

3-23-2016

## Utilizing Immediate Feedback in Piano Pedagogy

Michael Szabo

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Utilizing Immediate Feedback in Piano Pedagogy

by

Michael Szabo

A thesis submitted in partial fulfillment  
of the requirements for the degree of  
Master of Arts  
Department of Child and Family Studies  
College of Behavioral and Community Sciences  
University of South Florida

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Date of Approval  
March 22, 2016

Keywords: Tactile feedback, skill acquisition, behavior analysis, music education

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## **DEDICATION**

I dedicate this manuscript to my parents, Bob and Laura Szabo, for their constant support throughout my life. Their encouragement of my musical endeavors and education have been invaluable. I also dedicate this to my brothers at the Epsilon Iota chapter of Phi Mu Alpha Sinfonia for the values they instilled in me and their dedication to advancing music in America.

## **ACKNOWLEDGEMENTS**

I would like to acknowledge my entire thesis committee who have supported me throughout my education and this project. Most importantly, Tim Weil, whose interest in this study and willingness to explore new research areas allowed me to make this idea a reality, along with his constant feedback and dedication.

I would also like to thank all my lab members who served as an amazing support system throughout this process from its inception to its completion.

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## **ABSTRACT**

Piano pedagogy is the study of the teaching of piano performance. Several effective methods have been developed since the early 1700's, but lack empirically supported techniques. Immediate feedback procedures have been shown to be effective with skill acquisition in various capacities within the literature. While some innovative techniques are being developed which utilize technologies such as video and sensor-based feedback, the true impact of these interventions has not been empirically validated. There is also a paucity of research in the behavioral literature evaluating the efficacy of immediate feedback procedures in acquisition of music performance. The current study evaluated the effectiveness of an immediate tactile feedback procedure for teaching basic introductory piano to new learners by teaching three unique scales, proper hand/finger positioning, rhythm and tempo. All three participants successfully acquired the different skill sets which supported the learning of a simplified arrangement for a preferred song on the part of the participants.

## **CHAPTER ONE:**

### **INTRODUCTION**

Piano pedagogy is defined as the study of the teaching of piano performance (Thomas-Lee, 2003). Since the inception of the piano in 1709 (Agay, 2004), there has been a substantial amount of research in the field, attempting to develop better and more efficient ways to teach an individual how to play the piano. Some of the more common piano pedagogy methods were developed by Emile Dalcroze, Carl Orff, Zoltan Kodaly, and Shinichi Suzuki (Skaggs, 2004). Although these methods use different aspects such as ear training, singing, and clapping out rhythms, they have all proven effective for many individuals (Skaggs, 2004). While these are just a few different methods developed over the years, they all aim to achieve the same goal. The main difference in these methods is how key concepts are taught, such as rhythm and tempo, as well as motor skills such as fingering patterns and hand positions. One key aspect that is missing from most piano pedagogy methods is clearly defined target behaviors. While some of these approaches state to provide positive feedback or establish a warm rapport with the students (Etts, 2004), there is a substantial lack of empirically supported methods for using behavioral techniques, such as immediate feedback, to improve student performance.

Despite the lack of behavioral research in this field, the use of behavioral techniques is not a completely foreign idea. Ruckmich (1914) saw music as a process of skill acquisition that could benefit from scientifically based pedagogical approaches; however, given that this

occurred one hundred years ago, researchers and piano pedagogues did not have the knowledge of the behavioral principles that exist today. Ruckmich stated that once the necessary principles are established, a better piano pedagogical method could be created to replace the un-systemized approaches to teaching piano. Unfortunately, empirically based approaches have not been applied to teaching the piano despite the development of behavioral technology. Additionally, utilizing behavioral technology in piano pedagogy can have a positive impact on the students as learning piano and music participation in general from a young age has several benefits such as increased academic achievement (Southgate & Roscigno, 2009; Vaughn & Winner, 2000), better verbal memory (Ho, Cheung, & Chan, 2003), and improved spatial-temporal performance (Rauscher et al., 1997).

Most piano pedagogy methods are primarily based on the approaches of Orff and Dalcroze developed in the early 1900's (Rubí, Montilla-Salas, & Sureda-Garcia, 2014; Thresher, 1964); as well as manipulating variables such as the books and syllables used to teach basic principles such as proper technique, tempo, and rhythm (Skaggs, 2004). However, in recent years there have been a few tested innovative approaches that incorporate both technology and empirically based procedures. Deniz (2012) implemented a procedure that used video monitoring to improve the playing performance of experienced pianists who were also prospective teachers. Deniz found the prospective teachers reported that viewing video recordings and receiving feedback improved their performance quality, and they found the entire process to be very positive.

Hadjakos, Mühlhäuser, and Lukowicz (2011) proposed a sensor-based feedback system for piano pedagogy that looked to track the movements of the performer and provide him or her with feedback based on what the device recorded. This study did not provide empirical data on how this system could improve performance or skill acquisition as it was primarily focused on

developing the technology, but it set the stage for future research studies using this type of device. The research by Deniz (2012) and Hadjakos et al. (2011) represent efforts to investigate empirically based teaching procedures; however, they are two studies that may easily get lost in an area dominated by un-systematic research that has not utilized new technologies to advance the field.

Learning a complex behavioral repertoire can present myriad challenges which may function as aversive stimulation; thus causing frustration and drop out given thin schedules of reinforcement and feedback. These issues may be ameliorated by inclusion of explicit empirically validated teaching procedures that increase contact with reinforcement and feedback. Additionally, piano pedagogy may benefit greatly with the development and implementation of new empirically based principles and procedures. One aspect of piano pedagogy, communication between the student and teacher, is a promising area for systematic investigation. It is in this area that an immediate feedback procedure, specifically tactile, may greatly benefit the field of piano pedagogy and establish a basic framework in which to develop new empirically supported teaching methods.

### **Performance Feedback**

Performance feedback is information about a specific aspect of behavior that functions to correct or reinforce (Cooper, Heron, & Heward, 2007). It is a fairly common technique in behavior analysis, as well as other fields, and encompasses many components such as praise for correct behavior, reviewing data, corrective feedback, and addressing any questions or comments (Coddington, Feinberg, Dunn, & Pace, 2005). Performance feedback has been shown to contain motivational functions (Roscoe, Fisher, Glover, & Volkert, 2006), as well as discriminative or reinforcing functions, or any combination of the three (Duncan & Bruwelheide, 1985).

Performance feedback has been used to modify behavior in several areas such as animal behavior (Ferguson & Rosales-Ruiz, 2001; Langebin, Siebert, Nurenberg, & Manteuffel, 2007; McCall & Burgin, 2002), sports and fitness (Allison & Ayllon, 1980; Anderson & Kirkpatrick, 2002; Boyer, Miltenberger, Batsche, & Fogel, 2009; Kladopoulos & McComas, 2001; Scott, Scott, & Goldwater, 1997; Smith & Ward, 2006; Ward & Carnes, 2002), skill acquisition and training (Fogel, Weil, & Burris, 2010; Himle, Miltenberger, Flessner, & Gatheridge, 2004; Miltenberger et al., 2004; Miltenberger et al., 2005), teacher training (Ingvarsson & Hanley, 2006; Lerman, Vorndran, Addison, & Kuhn, 2004), and treatment integrity (Coddling et al., 2005; DiGenarro-Reed, Coddling, Catania, & Maguire, 2010; Kaufman, Coddling, Markus, Tryon, & Kyse, 2013). These studies show performance feedback to be effective using a variety of different methods, including public, individual, delayed, and immediate feedback.

Public feedback is mostly found in group settings such as competitive sports teams, and has been shown to be a successful intervention for improving a wide variety of skills (Schonwetter, Miltenberger, & Oliver, 2014; Smith & Ward, 2006; Ward & Carnes, 2002). Public feedback is typically posted, or otherwise delivered to the members of the group so all can see each other's performances. Individual feedback allows for improvements in performance and other behaviors in a more private non-group setting (e.g. Bryant, Henslee, & Correia, 2013; Himle et al., 2004). Whether it is public or individual, feedback can be delivered either immediately after the behavior occurs or after some period of time when the context does not support immediate opportunities. Additionally, there is some discussion regarding when feedback should be delivered given a period of time before the next response opportunity. When skills are produced only once and the next opportunity to engage in the skill is delayed, it may be beneficial to wait until just prior to the attempt to provide feedback from the prior observation (Mathews & Dix, 1992)

Although delayed feedback has been shown to be effective under certain conditions (Kern-Dunlap et al., 1992; Panyan, Boozer, & Morris, 1970), the latency between the targeted behaviors and when the feedback is provided can influence the efficacy of the intervention. Barbetta, Heward, Bradley, and Miller (1994) and Bennett and Cavanaugh (1998) both tested delayed and immediate feedback procedures to improve the skills of students with developmental disabilities in the area of education and found that immediate feedback resulted in greater improvement and in fewer sessions than delayed feedback.

