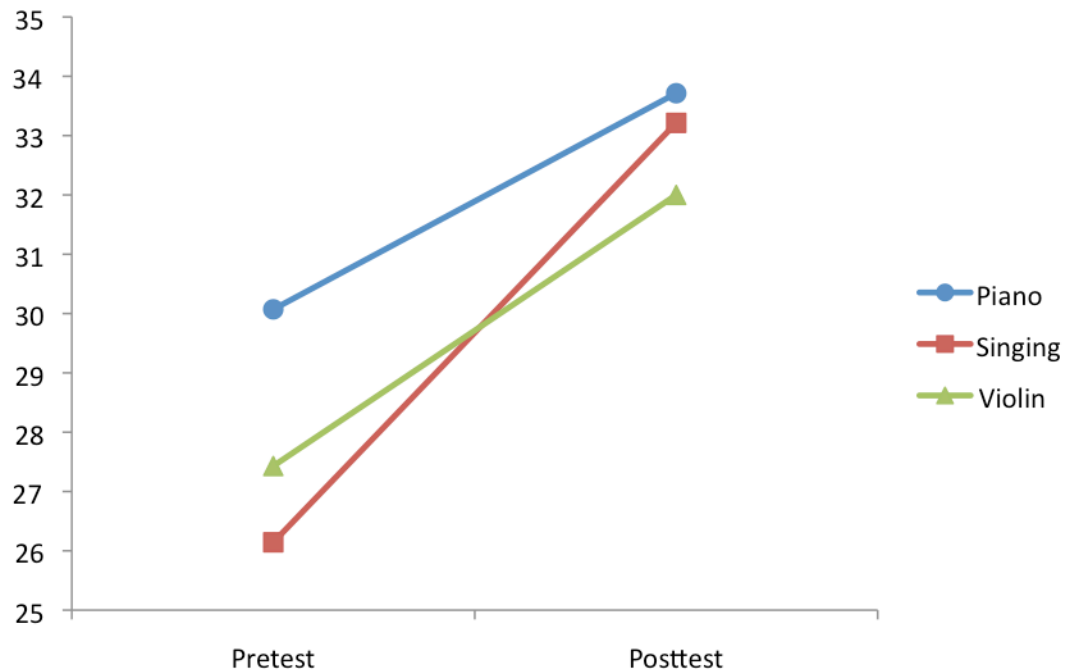
Table 10 Results of ANOVA with Repeat Measures: Tonal Aptitude

Source	df	F	Sig	Eta ²
Age 4-5 (PMMA)				
Between-Subject				
Group	(2, 39)	1.505	.235	.072
Within-Subject				
Time	(1, 39)	95.869*	< .001	.711
Time× Group	(2, 39)	3.871*	.029	.166
Source	df	F	Sig	Eta ²
Age 6-7 (IMMA)				
Between-Subject				
Group	(2, 43)	.893	.417	.040
Within-Subject				
Time	(1, 43)	5.704*	.021	.117
Time× Group	(2, 43)	.831	.443	.037

Note: * $p < .05$, ** $p < .001$

In the analysis of the PMMA data, results indicated a significant interaction effect between time and group, $F(2, 39) = 3.871$, $p < .029$, $\eta^2 = .166$, meaning the tonal aptitude scores were significantly different among the three instructional groups. Results showed that the singing group's tonal aptitude scores had a statistically significant increase, while the scores of violin and keyboard groups remained statistically constant over time (See Figure 3). Moreover, results indicated that the within-subject factor of time was statistically significant, $F(1, 39) = 95.869$, $p < .001$, $\eta^2 = .711$, indicating that the scores of pretest and posttest in the total sample were significantly different. Results showed that the posttest scores were significantly higher than the pretest scores in the total sample.

Figure 3 Performance of Tonal Aptitude of Four to Five Year Olds upon Group and Time



In the analysis of the IMMA data, no significant interaction effect of time and group was found, $F(1, 43) = .831, p = .443, \eta^2 = .037$, indicating that the treatment effect was not significantly different among the three instructional groups over time for the older group. Furthermore, results indicated that the within-subject factor of time was statistically significant, $F(1, 43) = 5.704, p < .021, \eta^2 = .117$, illustrating that the posttest mean scores were significantly higher than the pretest mean scores in the tonal sample. Compared to the effect size of the two age groups, data indicated that the treatment effect size of the older group ($\eta^2 = .117$) was relatively smaller than the effect size of the younger group ($\eta^2 = .711$). The means, standard deviations, and 95% of confidence intervals of tonal aptitude for all the instructional groups are presented in Tables 11.

Table 11 Descriptive Data: Tonal Aptitude

Group	Age 4-5 (PMMA)					Age 6-7 (IMMA)				
	n	M	SD	95% CI		n	M	SD	95% CI	
				UL	LL				UL	LL
Pre-test										
Violin	14	27.43	4.38	24.90	29.96	15	29.25	5.56	26.29	32.21
Keyboard	14	30.07	5.12	27.11	33.03	15	28.33	4.53	25.82	30.84
Singing	14	26.14	4.65	22.88	28.26	16	29.67	7.05	25.76	33.57
Post-test										
Violin	14	32.00	4.11	29.62	34.38	15	30.25	5.29	27.43	33.07
Keyboard	14	33.71	5.05	30.78	36.64	15	29.33	4.98	26.57	32.09
Singing	14	33.21	3.17	31.39	35.04	16	32.53	2.97	30.89	34.18

Note: CI= confidence interval; LL = lower limit, UL = upper limit

Rhythm Aptitude

The mixed design ANOVA was conducted to examine the group mean differences among the groups over four weeks of music instruction. The within-subject factor was time (pretest and posttest), while the between-subject factor was the instructional group. Table 12 presents the results of the ANOVA for rhythm aptitude. No interaction effect between time and group was found for either age group, indicating that there was no statistically significant difference among the three instructional groups on the rhythm aptitude scores. However, the within-subject time effect was found for both age groups, $F(1, 39) = 21.23, p < .001, \eta^2 = .35$, and $F(1, 43) = 11.99, p < .001, \eta^2 = .22$, indicating that the posttest scores were significantly higher than the pretest scores in the total sample for both age groups. In sum, results showed that the rhythm aptitude scores were not significantly different among the three instructional groups, although all the groups had gains on the scores of rhythm aptitude over four weeks of music instruction.