### **Immediate Feedback**

The studies conducted by Barbetta et al. (1994) and Bennett and Cavanaugh (1998) were implemented in educational settings and consisted of providing vocal verbal feedback by indicating whether the student's response was right and providing correction if they were wrong. However, the setting and delivery (mode) of immediate feedback can vary considerably (Anderson & Kirkpatrick, 2002; Boyer et al., 2009; Lantz & Stawiski, 2014; Scott et al., 1997; Yu, Moon, Oah, & Lee, 2013)

**Areas of application.** Immediate feedback has been used to improve performance and skill acquisition in several areas and can be implemented with a wide range of populations, such as children (Himle et al., 2004; Miltenberger et al., 2004; Miltenberger et al., 2005), individuals with developmental disabilities (Barbetta, Heward, Bradley, and Miller, 1994; Bennett and Cavanaugh, 1998), and healthy adults (Schega, Bertram, Fölsh, Hamacher, and Hamacher, 2014; Scott et al., 1997; Yu et al., 2013). In the area of sports and fitness, Eriksson, Halvorsen, and Gullstrand (2011) utilized an immediate visual and auditory feedback procedure on a treadmill to improve the running mechanics of experienced well-trained adult runners. Auditory feedback was presented via a headset worn by the participant through which instructions were given on how to correct their technique. In a separate trial, visual feedback was

presented on a screen mounted on the treadmill that displayed the participants' data on vertical displacement, step length, and how the participant compared to the target levels while running. The researchers found that the participants were able to quickly adjust their running technique accordingly when they received immediate feedback on their performance.

Lantz and Stawiski (2014) utilized immediate feedback in the classroom to improve memory and increase the speed of learning new material. Students were asked questions on new material and either given immediate feedback consisting of the correct answers following completion of the questions, or no feedback. When the students were tested two days later, the researchers found they performed substantially better with the immediate feedback than when the material was taught with no opportunity to receive any feedback. Immediate feedback has also been used to improve teacher behavior in educational settings. Coddington, Feinberg, Dunn, and Pace (2005) found that by using an immediate feedback procedure, teachers' treatment integrity increased when implementing behavior plans in the classroom. DiGenarro, Martens, and Kleinmann (2007) demonstrated this as well, and showed a correlation between higher treatment integrity of behavior plans and lower levels of problem behavior.

Another area showing benefit from immediate in-vivo feedback is driving behavior where safety of self and others is always of primary concern. Simmons-Morton et al. (2013) used immediate feedback to reduce risky driving behaviors in teenagers, such as hard braking and sharp turns that produce elevated gravitational force (g-force). Experimenters provided immediate visual feedback to the driver with a light when he or she was engaging in risky behavior. Additionally, footage of the event was sent to the participant's parents. This intervention package was shown to decrease the frequency of participants' risky driving behaviors. It is not clear, however, what effect the immediate feedback alone would have had on driving performance. That is, it is unclear what contingencies were experienced as a result of

the delayed feedback parent component of the intervention and thus, the effects of the feedback component are difficult to ascertain.

These studies demonstrate that immediate feedback procedures have been found to be effective, versatile, and can be utilized to improve performance with various populations. Another advantage found with immediate feedback is that it is not restricted to a particular form or modality.

**Sensory modality.** In the same way that immediate feedback can be implemented across various populations and topics, it can also be administered in several sensory modalities (Cooper et al., 2007). Feedback is most commonly provided through auditory stimuli (Anderson and Kirkpatrick, 2002; Scott, et al., 1997), visual stimuli (Schega et al., 2014), and tactile stimuli (De Korte, Huysmans, de Jong, van de Ven, & Ruijsendaal, 2012). Immediate feedback has been shown to be effective across all sensory modalities and equally effective when combining two or more modalities (e.g. Eriksson, Halvorsen, & Gullstrand, 2011).

While all of these modalities have their benefits, tactile feedback has been shown to be a more effective modality than visual and auditory feedback (Akamatsu, MacKenzie, & Hasbrouq, 1995; De Korte et al., 2012). It is possibly the case that some tasks would be better with particular modalities. For instance, these studies found tactile feedback to be the preferred modality as its efficiency allowed participants to continue engaging in the task while still yielding positive results. While this was shown in the field of medicine and robot-assisted surgery (Roke, Melhuish, Pipe, Drury, & Chorley, 2012), Marshall and Wanderley (2006) suggest that tactile sensations play an important role in music education as expert musicians find the vibrations generated by an instrument to be a vital component when performing. Given the lack of empirically established teaching procedures and the support of the educational and sports performance feedback literature more generally, there is potential for tactile feedback to



positively influence acquisition of musical performance

Whereas music has been referenced in the behavioral literature, it is mostly used as a reinforcer (Barmann, Croyle-Barmann, & McClain, 1980; Hume & Crossman, 1992; Lanovaz, Rapp, & Ferguson, 2012; Lanovaz, Sladeczek, & Rapp, 2011). Fields such as piano pedagogy could greatly benefit from empirically based interventions that effectively teach new learners the necessary skills required to play the piano, as well as improve the performance of experienced players. The current study aimed to evaluate the effectiveness of an immediate tactile feedback procedure for teaching basic introductory piano skills to new learners by teaching three unique scales, proper hand/finger positioning, rhythm and tempo. A combination of these skill supported the learning of a simplified arrangement for a preferred song.

## **CHATER TWO:**

### **METHOD**

#### **Participants and Setting**

The primary investigator recruited 5 participants, 3 male and 2 female, who were at least 18 years of age and had no experience with musical instruments or training on musical concepts, resulting in the production of three complete data sets. If participants had limited exposure to musical instruments that was part of an early learning experience, they were considered for inclusion in this study, unless that history involved direct experience with the piano. Baseline measures were the test for inclusion for these participants. Any baseline performance that reached 80% on any of the skill sets resulted in exclusion. Participants were recruited using flyers posted on the campus of the University of South Florida (USF). The flyers contained contact information for the primary investigator (PI), a brief description of the study and its purpose, and desired participant characteristics. Interested individuals contacted the PI via email or text message to further discuss the study and set up a time to meet in a private study room in the USF library to begin the consent process should they desire to participate.

Consenting as a process included meeting to discuss the consent form and the specifics of the study, providing an opportunity to ask questions, assurances of privacy and confidentiality, and finally, if the participant agreed to take part, signing the form and scheduling the first baseline visit. If the potential participant chose to decide later, they were provided 7 days to make a final determination. If the PI had not heard from the individual by

the seventh day, the PI would email them on one occasion to follow up to see if the individual was still interested in participating. If no response, the PI assumed that the individual did not want to participate.

The individual was told the purpose of the study and what was expected of them during their participation. Once they consented, the PI confirmed that they meet inclusionary criteria of no to minimal musical experience. Pseudonyms were used to identify all participant information throughout the study. All identifying information was in a secured locked cabinet and/or on a password protected hard drive.

The three participants that completed the study were Geddy, a 22 year old junior majoring in chemistry, Neil, a 28 year old senior majoring in chemical engineering, and Alex, a 22 year old 5<sup>th</sup> year senior majoring in French. The other two participants that were recruited did not complete the study, as one of them graduated before completion and the other dropped out due to time constraints.

All sessions were conducted in a private practice room that contained a piano in the College of Music at USF. The practice room was reserved through the College of Music at a time specified for the participant. The participant was seated on a piano bench in front of the piano while the PI stood slightly behind and to the left of the participant in a position where the keyboard was clearly visible.

## **Materials**

Two cameras were utilized to record the participants' behavior, as well as the PI's implementation of the intervention. One camera was focused on the participant and the other on the PI, and they were positioned so they clearly captured the playing behavior of the participant and the feedback implementation of the PI unobtrusively. The device was remotely controlled by the PI and provided a moderate vibration lasting less than a second, providing

tactile feedback for appropriate behaviors. The device was created by removing the vibrating component from a remote controlled dog training collar (manufacturer number CHY57129005) and attaching it to the participants' shirt sleeve so that it was making contact with their skin. The device was light weight, weighing only 6 ounces, and only provided the moderate vibration. A metronome with a (blinking light) was also used to introduce the concept of tempo in phase 3 and was slowly faded out.

### **Design**

The intervention was tested using a multiple-probe across behaviors design (Kazdin, 2010) with each behavior being a different skill set (e.g., scale, hand/finger placement, tempo, rhythm). This multiple-probe across behaviors was replicated across participants to demonstrate experimental control across training, mastery, maintenance, and generalization of skill acquisition for all three participants.

### **Dependent Variables and Measures**

The dependent variables consisted of four skill sets: note accuracy, hand/finger position, tempo, and rhythm. The main dependent measure was percentage correct on task analysis for these skill sets.

**Note accuracy.** This first skill set involved performance of a scale both up and down (29 keys with the left and right hand separately)—the basis of which is a behavior chain involving striking the correct key as indicated on the piece of music. Every attempt to play the scale was considered one trial and sessions consisted of 18 trials and lasted 15 minutes on average (3 different scales attempted three times with the right and then the left hand). Data were collected separately for each trial and then graphed as an aggregate of 18 trials per session. Each trial was scored as a percentage of correct notes played, in order, with each note being an opportunity for correct performance (29 opportunities per trial). The participant had to achieve and maintain 90

% correct note accuracy for an entire session across 3 consecutive sessions before moving to the next skill set.

**Hand/finger position.** Hand and finger position was multi-component skill set that included keeping wrist slightly bent, maintaining curvature of the fingers, proper hand placement, and correct fingering pattern. This topography may be considered difficult to acquire interobserver agreement with; however, it was actually considered easy given any angle of the wrist and curvature of the fingers would suffice for a correct hand/finger placement in this study (i.e., a very easy discrimination of the hand/fingers is/are straight, or bent/curved). As with the note accuracy skill set, each session consisted of 18 trials with data being collected for each trial and graphed as an aggregate per session with each trial being scored as a percentage of correct hand/finger position for each note (29 opportunities). The participant needed to achieve and maintain all four components 90% correct for 3 consecutive sessions before moving on to the next skill while maintaining the previous skill set.

**Tempo.** Tempo was defined as playing the rhythmic sequence of notes indicated on the music at the designated speed indicated on the piece of music in beats per minute. Tempo can also be understood as the behavior of playing piano coming under the discriminative control of the passage of time. The tempo for each scale was based on a 10% increase of the average tempo the participants demonstrated in the previous skill set. Each session consisted of 18 trials with data being collected for each trial. As with the other skills sets, data were graphed as an aggregate of trials per session with each trial being scored as percentage correct of tempo for each note (29 opportunities). Once again, the participant had to play at the correct tempo for 90% of 3 consecutive sessions to display mastery while maintaining the two previous skill sets.

**Rhythm.** The final skill set, rhythm, was defined as playing the next note after the

designated amount of time has elapsed since playing the previous note. In essence, this was an inter-response time measure (IRT) indicated on the sheet music as per the rhythmic notation. 18 trials were conducted per session with data being collected for correct performance of rhythm (29 opportunities) for each trial with data being graphed as an aggregate of trials per session. As with other measures, the participants needed to achieve and maintain 90% correct rhythm for 3 consecutive sessions while continuing to show mastery of the previous skills.

### **Interobserver Agreement**

All sessions were video recorded for an independent observer to assess Inter-Observer Agreement (IOA). IOA observations were conducted by research assistants who were trained by the PI. These research assistants were already experienced musicians and training mainly focused on the behavioral concepts. IOA was calculated as number of agreements divided by number of agreements and disagreements and this was for 43% of sessions overall with a 94% agreement.

### **Treatment Integrity**

The video recordings from the sessions were used to collect treatment integrity data to ensure the intervention was correctly implemented. Treatment integrity was assessed for 43% of sessions for each skill set and was computed as a percentage correct on the treatment integrity checklist, which consisted of 6 items for each skill set with an additional 2 items for tempo (Appendix B). Treatment integrity was 97% for this study.

### **Procedure**

The primary independent variable was tactile feedback. Verbal instructions were also used when describing each skill set when it was first introduced. This was only used for the first session of each skill set and tactile feedback was the primary intervention that continued to

facilitate learning throughout the intervention phases.

**Pre-baseline.** After informed consent was obtained, the participant was asked about any musical experience or knowledge of musical concepts they might have. Once it was verified that the participant met the inclusion criteria for this study, they were asked to select a song that they would like to be able to play upon the study's conclusion. The song could be a standard classical piece of music or a more modern popular song. This preferred song might have served as a motivating operation to continue throughout the experiment. A 16-24 measure portion of this song was arranged to fit their skill level and served as a follow-up generalization probe after intervention.

**Baseline.** Baseline consisted of at least two probe sessions conducted on different days for each participant. For these probes, the participants were given a piece of music and asked to play the three scales that were written (C Major, E flat Major, and C sharp harmonic minor) with each hand separately once with no feedback or instruction. The participants' performance was recorded and scored as percent correct on a composite of all four skill sets. The baseline probes were conducted (non-concurrently) for the three participants. For participant 1, the two baseline probes occurred on back to back days. Participant 2 had one additional probe, while participant 3 had 2 additional baseline probes. Once all baseline probes were completed, participants moved into intervention.

**Intervention.** The intervention phase began with the introduction of the tactile feedback process. The participant was shown how the device was worn and what it felt like when it was activated. The device was worn on the participants' arm and was activated five times to acclimate them to the sensation. After demonstrating this, the PI explained how the vibration signals correct performance of the skill. The participant was then given time to ask any questions about the tactile feedback procedure and device to clarify any confusion. This introduction took

place during the first session before instruction of the note accuracy skill set.

**Note accuracy.** Once the participant was familiar with the tactile feedback process, the note accuracy skill set was addressed. The PI introduced the 29 notes (Appendix I) used in each scale and provided vocal verbal instructions on how to play the correct notes. The notes were written out on a piece of sheet music and the PI reviewed the names of each note. Once this instruction took place, the participant received tactile feedback on correct performance of the note accuracy skill set in the form of a brief vibration given after each correct instance (note). The PI instructed the participant to play each of the three scales three times with the right hand and then three times with the left hand, resulting in 18 attempts. During these attempts correct performance of this skill was consequted with feedback and no vocal verbal communication or other forms of feedback occurred during the attempts.

Performance was scored following each session in order to track the participants' progress by dividing the number of correct instances by the total number of opportunities (percent correct). These sessions continued until the participant had achieved the mastery criteria of 90% correct. After demonstrating mastery, the tactile feedback was faded to every 4 notes in a total task presentation, and as mastery is maintained, fading continued to every 8 notes and every 16 notes. If learning did not occur, the PI broke down the skill set for the participant. Upon demonstrating mastery after fading, performance of the other three skill sets was probed.

**Hand/finger position.** Once the participants achieved mastery criteria for note accuracy, the skill set of hand and finger position was addressed. As with the prior skill set, the PI introduced the skills, described the different components, as per the task analysis, and provided vocal verbal instructions on how to correctly perform them (Appendix I). All sessions for each skill set consisted of the participant playing each scale three times with the right hand and three



times with the left hand. Every instance of correct performance of the hand and finger position skill was tagged during each attempt, with no other feedback provided, and sessions continued until mastery criterion of 90% correct is met. Performance was only recorded as correct if all four components of the skill set were completed. As before, feedback was faded out to every 4 notes after the mastery criteria was achieved and every 8, and then every 16 as it is maintained. If learning did not occur, a further task analysis of the skill set would take place. After demonstrating 90% correct performance after fading, all other skill sets were probed.

***Tempo.*** After the participants achieved mastery of the note accuracy and hand and finger position skill sets, tempo was assessed. During this phase, data continued to be collected for these previous skill sets so they can be retrained if there is a decline in their performance. The PI introduced tempo and provide instructions on how to perform this skill set, as well as introduced a metronome to assist in learning. The metronome consisted of a blinking light that is equivalent to the proper number of beats per minute and the PI demonstrated how to play in time with the metronome. Once these instructions were given, correct instances of this skill were tagged throughout each attempt. Prior to each attempt, the metronome blinked for 4 beats before being terminated during the playing. If the participant was not able to start at the correct tempo for three consecutive sessions, the metronome would then produce 4 audible clicks before being terminated during the attempt. The feedback began to be faded as well as per the other skill sets, every 4 notes after mastery and every 8 and 16 after further maintenance. After the feedback was faded, the tempo was altered to further demonstrate mastery. A further task analysis and instructional session occurred if learning was not achieved. After mastery criteria was achieved, probes were conducted for all other skill sets.