Table 12 Results of ANOVA with Repeated Measures: Rhythm Aptitude

Source	df	F	Sig	Eta ²
Age 4-5 (PMMA)				
Between-Subject				
Group	(2, 39)	.134	.875	.007
Within-Subject				
Time	(1, 39)	21.228**	< .001	.352
Time× Group	(2, 39)	.651	.527	.032
Age 6-7 (IMMA)				
Between-Subject				
Group	(2, 43)	.755	.476	.034
Within-Subject				
Time	(1,43)	11.988**	< .001	.218
Time× Group	(2, 43)	.627	.539	.028

Note: * $p < .05$, ** $p < .001$

Table 13 Descriptive Data: Rhythm Aptitude

Group	Age 4-5 (PMMA)					Age 6-7 (IMMA)				
	n	M	SD	95% CI		n	M	SD	95% CI	
				UL	LL				UL	LL
Pre-test										
Violin	14	22.21	5.11	19.26	25.17	15	26.13	4.32	23.82	28.43
Keyboard	14	23.07	6.67	19.22	26.92	15	24.47	4.43	22.01	26.92
Singing	14	23.43	5.56	20.24	26.61	16	27.07	5.45	24.05	30.08
Post-test										
Violin	14	27.29	4.32	24.79	29.78	15	28.56	4.16	26.34	30.78
Keyboard	14	28.07	6.49	24.33	31.82	15	28.00	3.57	26.03	29.97
Singing	14	26.21	4.71	23.49	28.93	16	28.60	4.29	26.22	30.98

Note: CI= confidence interval; LL = lower limit, UL = upper limit

Null Hypotheses of Music Aptitude

The results of the null hypotheses for tonal aptitude and rhythm aptitude are presented below:

- 3a. There is no significant difference among music instructional conditions (violin, keyboard, and singing) on tonal aptitude for four- to five-year-old children. This null hypothesis was retained. No significant difference was found among the three instructional groups on tonal aptitude for four- to five-year-old children.
- 3b. There is no significant differences between the pretest and posttest on tonal aptitude of four-to five-year-old children. This null hypothesis was rejected. The posttest scores were significantly higher than the pretest scores on tonal aptitude for four- to five-year-old children.
- 3c. There is no interaction effect between time (before and after instruction) and music instructional conditions (violin, keyboard, and singing) on tonal aptitude of four- to five-year-old children. This null hypothesis was rejected. The scores of the singing group were significantly higher than the violin and keyboard groups on tonal aptitude for four- to five-year-old children.
- 3d. There is no significant difference among music instructional conditions (violin, keyboard, and singing) on rhythm aptitude of four- to five-year-old children. This null hypothesis was retained. No significant difference was found among the three instructional groups on rhythm aptitude for four- to five-year-old children.
- 3e. There is no significant differences between the pretest and posttest on rhythm aptitude of four- to five-year-old children. This null hypothesis was rejected. The posttest scores were significantly higher than the pretest scores on rhythm aptitude for four- to five-year-old children.
- 3f. There is no interaction effect between time (before and after instruction) and music instructional conditions (violin, keyboard, and singing) on rhythm aptitude of

four- to five-year-old children. This null hypothesis was retained. No significant difference was found among the three instructional groups on rhythm aptitude for four- to five-year-old children over time.

4a. There is no significant difference among music learning conditions (violin, keyboard, and singing) on tonal aptitude of six- to seven-year-old children. This null hypothesis was retained. No significant difference was found among the three instructional groups on tonal aptitude for six- to seven-year-old children.

4b. There is no significant differences between the pretest and posttest on tonal aptitude of six- to seven-year-old children. This null hypothesis was rejected. The posttest scores were significantly higher than the pretest scores on tonal aptitude for six- to seven-year-old children.

4c. There is no interaction effect between time (before and after instruction) and music instructional conditions (violin, keyboard, and singing) on tonal aptitude of six- to seven- year-old children. This null hypothesis was retained. No significant difference was found among the three instructional groups on tonal aptitude for six- to seven-year-old children over time.

4d. There is no significant difference among music instructional conditions (violin, keyboard, and singing) on rhythm aptitude of six- to seven-year-old children. This null hypothesis was retained. No significant difference was found among the three instructional groups on rhythm aptitude for six- to seven-year-old children.

4e. There is no significant differences between the pretest and posttest on rhythm aptitude of six- to seven-year-old children. This null hypothesis was rejected. The posttest scores were significantly higher than the pretest scores on rhythm aptitude for six-

to seven-year-old children.

4f. There is no interaction effect between time (before and after instruction) and music instructional conditions (violin, keyboard, and singing) on rhythm aptitude of six- to seven-year-old children. This null hypothesis was retained. No significant difference was found among the three instructional groups on rhythm aptitude for six- to seven-year-old children over time.

Summary for Music Aptitude

The posttest mean scores were significantly higher than the pretest mean scores on music aptitude for both age groups. With regard to tonal aptitude, the treatment effect was significantly different among the three instructional groups over four weeks of music instruction for 4- to 5-year-old children. The singing group had a statistically significant increase on the tonal aptitude scores while the violin and piano groups did not show a significant increase. For children ages 6-7 years old, no significant differences were found among the instructional groups, indicating that the type of music instruction is not a significant factor for 6- to 7-year-old children on tonal aptitude. In terms of rhythm aptitude, although the rhythm aptitude scores increased in the total sample over four weeks of music instruction, no significant differences were found among the instructional groups for either age level.

CHAPTER 5 DISCUSSION OF RESULTS AND CONCLUSIONS

While the preceding chapter presented the results of data analysis, this chapter consists of a summary of the study, discussion of the findings, implications for music education, recommendations for future research, and conclusions. In an effort to provide further understanding about the effect of music learning on child development, the goal of this chapter is to discuss the research findings of the present study regarding the relationship among music learning, spatial reasoning and music aptitude of young children. In addition, the limitations of the research design and recommendations for future studies targeting the related research questions are presented in this chapter.