***Rhythm.*** The last skill set assessed was rhythm. Data collection continued for previous skill sets to ensure maintenance and was retrained if necessary. The PI introduced rhythm and

how it's notated (Appendix A), as well as provided vocal verbal instructions on how to perform this skill. This skill set included four different rhythmic notations (whole note, half note, quarter note, and eighth note). The PI demonstrated these rhythmic notations three times so that the participant was familiar with the notation. After these instructions, they played the scales using a mixture of all three rhythmic notations throughout and feedback was provided after each correct instance. Once they achieved mastery criteria, feedback was faded as per the previous skill sets to every 4 notes and then every 8 and 16. If the skill set was not acquired, further instruction was given on how to perform the skill. Once mastery criteria was reached after fading for this final skill set, maintenance of the three previous skill sets was probed. When the participants demonstrated mastery and maintenance of all four skill sets for each scale, they had completed the intervention phase and began the generalization probe trial.

**Generalization probes.** The generalization probes consisted of the preferred song that each participant identified at the beginning of the study. The song was arranged by the PI to appropriately match their skill level and proficiency demonstrated at the end of the intervention and was 16-24 measures long. They were asked to play the right and left hand parts of the arrangement separately three times each and then attempt to play both parts simultaneously three times each. No feedback was given during these probes and the data were graphed following each session to see if performance improved demonstrating skill acquisition. These probes continued for at two sessions before reintroducing the tactile feedback. While the researchers anticipated that the participants could achieve mastery on their own, this might have taken a substantial amount of time and participants may feel discouraged. Unlike the intervention phase where different skill sets were individually assessed, tactile feedback was given for correct performance on a composite of all four skill sets (playing the correct note with proper hand/finger position at the tempo and rhythm designated on the sheet music). The

feedback was used until they achieve 90% correct performance for the entire song.

**Social validity.** After the generalization probes were completed, the participants completed a brief 5-item questionnaire developed by the primary investigator (Appendix III) to assess social validity. These questions were answered on a 5 point Likert scale and assessed whether or not the participant found the intervention to be effective, enjoyable, and if they would recommend this approach to others interested in learning the piano.

## **CHAPTER THREE:**

### **RESULTS**

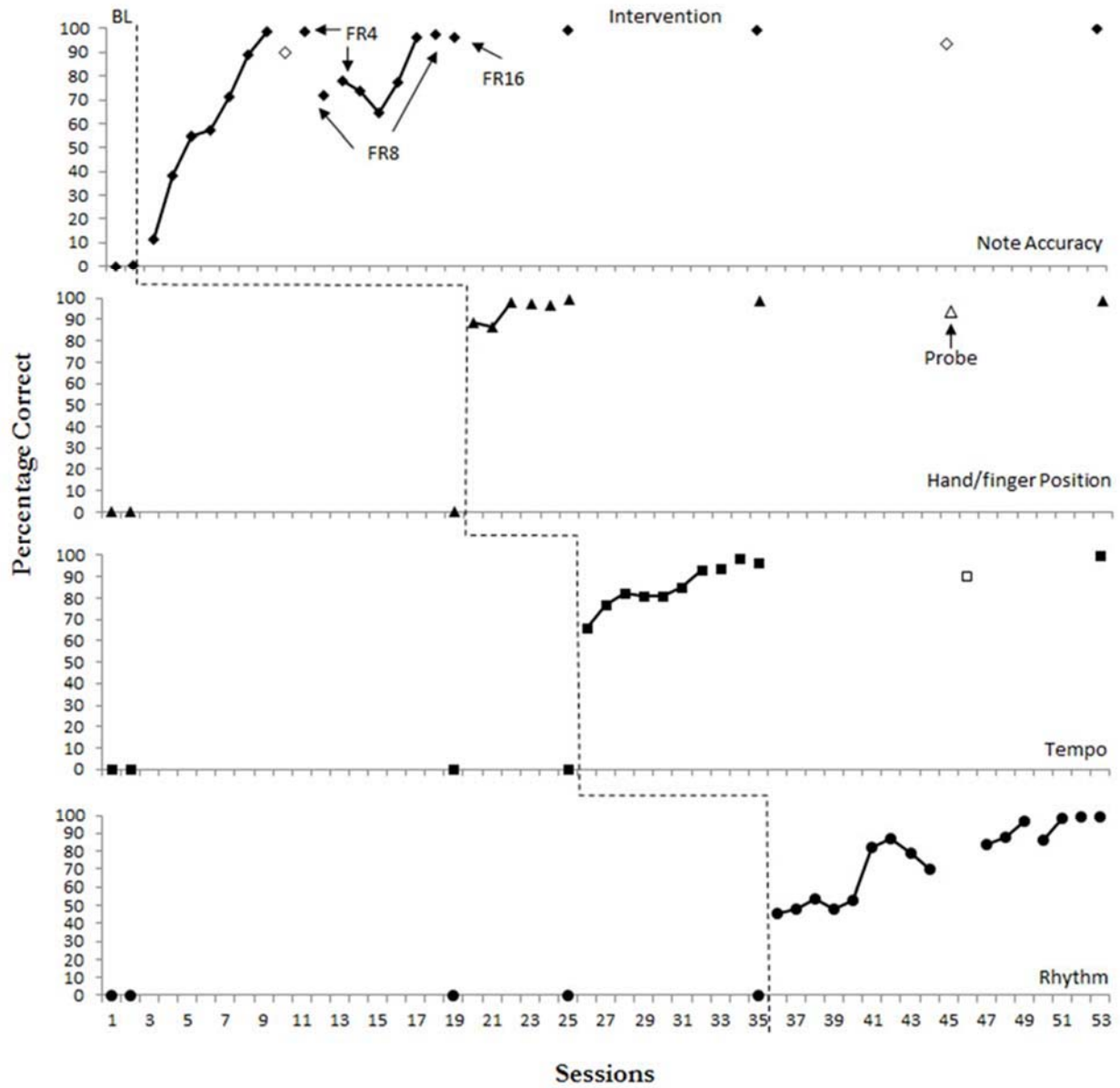
#### **Participant 1 (Geddy)**

Geddy indicated during pre-baseline that they had no musical experience or formal music training. Baseline consisted of 2 probe sessions in which Geddy scored 0% correct across all four skill sets for both sessions. After the tactile feedback procedure was presented and the 29 notes for the note accuracy skill set were introduced, Geddy played 11.5% of the notes correctly in the first intervention session. It took seven total sessions to achieve the mastery criteria of note accuracy and sixteen total sessions until the tactile feedback was faded while maintaining mastery. The hand and finger position task analysis was presented to Geddy, who then scored 88.7% on first intervention session for hand and finger position. Mastery criteria was achieved in three total sessions and feedback was faded while maintaining mastery after six total sessions. Geddy scored 66.3% in the first intervention session for tempo following the introduction to the skill. Mastery criteria was achieved in seven total sessions and feedback was faded while maintaining mastery after ten total sessions. The last skill set of rhythm was introduced and Geddy scored 45.2% in the first intervention session. Mastery criteria was achieved after twelve total sessions and feedback was faded while maintaining mastery after sixteen total sessions. Intervention lasted 48 sessions with three additional probe sessions that were conducted during intervention to assess maintenance of the skill sets after extended periods of time between sessions occurred. The song for the generalization probe was introduced and demonstrated and

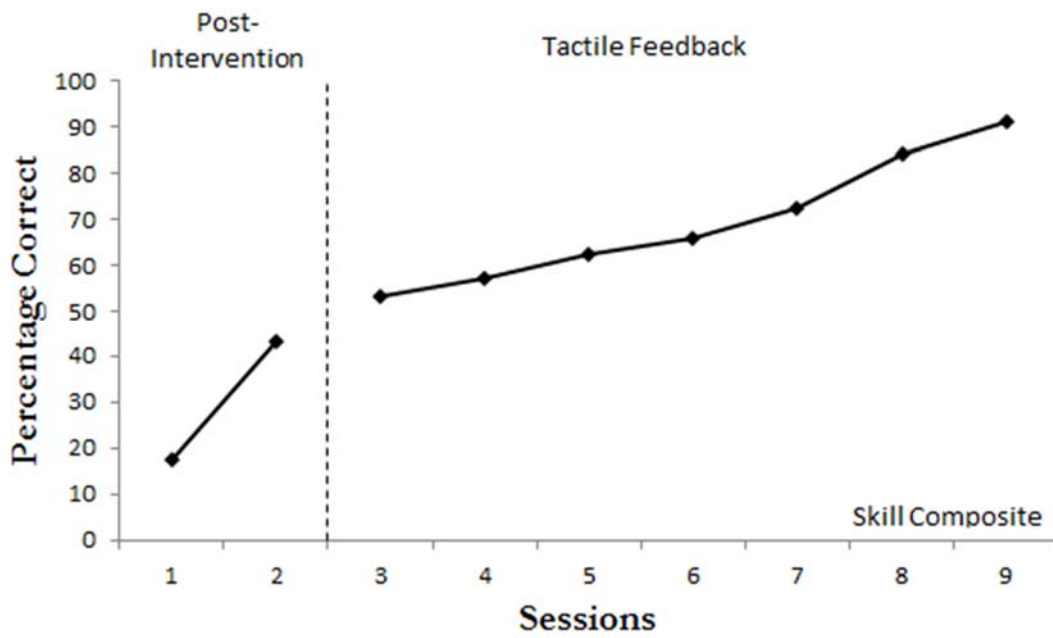
Geddy scored 17.4% and 43.3% in the first two generalization sessions. It took nine sessions with feedback until mastery criteria was achieved. IOA for Geddy was calculated for 47% of sessions and was found to be 93%. These results are depicted in figures 1 and 2 below.

### **Participant 2 (Neil)**

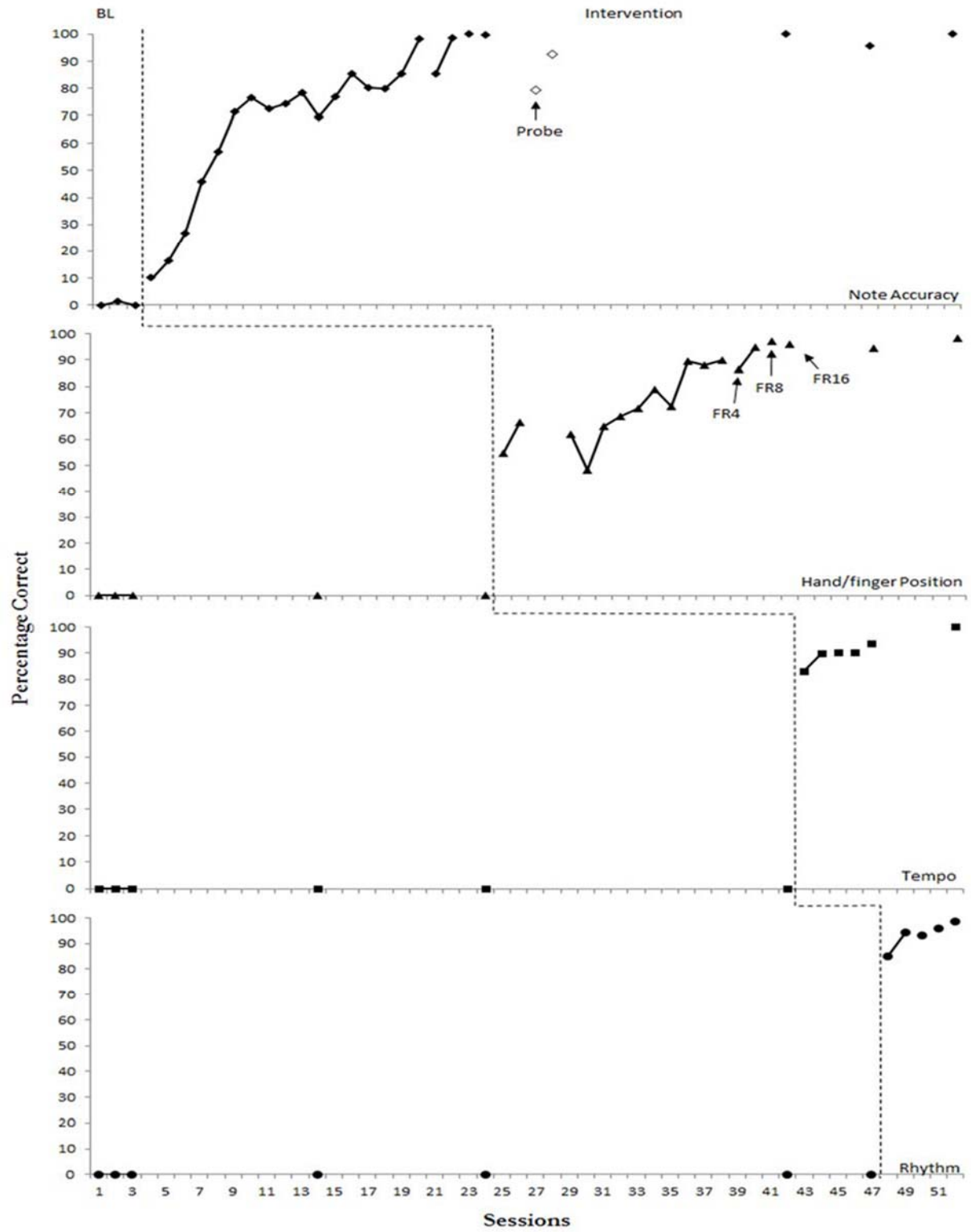
Neil indicated during pre-baseline that they had no musical experience or formal music training. Baseline consisted of 3 sessions in which Neil scored less than 1% correct across all four skill sets for all three sessions. After the tactile feedback procedure was described and the 29 notes for the note accuracy skill set were introduced, Neil played 10.0% of the notes correctly in the first intervention session. It took seventeen total sessions to achieve the mastery criteria of note accuracy and twenty one total sessions until the tactile feedback was faded while maintaining mastery. The hand and finger position task analysis was presented to Neil, who then scored 54.6% on first intervention session for hand and finger position. Mastery criteria was achieved in twelve total sessions and feedback was faded while maintaining mastery after sixteen total sessions. Neil scored 83.1% in the first intervention session for tempo following the introduction to the skill. Mastery criteria was achieved in 2 total sessions and feedback was faded while maintaining mastery after 5 total sessions. The last skill set of rhythm was introduced and Neil scored 84.8% in the first intervention session. Mastery criteria was achieved after 2 total sessions and feedback was faded while maintaining mastery after 5 total sessions. Two probe sessions were also conducted during intervention to assess maintenance of the skill sets after an extended period of time between sessions. The song for the generalization probe was introduced and demonstrated and Neil scored 15.3% and 35.6% in the first two generalization sessions. It took seven sessions with feedback to reach 72.1% correct, with acquisition trending upward toward mastery criteria. IOA was calculated for 37% of sessions and was found to be 95%. These results are depicted in figures 3 and 4 below