Summary of the Study

The purpose of the present study was to investigate the effects of three types of music learning (violin, keyboard, and singing) on the development of spatial reasoning and music aptitude of young children. A stratified random-sampling approach was used to assign participants ($N=88$) to one of three instructional groups (violin, keyboard, or singing). The study used a two by three factorial design in which the ages of children (2 levels) and music instruction (3 levels) were the independent variables; spatial ability and music aptitude served as the dependent variables. The outcome measure for spatial ability included spatial-temporal reasoning and spatial recognition, while music aptitude included tonal and rhythm aptitude.

The present study consisted of three stages: pretest, treatment/music instruction, and posttest. In the treatment/music instruction period, each child received 45 minutes of assigned music instruction four times a week for four weeks. The lesson activities in the

instructional groups included ear training, rhythmic movement, singing, and study of music notation. However, the violin and the keyboard instruction groups focused on playing techniques (e.g., instrument holding, playing posture, and hand position) and note reading in which the child transferred visual information from music notation to the finger placement on the instruments. The singing group focused on singing activities and music notation without playing instruments during the lessons.

During the pretest and posttest period, the Object Assembly and Block Design, subtests of the WPPSI-III (Wechsler, 2002) were administered to evaluate children's spatial reasoning, while the PMMA or the IMMA (Gordon, 1986) was administered to assess children's music aptitude. The test scores on these tests were used for data analysis. Mixed design analyses of variance (ANOVAs) with time as a repeated measure were conducted to compare the mean scores among the instructional groups.

Discussion of the Findings

Spatial-Temporal Reasoning

Perhaps the most important finding is that posttest spatial-temporal reasoning scores of the violin and keyboard groups were higher than their corresponding pretest scores while the scores of the singing group remained statistically constant from pretest to posttest. This finding suggests that both violin and keyboard instruction have a positive effect on children's spatial-temporal reasoning. Data from the present study showed that scores of spatial-temporal reasoning on the posttest were significantly higher than the scores on the pretest for the total sample. Given the adequate test-retest reliabilities ($r = .74$) and the high treatment effect size ($\eta^2 = .47$) for spatial-temporal reasoning tasks, findings suggest that four weeks of music instruction may enhance the spatial-temporal

reasoning of young children. This result is consistent with other research findings that active music learning might enhance spatial-temporal reasoning of young children (Bilhartz, Bruhn, & Olson, 2000; Presellin, 2000; Rauscher et al., 1997; Rauscher & Rupan, 2000; Zafranas, 2004).

Previous research has suggested that learning a musical instrument that provides a linear relationship between pitches on the instruments (i.e., keyboard or xylophone) can help in the development of spatial-temporal reasoning for young children (Rauscher & Zupan, 2000). Because learning these instruments involves the process of coupling visual information on the instruments with aural information, this cognitive process can stimulate neural pattern development in the brain structure relevant to spatial-temporal reasoning (Rauscher et al, 1997). Since no previous studies have shown the relationship between string instruction and development of spatial-temporal reasoning, one contribution of the present study was to discover that learning to play violin can improve young children's spatial-temporal reasoning. In addition, the present study also supports previous research indicating that keyboard instruction helps to enhance young children's spatial-temporal reasoning (Costa-Giomi, 1999; Rauscher & Zupan, 2000; Zafranas, 2004); singing instruction does not seem to have an effect on spatial-temporal reasoning (Rauscher et al, 1997; Hanson, 2003).

Another contribution of the present study was the discovery that learning violin or keyboard may help children to enhance their spatial-temporal reasoning, while learning music with no instrument may not lead to the same results. Rauscher et al. (1997) stated that learning to play piano involves the process of coupling visual information on the instruments with aural information; this process may stimulate the neural pattern

development relevant to spatial-temporal operations in the brain system. Findings of the present study also support this point of view; further, findings demonstrated that learning to play violin also has a positive effect on spatial-temporal reasoning.

In the present study, both keyboard and violin instruction required the child to transfer music from a musical staff to the finger placement on the instruments, physically make sound on the instruments, and aurally perceive the sound produced by the instrument. This instruction with a combination of visual, aural, spatial, and physical endeavors may help children improve their spatial-temporal reasoning in violin and keyboard instruction. Although the singing instruction also engaged children in ear training, singing, movement, and study of music notation on musical staff, no instrumental playing was included in the class activities. Children in the singing group did not have opportunities to visualize the relationship of pitch patterns on the instrument and exercise the process of translating music from the staff to finger placement on the instrument. While previous research found that music instruction may enhance children's spatial-temporal reasoning (Hetland 2000a), this study suggests that types of music instruction is an important factor in the relationship of music learning to spatial-temporal reasoning.

Another important finding was that the younger group had a statistically significant increase on the spatial-temporal reasoning scores while the older group did not show a significant improvement over four weeks of music instruction. This result implies that music learning shows a greater effect on spatial-temporal reasoning for younger children than for older children. Hetland (2000a) states that spatial abilities for younger children (3-5 year olds) are more likely to be affected by music learning than those of

older children (6-7 year olds). Results of the present study support this point of view.

Spatial Recognition

Spatial recognition was another spatial reasoning ability that was examined in the present study. Although data from the present study showed that all groups improved their scores of spatial recognition tasks, the scores were not significantly different among the three instructional groups over four weeks of music instruction. It appears that type of music instruction may not be a significant factor in the performance of spatial recognition tasks. This finding is consistent with the results of existing research that music instruction may not have an effect on spatial recognition (Bilhartz, Bruhn, & Olson, 2000; Rauscher et al., 1997). Spatial recognition is the process of matching, classifying, and recognizing similarities or differences among displayed objects. It is a different cognitive endeavor than spatial-temporal reasoning, which involves the abilities of visual organization, mental transformation and synthesis of part-whole relationship (Rauscher, 1999). While no significant differences were found among the three instructional groups, it is possible that skills involved in instrumental playing may not relate to the cognitive process of spatial recognition such as matching and classifying abstract objects in spatial recognition. This might be the reason that children in the instrumental groups did not score significantly higher than the children in the singing group on the spatial recognition tasks.