**Figure 1.** Percentage correct of each skill set for Geddy; open data points represent probe sessions.

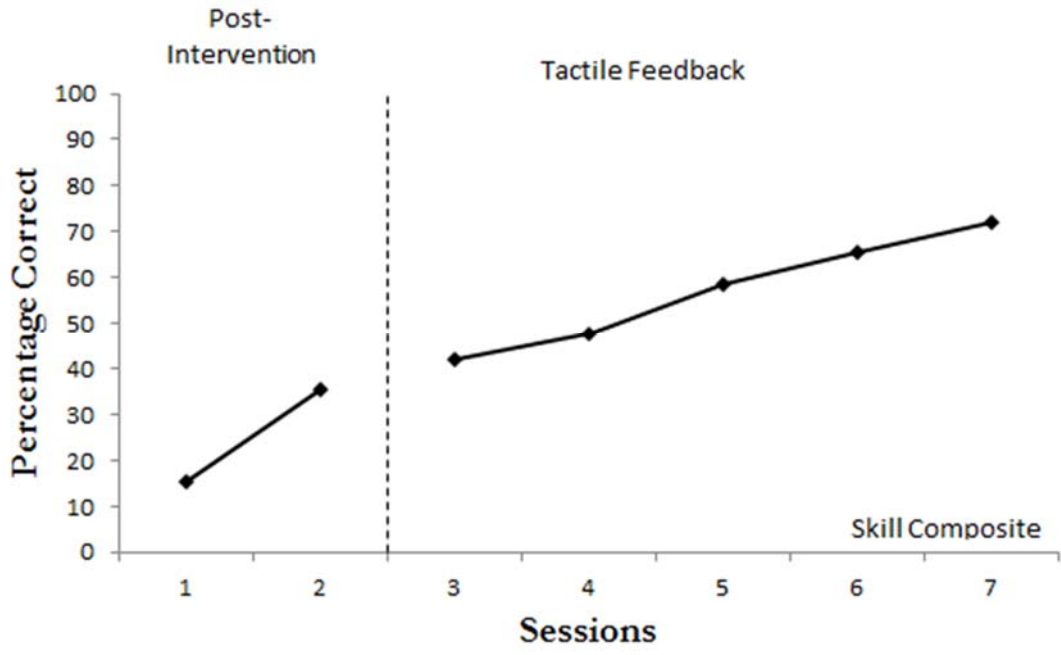


**Figure 2.** Percentage correct of a composite of all 4 skill sets for Geddy's generalization probe.



**Figure 3.** Percentage correct of each skill set for Neil; open data points represent probe sessions.

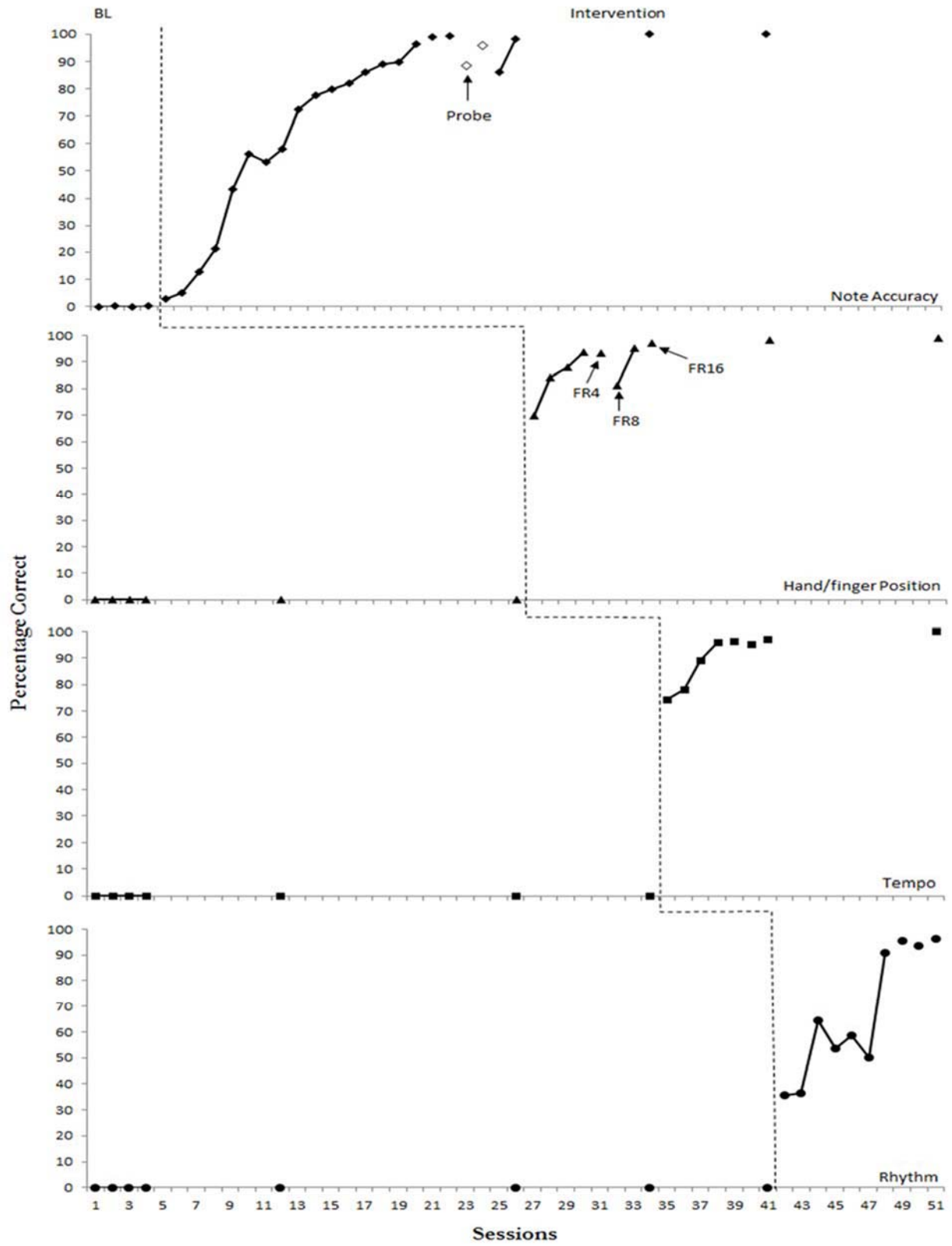


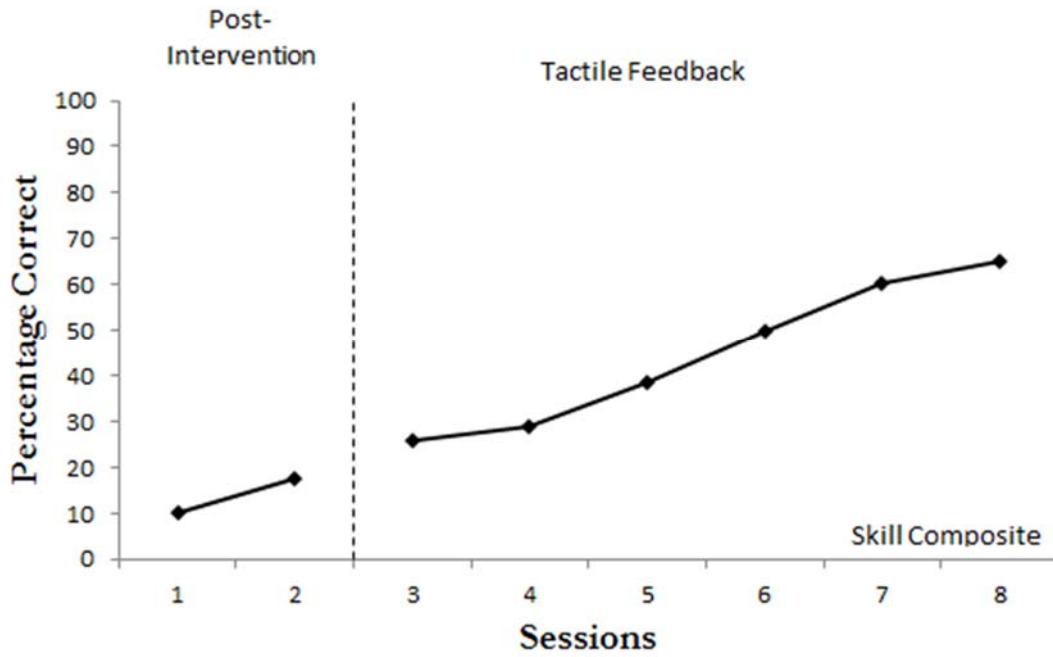


**Figure 4.** Percentage correct of a composite of all 4 skill sets for Neil’s generalization probe.

### **Participant 3 (Alex)**

Alex indicated during pre-baseline that they had no musical experience or formal music training. Baseline consisted of 4 sessions in which Alex scored 0% correct across all four skill sets for all four sessions. After the tactile feedback procedure was described and the 29 notes for the note accuracy skill set were introduced, Alex played 2.9% of the notes correctly in the first intervention session. It took sixteen total sessions to achieve the mastery criteria of note accuracy and twenty total sessions until the tactile feedback was faded while maintaining mastery. The hand and finger position task analysis was presented to Alex, who then scored 69.7% on first intervention session for hand and finger position. Mastery criteria was achieved in four total sessions and feedback was faded while maintaining mastery after eight total sessions. Alex scored 74.3% in the first intervention session for tempo following the introduction to the skill. Mastery criteria was achieved in four total sessions and feedback was faded while maintaining mastery after seven total sessions. The last skill set of rhythm was introduced and Alex scored 35.8% in the first intervention session. Mastery criteria was achieved after seven total sessions and feedback was faded while maintaining mastery after ten total sessions. Two probe sessions were also conducted during intervention to assess maintenance of the skill sets after an extended period of time between sessions. The song for the generalization probe was introduced and demonstrated and Alex scored 10.3% and 17.4% in the first two generalization sessions. It took eight sessions with feedback to reach 65.3% correct, with acquisition trending upward toward mastery criteria. IOA was calculated for 44% of sessions and was found to be 94%. These results are depicted in figures 5 and 6 below.