Another finding was regarding the relationship between age and spatial recognition in the given music instruction. Results showed that there were no statistically significant differences between the two age groups on the performance of spatial recognition over four weeks of music instruction. This finding is surprising as research

has shown that influences of music on the development of brain structure are related to an early age of music learning (Schlaug et al, 1995; Elbert et al, 1998). Also, this result seems to conflict with Hetland's (2000a) report that younger children's spatial abilities are more likely to be enhanced by music instruction than those of older children.

Several reasons might explain the mixed results about the influence of age on spatial-temporal reasoning and spatial recognition during music instruction. First, the two age levels in this research design are only one year apart from each other and any differences due to age may not be revealed. Future studies should include ages of population that are more widely dispersed in the research design to validate the relationship among age, music learning, and development of spatial reasoning. Second, the youngest sample population in Hetland's (2000a) study was children ages three years old, while the present study did not include three-year-old children in the sample population. Thus the conflicting result may be due to the differences in age of the sample population between the two studies.

Third, the difficulty in defining various spatial abilities in the existing research might also be the reason for the conflicting result. Although spatial intelligence is one of the cognitive areas in child development, little consensus has been established concerning identification of spatial abilities (McGee, 1979; Linn & Peterson, 1985). In Hetland's meta-analysis (2000a), findings regarding the relationship between age and spatial development were based on the analysis of a set of spatial abilities identified as spatial reasoning. However, results from Hetland's study were not clear about the relationship among music instruction, age and specific types of spatial abilities.

Fourth, measurement may also be an issue that leads to the ambiguous results on

spatial-temporal reasoning and spatial recognition. Hetland (2000a) notes that the problem of unreliable measurement with younger children is usually greater when compared to the measurement errors with older children. Likewise, the possibility of unreliable measurement with the younger children in the present study should be considered as well. Thus, more replicated research concerning the effects of age on spatial-temporal reasoning and spatial recognition during music instruction is needed to validate the findings of the present study.

Music Aptitude

The second question sought to investigate the effect of three types of music instruction (violin, keyboard, and singing) on tonal and rhythm aptitude of young children. Similar to previous research concerning the effects of active music learning on music aptitude (Flohr, 1981, Gordon, 1979), the present study found that music instruction helped young children improve their music aptitude. Data from the present study showed that both tonal and rhythm aptitude scores on the posttest were significantly higher than the scores on the pretest in the total sample. Given the adequate test-retest reliabilities for the PMMA and IMMA ($r = .73$ and $r = .60$ for the PMMA; $r = .88$ and $r = .84$ for the IMMA), the present study suggests that active music learning can improve young children's tonal and rhythm aptitude over four weeks of music instruction. Another finding about music aptitude from the present study is that younger children's music aptitude may be more likely to be affected by music learning than that of older children. Data from the present study showed that the treatment effect size was larger in both tonal aptitude ($\eta^2 = .71$) and rhythm aptitude ($\eta^2 = .35$) for the four-to five-year-old children than those of six- to seven-year-old children (tonal aptitude, $\eta^2 =$

.12; rhythm aptitude, $\eta^2 = .22$).

Tonal aptitude.

Another interesting finding of the present study is that the younger singing group had a statistically significant increase on the tonal aptitude scores from the pretest to posttest, while the scores of the violin and keyboard groups did not significantly increase. For the older children, the singing group improved more than the violin and keyboard groups over the same period of instruction time, although the scores were not significantly different among the three instructional groups over four weeks of music instruction.

Several studies on music aptitude of children focused on the relationship between tonal aptitude and singing achievement. Some researchers found that tonal aptitude is a significant indicator of singing achievement (Martin, 1991; Phillips & Aitchison, 1997); however, others discovered that the relationship between children's singing abilities and development of tonal aptitude is small (Hornbach & Taggart, 2005; Phillips, Aitchison & Nompula, 2002; Rutkowski, 1996). Exploring the issue of music aptitude from a different perspective, the aim of the present study was to investigate the relationship between types of music instruction and development of music aptitude in children. Findings of the present study demonstrated that that singing instruction may help young children improve their tonal aptitude.

In the present study, singing instruction did not involve students playing instruments but did include ear training (aural discrimination skills), rhythmic movement, singing songs, and study of music notation. The following processes are underlying through these activities: (a) perceiving and internalizing the sound (e.g., ear training in

high/ low tones; responding to music with movements), (b) using the human voice as an instrument to sing/vocalize the pitches sung by the teacher, (c) visualizing music notation and transferring visual information from the notation to sing the appropriate pitches. Research has shown that cognitive processes underlying singing activity are essential for developing melodic perception (e.g., melodic contour and interval size) and the sense of tonality (Davidson, 1985; Dowling, 1988). The result that singing instruction enhances children's tonal aptitude in this study supports the previous research findings.

The instrumental instruction in the present study emphasized children's playing skills. Since children spent most of lesson time on playing instruments, the focus on playing techniques and visual information on the instruments may restrain or distract children from internalizing pitches and perceiving sounds during playing. In the singing instruction, on the other hand, the process of translating visual information of music notation to pitches through singing is a different cognitive endeavor in which children need to aurally internalize pitches and perceive sounds before singing. This process may help children's pitch perception and enhance their tonal aptitude.

Rhythm aptitude.

Another finding is regarding the relationship between music instruction and rhythm aptitude of children. No statistically significant differences were found among the three instructional groups over four weeks of music instruction for either age group. In contrast to the results of tonal aptitude, types of music instruction seem not to be a significant factor for rhythm aptitude.

The following reason may be able to explain why no significant differences were found in the rhythm aptitude scores among the three music instructional groups. First,

since rhythm training was not the main focus in the music instruction of the present study, the amount of the class time spent on rhythmic activities was not controlled and may have differed among the instructional groups. Both the violin and keyboard groups spent most of the lesson time on instrumental playing, while the singing group focused on singing. Therefore, the limited amount of class time spent on rhythmic training might be a reason for non-significant findings.