**Figure 6.** Percentage correct of a composite of all 4 skill sets for Alex's generalization probe.

## Social Validity

The social validity questionnaire was sent to each participant via email upon conclusion of the intervention phase. Participants completed the questionnaire with an average response of 4.6 on the 5-point likert scale, with 5 being strongly agree, 1 being strongly disagree, and 3 being neutral. The results of the social validity questionnaire for each participant, along with averages for each participant and item, can be seen below in table 1.

**Table 1:** Participant responses and averages on the social validity questionnaire.

	Geddy	Neil	Alex	Average
I feel like I have a greater knowledge of music than when I began the study	5	5	4	4.7
I found the tactile feedback process to be very effective in improving my performance	4	5	5	4.7
I found the process of learning through tactile feedback to be enjoyable	3	5	4	4
I found this whole process to be a positive experience	4	5	5	4.7
I would recommend this approach to be used in conjunction with traditional methods	5	5	5	5
Average	5	5	5	

## **CHAPTER FOUR:**

### **DISCUSSION**

This study evaluated the effectiveness of an immediate tactile feedback procedure for teaching basic introductory piano skills to new learners by teaching three unique scales, proper hand/finger positioning, rhythm and tempo, as well as a simplified arrangement of a preferred song. Results showed that all three participants successfully acquired the four skill sets through the intervention protocol. These results add to the performance feedback literature showing the effectiveness of immediate feedback procedures with respect to skill acquisition. Each participant required a different number of total sessions to master the skill sets, but they followed similar trends of acquisition. Across all phases of the study, participants met with the PI during sessions for an average of 15 hours. Note accuracy was the first skill set trained and took the longest to acquire among the participants. This was expected given that the participants were chosen for their lack of musical knowledge and experience. Both Geddy and Alex acquired the hand and finger position skill set much quicker requiring eight sessions or less. The hand and finger position skill set was predicted to be mastered in substantially fewer sessions as it builds upon the note accuracy skill set. It was also reported by the participants that learning the proper finger pattern made it easier to play the scales correctly. While Geddy took ten sessions to acquire tempo, Neil and Alex acquired them much quicker. Geddy reported that the troubles experienced with tempo early on were due to interference counting the beats in their head and using the correct numbered finger. After these struggles, they began tapping their foot in time with the metronome at the beginning of each attempt, which happened to be the approach Neil and Alex took to mastering the skill set. Aside from note accuracy, the rhythm

skill set produced the lowest initial scores for each participant. This was expected as rhythm is a more nuanced skill in both concept and notation than the previous skill sets. Rhythm also showed to be the hardest skill set to acquire requiring the most sessions aside from note accuracy, with Neil being an exception. Neil's quick acquisition of rhythm was expected based on his previous performance with the tempo skill set and the understanding he demonstrated when rhythm was first introduced. Each participant showed similar trends when learning their chosen song after the main intervention was completed. All three showed low initial levels, but were able to improve their performance without any immediate tactile feedback. However, in order to keep the participants from feeling discouraged, immediate feedback was re-introduced, and an upward trend towards mastery can be seen with all three participants.

Geddy acquired all four skill sets in 48 sessions with the addition of three probes sessions and as depicted in Figure 1. A steady upward trend was seen in acquiring the note accuracy skill resulting in achieving mastery criteria. The first probe sessions occurred during the note accuracy skill set and was conducted as there was a three week break between sessions due to time off between summer and fall semesters. Despite achieving mastery in the previous sessions, feedback was not faded for the probe as its purpose was to assess if performance maintained from the previous session. After the probe, feedback began being faded, but due to poor performance during the second step of fading (every 8 notes correct), feedback was provided for every 4 correct notes going forward. Geddy continued to demonstrate struggles, which were due to confusing the E-flat and c-sharp harmonic minor scales. Once Geddy overcame this issue, performance reached mastery again and feedback was successfully faded. Both hand/finger position and tempo showed steady upward trends and were acquired quickly with performance maintaining level above 90% during fading. Rhythm also showed an overall upward trend, but was much more variable than the other skill sets. This

was mostly due to a string of three sessions in which Geddy confused the notation between eighth notes and quarter notes. Two more probe sessions were conducted during the rhythm skill set due to another extended period of time between sessions due to time off between fall and spring semesters. The first probe assessed both note accuracy as well as hand and finger position with feedback being given for every correct note. The second probe assessed the tempo skill set with feedback being given for every correct note played in tempo. Both probes resulted in scores above 90% demonstrating maintenance despite the extended period of time between sessions. Upon completion of the probes, the rhythm skill set was quickly mastered with fading only requiring four out of a minimum 3 sessions. The generalization probe in which Geddy learned a song of their choosing began after rhythm was mastered. The song was first demonstrated by the PI and two new notations that were not used in the intervention were explained. Geddy's first attempt produced a low score on a composite of all four skills, but this is expected as this was essentially sight reading, which in music refers to playing a new song for the first time and is difficult for even experienced musicians. However, after the first attempt, correct performance increased substantially. After these two sessions, the immediate feedback was introduced again and a steady upward trend, as seen in figure 2, emerged and continued until mastery.

Neil acquired all four skill sets in 47 sessions with the addition of two probes sessions, as depicted in figure 3. An overall upward trend was seen for the note accuracy skill set, with some variability after the first seven sessions. Similar to Geddy, the variability was due to mixing up the notes between E-flat major and c-sharp harmonic minor scales. After mastery was achieved, feedback was faded in 4 sessions. The two probe sessions occurred after the first two sessions of the hand and finger position skill set. The probes were conducted as there was a three week break between sessions due to time off between fall and spring semesters. The probe



sessions assessed the note accuracy skill set for maintenance. The first probe yielded a score of 79.3%, so a second probe was conducted which produced a score of 92.5%. After the probes, training of the hand and finger position skill set resumed, with early variability followed by an upward trend to mastery criteria. Feedback was quickly faded requiring only 4 total sessions. Neil began both tempo and rhythm with relatively high scores and achieved mastery in both skill sets after only two sessions. This quick acquisition was expected as Neil demonstrated a strong understanding of the concepts when they were introduced. Both tempo and rhythm were faded quickly in 3 sessions each. Similar to Geddy, Neil performed the first session at a low level, but increased substantially after playing through the piece once and becoming familiar with it. Once again, the introduction of the tactile feedback helped facilitate learning resulting in an upward trend as seen in figure 4.

Alex acquired all four skill sets in 45 sessions with the addition of two probes sessions, as depicted in figure 5. A slow upward trend was seen for the note accuracy skill set with very little variability. After mastery was achieved, feedback was faded in 4 sessions. The two probe sessions occurred during the fading sessions as there was a three week break between sessions due to time off between fall and spring semesters. The probe sessions assessed the note accuracy skill set for maintenance. The first probe yielded a score of 88.5%, so a second probe was conducted which produced a score of 95.7%. After the probes, fading of the feedback for the note accuracy skill set resumed. Alex demonstrated upward trends for both hand/finger position and tempo, with both skill sets being mastered in four sessions. There was one low score during fading of hand and finger position, but this was considered as an outlier as Alex began two of the 18 attempts on the wrong note which resulted in 0% correct. Feedback for tempo was quickly faded requiring the minimum amount of sessions. Unlike the previous two skill sets, rhythm required more sessions and had much more variability. This variability is

attributed to Alex's struggles differentiating between the rhythmic notations for quarter notes and eighth notes. After the first two sessions, Alex demonstrated the understanding that quarter notes are twice as long in duration as eighth notes, but still struggled to play them correctly. This mainly occurred when quarter notes were immediately followed by eighth notes, leading to incorrect performance of the quarter notes. After four sessions though, Alex overcame these errors stating that they focused more on slowing down the quarter notes and did not experience as many difficulties through mastery and fading. Once this final skill set was faded, Alex began the generalization probe. As with Geddy and Neil, Alex showed poor performance in the first session, with improved performance in the second. While the improvement wasn't as substantial as the other participants, this was expected as Alex showed the slowest initial acquisition of note accuracy. However, once the immediate feedback was added, an increased upward trend emerged as seen in figure 6.