Second, it has been suggested that an appropriate use of percussion instruments (e.g., sand blocks, rhythm sticks, or drums) is an effective teaching strategy to help children develop the sense of rhythm in music (Dalby, 2005; Ester, Scheib, & Inks, 2006). However, the singing instruction in this present study used no instruments in the lessons; the violin and keyboard might not be the most efficient instruments for rhythmic training. Thus, the lack of using percussion instruments may influence the effectiveness of rhythmic instruction in the music lessons.

Implications for Music Education

In light of examining the influences of different types of music instruction on children's spatial ability and music aptitude, the present study provides insight into several pedagogical connections among music learning, spatial ability, and music aptitude. Music teachers, parents, or school administrators who are interested in understanding the relationship between music instruction and cognitive development of children may find results of the present study useful.

Spatial-temporal reasoning – a way of analyzing and understanding how objects fit together in space and time – is an important cognitive ability for children to learn abstract concepts and develop logical thinking skills in their lives. In education, this

ability is also required for children to study subjects such as mathematics, architecture, and science. Researchers have been studying the relationship between music learning and children's spatial-temporal reasoning development for more than 20 years (Persellin, 2000). As music psychologists found that music learning experiences were closely related to children's spatial cognition (Hassler, Birbaumer, & Feil, 1985; Karma, 1979), some neurological researchers have discovered that the process of music cognition and spatial-temporal reasoning is interrelated in the cortex of human brain (Leng & Shaw, 1991; Shaw, 2000).

One interesting finding in the present study is that playing violin or piano will most likely help children enhance their spatial-temporal reasoning ability. During the instruction, children were encouraged to recognize the pitches on the instruments, understand the music notation and relationship between pitches, and then transfer music notation to the placement of fingers on the instruments. This process of coordinating eyes (e.g., visual information/music notation), ears (e.g., aural information/sounds) and hands (e.g., physically instrumental playing) in time (e.g., specified rhythm or tempo) might assist the neural pattern in the brain development relevant to spatial-temporal reasoning. This finding is consistent with the results of previous research that keyboard/piano instruction has a positive effect on spatial-temporal reasoning (Costa-Giomi, 1999; Rauscher et al. 1997). Furthermore, the present study revealed that violin instruction also has a positive effect on spatial-temporal reasoning.

Another pedagogical implication of the present study is regarding the use of instructional approaches in singing class. Research has shown that the use of appropriate pedagogical approaches in singing instruction can effectively help children develop pitch

discrimination and other musical skills (Buckton, 1977). Results of the present study suggest that musical concepts (e.g., low/high tones, melodic directions, relationship between pitches) should be expressly addressed as children engage in singing activities or games. In addition, these abstract musical concepts can also be effectively introduced through the use of visual aids (i.e., color papers, or poster), solfège along with the Kodály hand signs, and listening activities (i.e., responding to the music with movement). Using these instructional approaches in the singing instruction might help children improve their pitch perception and tonal aptitude.

Singing is often a common musical experience in the early childhood years and elementary school music curriculum. If children are engaged in singing activities without attention to musical concepts or sequences of learning, this learning process may not be effective to help children strengthen tonal aptitude or other musical skills. Kenny (1997) notes “that the music curriculum should be conceived not as a collection of activities but rather as a well-planned sequence of learning experiences leading to clearly defined skills and knowledge” (p.108).

While these pedagogical approaches might be related to enhancement of spatial-temporal reasoning and tonal aptitude in music instruction, it is important to ensure that scientific goals do not replace the developmentally appropriate instruction approach in early childhood music teaching. It should be noted that the purpose of the present study was to provide empirical data that explained the relationship among music learning, spatial ability, and music aptitude. Based on various teaching methods, music teachers may have different teaching philosophies and pedagogical perspectives about instrumental and general music teaching in early childhood music education. Thus, music

teachers should hold the scientific premise of the present study in mind while implying these discussed pedagogical implications in the music teaching.

Data from the present study showed that learning violin or keyboard has a positive effect on spatial-temporal reasoning for children, while singing instruction helps children in tonal aptitude. For parents, it may be valuable for children to experience a variety of music learning conditions since different musical activities may stimulate different areas of cognition. Because each type of music instruction achieves its own educational goals through different instructional approaches and class activities, a variety of music instruction may benefit children's cognitive development in different ways.

Finally, results of the present study showed that keyboard and violin instruction in a group or classroom context are influential on improvement of spatial-temporal reasoning. This finding implies that violin and keyboard programs could be integrated in the early childhood school music curriculum so that more children can benefit from these types of music programs. In current American elementary school music curricula, children usually only receive general music instruction once or twice a week. Instrumental instruction such as keyboard or string instruction might not be available in the school curriculum until children are in third grade or higher. Since the present study and other research (see Hetland, 2000a) found that children ages 3 to 5 are more likely to benefit from early music training and smaller-sized keyboards and violins are available for children to play without physical constraints, there seems to be no developmental reason to postpone instrumental music programs until children are older.

Recommendations for Future Research

Findings of the present study regarding the relationship among music learning,

spatial-temporal reasoning and music aptitude suggest several possible directions for future research. The present study found that violin instruction has influences on spatial-temporal reasoning for young children. However, it should be noted that the influence of violin instruction on spatial ability of young children was examined for the first time in the present study. More duplicated studies examining effects of violin instruction on spatial ability are needed to validate the results of the present study. In addition, future studies designed to examine the influence of other types of music instruction available for children (e.g., recorder, guitar) could be valuable to the profession.

Future research exploring the effects of string instruction on spatial-temporal reasoning should focus on the use of finger placement markers on the instruments. In the present study, children in the keyboard instruction group were able to visualize the “pitch pattern” on the instrument. Correspondingly, the approach of finger placement marker was used during the violin instruction to match to the pedagogical process of the keyboard instruction. Similar to the keyboard instruction, the finger placement markers on the violin present the pitch relationships (e.g., whole step or half step) and help children visually identify pitches and finger placements on the instruments during the playing process. Since the violin instruction can be provided with no use of finger placement marker, it could be interesting to understand whether missing the visual information on violin also leads to a significant result on spatial ability. Future researchers can conduct experimental studies to compare violin instruction using the two approaches (use versus no use of finger placement marker) in order to determine whether the visual information on violin is a factor related to the improvement of spatial-temporal reasoning.

Another recommendation for future researchers interested in understanding effects of instrumental playing on spatial-temporal reasoning is to examine the relationship between study of music notation and development of spatial-temporal reasoning. Hetland (2000a) states that music lessons that included learning standard Western music notation led to higher spatial-temporal reasoning than lessons with nonstandard or no notation instruction. In addition, it was assumed that the piano instruction coupled with the use of standard notation produces greater effects on spatial-temporal reasoning. Other studies also found a positive relationship between study of music notation and spatial-temporal reasoning ability in the instrumental music learning contexts (Sergent, Zuck, Terriah, & McDonald, 1992; Gromko, 2004; Hayward & Gromko, 2009).

Findings of the present study support Hetland's point of view that keyboard instruction coupled with study of standard music notation may help children enhance their spatial-temporal reasoning skills. However, no empirical data illustrate whether study of music notation is a reason that helps children improve their spatial-temporal reasoning during music instruction. As children of the three instructional groups in the present study received note-reading instruction, data from the present study were not able to determine whether study of music notation is related to enhancement of spatial-temporal reasoning during music instruction. In current methods of music teaching, however, some teaching methods (e.g., the Suzuki method) delay the presentation of note reading on music staff in the beginning stage of instrumental instruction. Researchers need to further examine whether violin and keyboard instruction still have a positive influence on development of spatial-temporal reasoning when visual stimulations (note

reading and study of music notation) are absent in the instruction. In addition, it could be interesting to understand whether learning music notation alone with no music instructional contexts would lead to a significant effect on spatial ability for children. Future researchers can examine effects of studying music notation in different music instructional contexts to further understand the relationship between study of music notation and children's spatial ability in music instruction.

While investigating the relationship between age and development of spatial ability in music learning, future researchers should include a wide range of age levels or compare more than two age groups of populations. To date, research examining the relationship of music learning to spatial ability has focused on children in age from three to twelve years (Hetland, 2000a). Nevertheless, whether music learning experiences affect other age groups are yet unknown. Future studies concerning the relationship between age and spatial ability in music learning could include adolescent or adult populations in the research design to determine whether music learning has effects on older learners.

Further, Hetland (2000a) points out that music learning may show greater effects on younger children (3-5 years old) than on older children (6-12 years old) in regard to musical effects on development of spatial ability. The present study compared the effects of music instruction on spatial-temporal reasoning and spatial recognition of younger children (4-5 years old) to older children (6-7 years old). However, data from the present study showed the mixed findings between these two age groups. The present study found that the younger group scored significantly higher than the older group for spatial-temporal reasoning tasks, while no significant differences were found between the two

age groups for spatial recognition. This finding did not completely support Hetland's point of view that musical effects are greater on younger children than on older children.

As mentioned previously, the reason for the non-significant findings for spatial-temporal reasoning may be that the present study did not include three-year-old children in the sample population. In addition, the two age levels in the present study are only one year apart from each other in which the difference due to age may not be demonstrated. According to these limitations, future research should include age levels that are a few years apart from each other (e.g., 3-4 years old versus 8-9 years old). Furthermore, future researchers could examine what optimal age for music instruction would lead to the largest effect on spatial reasoning ability. Rauscher and Zupan (2000) state that the cortical plasticity might induce a largest effect on spatial-temporal reasoning for children younger than three years of age. More studies are needed to validate whether the age of three years is critical for musical effects on spatial-temporal reasoning.

Although research has found that music instruction have a positive effect on children's spatial ability and music aptitude, many researchers address concerns about how long the effects last. In a longitudinal study, Costa-Giomi (1999) found that effects of piano instruction on spatial ability were only found during the first two of three years of piano instruction; no significant differences were found between the instruction and control group in the third year of study. Persellin (2000) discovered that any effect of music instruction disappeared six months after instruction was concluded. According to these findings, music learning seems only to have a short-term effect on spatial-temporal reasoning.

Future researchers examining effects of music learning on spatial-temporal

reasoning and music aptitude should consider the issues about the lasting effect of music instruction on spatial intelligence and music aptitude. More longitudinal studies are needed to investigate whether music learning only has temporary effects on spatial ability, whether learning music might just simply accelerate the progress of spatial reasoning development of children, or whether the influence of music learning on music aptitude is also a short-term effect.

A contribution of the present study was to understand that instrumental playing might be related to enhancement of spatial-temporal reasoning in music instruction. However, the question whether other variables such as years of formal music training or informal musical environments at home are also related to development of spatial-temporal reasoning remains unanswered. It has been noted that a rich musical home environment, experiences of formal music learning, and the musical background of a child's parents can positively affect musical development of children (Hargreaves, 1986). Future researchers should use a variety of data collection methods (e.g., survey or longitudinal data collection) to further examine the relationship between variables of musical learning environment and cognitive abilities such as spatial abilities and music aptitude.

Finally, more studies are needed to examine the relationship among music learning, age of children, and development of music aptitude. Data from the present study showed that singing instruction has a positive effect on tonal aptitude for the younger children (4-5 year olds) using the PMMA; however, the similar effect was not found for the older children (6-7 year olds) using the IMMA. This conflicting finding may be due to the differences in two measurement tools. On the other hand, it might be possible that

age is a significant factor in relationships between singing instruction and tonal aptitude. More empirical data are needed to support these concerns and assumptions.

Gordon (1997) believes that development of music aptitude is not stabilized until nine years of age; formal music instruction and rich musical environment can enhance young children's music aptitude. However, others have found that music aptitude stabilizes by age six or earlier (Schleuter & Deyarman, 1975). It seems that age is related to development of music aptitude for children. To gain a better understanding of relationships between singing instruction and tonal aptitude, future researchers should include multiple age levels of children (e.g., age six, or age levels older and younger than age nine) in the research design or utilize cross-sectional studies (the same tasks are administered to children across the study) to determine how age relates to the tonal aptitude in singing instruction.

Conclusions

In Gardner's theory of multiple intelligence, spatial and music intelligences are two important cognitive areas in child development (Gardner, 1983). Over the past decades, the relationships among music learning, spatial reasoning, and musical development have long been discussed in the area of child development (Jordan-Decarbo & Nelson, 2002). Further, research in music education also showed positive influences of music learning on spatial-temporal reasoning and music aptitude in young children (Bilhartz, Bruhn, & Olson, 2000; Flohr, 1981; Gordon, 1979; Hetland, 2000a).

The present study expands the work of previous researchers by providing insights into what pedagogical approaches in music learning are related to enrichment of spatial-temporal reasoning and music aptitude. This study suggests that learning to play

keyboard and violin may help children enhance their spatial-temporal reasoning. The cognitive processes involved in instrumental performance are a combination of visual, aural, spatial, and physical skills. This multifaceted process in the violin and keyboard learning may be related to spatial-temporal information processing in young children's brain functioning.

In terms of music learning and development of music aptitude, the present study suggests that the use of an appropriate pedagogical approach in the singing instruction helps young children improve their tonal aptitude. Singing is a unique means to help children perceive sounds and pitch relationship through the human voice. In addition to rote singing, integrating the use of ear training exercises (e.g., pitch discrimination or melodic direction), note reading, and solfège is encouraged in singing classes for young children. These instructional components are able to enrich children's melodic perception, understanding of pitch relationships, concept of low/high tones, and aural skills, which are related to their development of tonal aptitude.

According to the results of the present study, music learning does have a positive effect on spatial ability and music aptitude. Since spatial and musical intelligences are important cognitive areas in child development, the influence of music learning on these two cognitive abilities cannot be ignored. While some controversy about intrinsic and extrinsic values of music learning still exists in music education profession, the present study provides empirical data, showing a small link between music instruction and cognitive development of young children. It is important to acknowledge that the value of music learning is multifaceted; the present study supports that music education can be a potential education tool that helps children's spatial ability in cognitive development.

It should also be noted that the long-term goals of musical growth and enjoyment in music learning should not be neglected when considering extra-musical benefits of music instruction. Reimer (1999) states his concern that quality of music education may be in danger of corruption if music educators teach music for non-musical outcomes, rather than developing musical understanding. These concerns are pertinent when attempting to bridge the gap between empirical research and music teaching practice. However, the value of research on examining the relationship between music learning and child development is to advance understanding on how music learning relates to child development and to highlight the importance of music education in young children.

APPENDICES

Appendix A Letter to Parents

Dear Parents:

My name is Tzu-Ching Tai, a PhD candidate in music education at the University of Maryland. I am writing this letter to invite your child, _____, to participate in a research project titled, “Effects of Violin, Keyboard, and Kodaly-based Music Instruction on Spatial-temporal Reasoning and Developmental Music Aptitude of Young Children.” The purpose of this study is to examine the effects of different types of music instruction on young children’s development of spatial-temporal reasoning and music aptitude. Spatial-temporal reasoning is a cognitive ability that helps children think, reason, and create in the learning process.

If you and your child agree to participate in this study, your child will receive 45-minute music lessons four days a week for four weeks (June 22, 2009—July 16, 2009). The classes will be scheduled between 4pm to 6pm at the University of Maryland, College Park. Your child will be randomly assigned to violin, keyboard or singing/music reading-based music programs. Before and after the music instruction, two appointments will be scheduled for spatial-temporal reasoning and music aptitude tests. The spatial-temporal reasoning will be measured by completing four subtests in the Wechsler IQ tests while the music aptitude will be measured by completing the Gordon Music Aptitude test. The subtests from the Wechsler IQ test will take approximately 20 minutes to complete; the Gordon music aptitude test will take approximately 50 minutes to complete.

All the music lessons are at no cost to your family. The children who are assigned to the violin program need to bring in a violin to be able to participate in the violin classes. Your children’s test scores will not be used for any educational judgment, but only be utilized for the research purpose. In addition, your child’s name will not be included in the report of this study. To thank your child for participating in this study, he or she will receive a small reward (the value of reward is under \$5) after completing each test and class.

If you and your child are interested in the participation of this study, please sign the attached Parental Consent Form. The attached Child Assent Form will also be read to your child before the study begins. If you have any questions regarding this project, please contact me at ttai@umd.edu or 240-462-5365.

Sincerely,
Tzu-Ching Tai

Appendix B Parental Consent Form

Project Title: The Effects of Violin, Keyboard, and Kodaly-based Music Instruction on Spatial-temporal Reasoning and Developmental Music Aptitude of Young Children

Why is this research being done? This is research project being conducted by Tzu-Ching Tai under the supervision of Dr. Michael Hewitt in the School of Music at the University of Maryland, College Park. We are inviting you to participate in this research because your child is either 4- to 7- years-old, and you and your child are interested in music learning. The purpose of this research project is to examine the effects of different types of music instruction on young children's development of spatial-temporal reasoning and music aptitude.

What will my child and I be asked to do? If you agree to participate in this study, your child will be asked to come to the School of Music at the University of Maryland and to receive 45 minutes of music instruction either in violin, keyboard or singing/music reading-based music program, four days a week for one month. Your child will be engaged in various kinds of music learning activity including listening, singing, playing, moving, and music reading. If your child is assigned to the violin program, you will need to bring a working instrument to be able to participate in the class. Before and after the music instruction, two appointments will be scheduled for your child to take the Gordon Music Aptitude test and a portion of the Wechsler IQ test to measure his/her music aptitude and spatial-temporal cognitive skills. The IQ test will take about 20 minutes to complete while the music aptitude test will take approximately 50 minutes to complete.

What about confidentiality? We will do our best to keep your personal information confidential. To help protect your confidentiality, your child's name will not be included in the documentation of this study. If we write a report or article about this research project, your identity will be protected to the maximum extent possible. Your information may be shared with representatives of the University of Maryland, College Park or governmental authorities if you or someone else is in danger or if we are required to do so by law.

What are the risks of this research? There are no known risks associated with participation in this study.

What are the benefits of this research? The benefits to you include that your child will experience musical enjoyment by completing games and tasks in the music classes and develop certain level of musical abilities including singing, playing and music reading. This research also helps the music education profession learn more about the effects of music instruction on young children's cognitive development.

Do I have to be in this research? Can I stop participating at any time? You and your child's participation in this research are completely voluntary. You may choose not to participate or withdraw your participation from this study at any time, and you will not be penalized. If your child does not complete either the IQ or the music aptitude test before the music instruction begins, your child will no longer be eligible to participate in the music classes.

What if I have questions? The research is being conducted by Tzu-Ching Tai at the University of Maryland, College Park. If you have any questions about the research study itself, please contact Tzu-Ching Tai at ttai@umd.edu or 240-462-5365. Or you may contact the advisor of this study, Dr. Michael Hewitt at mp Hewitt@umd.edu /301-405-5504/2130C Clarice Smith Performing Arts Center, University of Maryland, College Park, 20742. If you have questions about your rights as a research subject or wish to report a research-related injury, please contact: Institutional Review Board Office, University of Maryland, College Park, Maryland, 20742; (e-mail) irb@deans.umd.edu; (telephone) 301-405-0678
This research has been reviewed according to the University of Maryland, College Park IRB procedures for research involving human subjects.

Statement of Age of Subject and Consent: Your signature indicates that you are at least 18 years of age; the research has been explained to you; your questions have been answered; and you freely and voluntarily choose to participate in this research project.

Signature and Date:

Name of Child _____

Name of Parent _____

Signature of Parent _____

Date _____

Appendix C Assent Form for Children

You are invited to do a research study. A research study is a special way to discover something new. In this discovery, I am trying to find out whether music learning makes children change in any ways.

If you want to be a part of this study, you will come to the university to have music lessons this summer. You will have a chance to learn how to play violin, keyboard, or singing/music reading games. You will also be invited to play several music games with me and the music teachers. The games include playing puzzles, building blocks, drawing pictures and listening to the music. Because I want to thank you for being part of this study, you will receive a small gift such as stickers, pencils or candy after you complete each task and class.

There are two things you need to know about this invitation. First, you can choose not to participate in this study. Just say no. If you do choose to participate in this study, you can stop at any time and you will not be in trouble. Second, when I am done with this study, I will write a report about what I find about all the kids who participate, but your name will not be included in the report.

Check this box if you want to participate

Name (PRINT) _____

Date _____

If the subject cannot read, this assent form will be read to the child with their parent(s)/legal guardian present to assist. The child will understand the contents of this assent form.

Signature of Investigator _____

Date _____

Appendix D Sample Lesson Plan for Violin Instruction

Topic:

-Review last week materials: steady beat, up & down melodic direction, holding violin, strings on violin, pizzing.

Goal/Objective:

-SWBAT remember all the materials learned from last week (the 1st week)

Materials:

Violin, rhythmic flashcards, strings/finger chart

Procedure:

1. Hand in sticker book and take violin case to their seat
2. Rhythms with flashcards- 1) I only see the cards and clap the rhythms (around 10)
2) Students will get to see the cards and count 1 2 3 4,
AFTER me
3) I will sing in Kodaly syllables and students will echo me
4) Challenge students to do it by themselves
3. Review the steady beat, up & down melodic direction – 1 minute
4. Take out violin, students stand up.
I will sing rest position song and students just follow my motions
5. Monkey swings for playing position!
6. Elbow swings- RELAX students and arms. Strum gently 4 strings with curved pinky
7. Violins down- Review strings and violin parts
8. Violins up: Review how to pluck- the “backward L”, thumb sits on corner of fingerboard close
to E string
9. End review by playing Simon says with pizzing (note duration- I clap, students pizz)

Closure:

1. Put violin away
2. Sing closure song while doing motion
3. Students will return violin and receive their sticker books

Management Technique

3 Warnings = No playing

Appendix E Sample Lesson Plan for Keyboard Instruction

Concept

Notes C, D, E, F and G

Objective

Students will be able to recall the location of C, D, and E

Students will be able to review and learn the location of F and G

Students will be able to read different rhythm patterns using quarter notes and half notes

National Standards

1. Singing, alone and with others, a varied repertoire of music.
2. Performing on instruments, alone and with others, a varied repertoire of music.
5. Reading and notating music.

Materials

Pianos, iPod Touch, Speakers, and Paper Keyboards

Procedures

1. Echo sing attendance – Teacher sings “[Insert student’s name], where are you?” in a sol-mi pattern. Students echo “Here I am” in a sol-mi pattern.
2. Listen to The Elephant March from The Jungle Book while keeping a steady beat with our feet.
3. Gather the students around the grand piano and find all of the 2 black keys and 3 black keys as a group.
4. Ask each student to find all of the C’s on the grand piano.
5. Sit in a circle on the floor and play the pointing game for the different notes on the paper keyboard. As the students play the paper keyboard, teacher plays the iPod Touch keyboard to help them connect the keys to the sound.
6. Add or review the notes F and G by showing them the C to G paper keyboard. Play the pointing game with the new notes added.
7. Sing Hot Cross Buns.
8. Practice the E-D-C melody on the paper keyboard and then allow the students to practice on the real keyboards.

Evaluations

Were the students able to sing a melody on sol and mi for “here I am?”

Were the students able to find all of the C’s?

Were the students able to point to the notes C, D, E, F, and G accordingly?

Were the students successful in recalling the notes C, D, and E?

Were the students successful in playing the E-D-C melody on the paper keyboard and the real keyboard?

Appendix F Sample Lesson Plan for Singing Instruction

Objectives: Students will practice dictation with the aid of the teacher based on simple melodies using la, sol, and mi.

Materials Needed: Making Music Grade 1, blue tape

Procedure:

- 1.) Hello Song
- 2.) Review la, sol, and mi using Kodaly hand signs.
- 3.) Show students where la, sol, and mi are on the big staff on the floor.
- 4.) Using popsicle sticks with names, ask students to come up to the staff on the floor in groups of three to jump to simple patterns. Sing some of the patterns, play others on the piano for a more challenging activity.

Assessment:

Can students identify when they hear pitches la, sol, and mi?

Can students find the appropriate line or space for the pitches they hear?

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