The independent variable of tactile feedback in the form of a vibrational stimulus was shown to be effective as evidenced by the results. The participants also reported that receiving the feedback immediately during each session allowed them to acquire the skill sets faster, as it allowed them to make adjustments while playing, as compared to receiving feedback at the end and having to carry that into the next session. The device worked reliably throughout the duration of the study and the participants found it to be non-obtrusive. One participant, Geddy, commented that the tactile stimulation provided by the device was not overwhelming, but still very distinct. They also reported that they were able to attend to tactile feedback while still focusing on the acoustic feedback produced by the piano itself. While this study shows the effectiveness of immediate tactile feedback, it is too early to state whether it is more effective than other sensory modalities as they were not evaluated. Overall, all three participants successfully acquired the four skill sets during intervention and this learning was supported by

each participant learning a song of their choosing. They also found the intervention to be effective and the experience of learning how to play the piano enjoyable as the average response of the social validity measure was 4.6 with 5 being the highest.

### **Limitations**

The main limitation encountered during this study was the somewhat irregular scheduling of sessions. This was due to both an inability to access the necessary facilities during semester breaks and individual changes in the participants' schedule. With the participants having no musical knowledge or experience prior to the study, it was desired to meet 4 days a week; however, the scheduling issues resulted in some weeks with only 2 meetings and in other cases none.

Another limitation was the number of sessions run per meeting. It was desired to run at least two sessions per meeting; however, depending on how long the participant took to complete a full session, sometimes only one would be conducted. This occurred mostly during the first two skills sets where one sessions would take nearly 30 minutes in some instances. This was done as a precaution to avoid burnout during an already long session.

One last difficulty encountered during this study was implementing the feedback and scoring sessions during the rhythm skill set. While treatment integrity was 97% and overall IOA was 94%, most disagreements occurred during the rhythm skill set. This was to be expected as rhythm is harder to observe as it's purely an aural concept with no visual component such as note accuracy and hand/finger position. Rhythm also tends to be a more fluid concept amongst experienced musicians. While the different notations clearly state the duration of each note, performers will sometimes take their own liberties and with rhythm to add a more individualistic style to the music they are playing. Unfortunately, there is no easy trick to improve implementation and agreement with rhythm aside from rigorous training, focus, and

experience.

### **Future Research**

This study provides the foundation for the teaching of music skill with a behavioral analytic approach. The behavior analysis literature references music as a reinforcer, but has not evaluated as a teachable skill. While this is one approach, other immediate feedback procedures can be utilized with other sensory modalities. This immediate tactile feedback procedure was shown to be effective in teaching three unexperienced learners basic piano skills; however, this shouldn't be used as a stand-alone piano pedagogical approach. In addition to extending and replicating these procedures, the bulk of future research should involve combining behavioral analytic principles, such as immediate feedback, with traditional piano teaching methods. As stated early on, some of the current approaches to piano pedagogy have been proven to be successful for over a hundred years, but could benefit greatly from basic behavior analytic principles.

## REFERENCES

- Agay, D. (2004). Elements of technique. In D. Agay, . & H. G. Skaggs, (Eds.), *The art of teaching piano: The classic guide and reference book for all piano teachers* (pp. 11-28). New York, New York: Yorktown Music Press, Inc.
- Akamatsu, M., MacKenzie, I . S., & Hasbroucq, T. (1995). A comparison of tactile, auditory, and visual feedback in a pointing task using a mouse-type device. *Ergonomics*, *38*, 816-827.
- Allison, M. G., & Ayllon, T. (1980). Behavioral coaching in the development of skills in football, gymnastics, and tennis. *Journal of Applied Behavior Analysis*, *13*, 297-314.
- Anderson, G., & Kirkpatrick, M. A. (2002) Variable effects of a behavioral treatment package on the performance of inline roller speed skaters. *Journal of Applied Behavior Analysis*, *35*, 195-198.
- Barbetta, P. M., Heward, W. L., Bradley, D. M., & Miller, A. D. (1994). Effects of immediate and delayed error correction on the acquisition and maintenance of sight words by students with developmental disabilities. *Journal of Applied Behavior Analysis*, *27*, 177- 178.
- Barmann, B. C., Croyle-Barmann, C., & McClain, B. (1980). The use of contingent-interrupted music in the treatment of disruptive bus-riding behavior. *Journal of Applied Behavior Analysis*, *13*, 693-698.

- Bennett, K., & Cavanaugh, R. A. (1998). Effects of immediate self-correction, delayed self-correction, and no correction on the acquisition and maintenance of multiplication facts by a fourth-grade student with learning disabilities. *Journal of Applied Behavior Analysis, 31*, 303-306.
- Boyer, E., Miltenberger, R. G., Batsche, C., & Fogel, V. (2009). Video modeling by experts with video feedback to enhance gymnastics skills. *Journal of Applied Behavior Analysis, 42*, 855-860.
- Bryant, Z. E., Henslee, A. M., & Correia, C. J. (2013). Testing the effects of e-mailed personalized feedback on risky alcohol use among college students. *Addictive Behaviors, 38*, 2563-2567.
- Codding, R. S., Feinberg, A. B., Dunn, E. K., & Pace, G. M. (2005). Effects of immediate performance feedback on implementation of behavior support plans. *Journal of Applied Behavior Analysis, 38*, 205-219.
- Cooper, J. O., Heron, T. E., & Heward, W. L. (2007). *Applied behavior analysis* (2<sup>nd</sup> Ed.). Upper Saddle River, New Jersey: Pearson Education, Inc.
- De Korte, E. M., Huysmans, M. A., De Jong, A. M., Van de Ven, J. G. M., & Ruijsendaal, M. Effects of four types of non-obtrusive feedback on computer behavior, task performance, and comfort. *Applied Ergonomics, 42*, 344-353.
- Deniz, J. (2012). Video recorded feedback for self regulation of prospective music teachers in piano lessons. *Journal of Instructional Psychology, 39*, 17-25.

- DiGennaro, F. D., Martens, B. K., & Kleinmann, A. E. (2007). A comparison of performance feedback on teachers' treatment implementation integrity and students' inappropriate behavior in special education classrooms. *Journal of Applied Behavior Analysis, 40*, 447- 461.
- DiGennaro-Reed, F. D., Coddling, R., Catania, C. N., & Maguire, H. (2010). Effects of video modeling on treatment integrity of behavioral interventions. *Journal of Applied Behavior Analysis, 43*, 291-295.
- Duncan, P. K., & Bruwelheide, L. R. (1985). Feedback: Use and possible behavioral functions. *Journal of Organizational Behavior Management, 7*, 91-114.
- Eriksson, M., Halvorsen, K. A., & Gullstrand, L. (2011). Immediate effect of visual and auditory feedback to control the running mechanics of well-trained athletes. *Journal of Sports Sciences, 29*, 253-262.
- Etts, M. L. (2004). What are the elements of a good piano lesson. In Agay, D., & Skaggs, H. G. (Eds.), *The art of teaching piano: the classic guide and reference book for all piano teachers* (pp. 463-465). New York, New York: Yorktown Music Press, Inc.
- Ferguson, D. L., & Rosales-Ruiz, J. (2001). Loading the problem loader: The effects of target training and shaping on trailer-loading behavior of horses. *Journal of Applied Behavior Analysis, 34*, 409-424.
- Fogel, V. A., Weil, T. M., & Burris, H. (2010). Evaluating the efficacy of TAGteach as a training strategy for teaching of golf swing. *Journal of Behavioral Health and Medicine, 1*, 25-41.

- Gunby, K. V. & Rapp, J. T. (2014). The use of behavioral skills training and in situ feedback to protect children with autism from abduction lures. *Journal of Applied Behavior Analysis, 47*, 856-860.
- Hadjakos, A., Mühlhäuser, M., & Lukowicz, P. (2011). Sensor-based feedback for piano pedagogy (Doctoral Dissertation). Technische Universität Darmstadt, Darmstadt Germany. Retrieved from <http://www.tuprints.ulb.tu-darmstadt.de/>
- Himle, M. B., Miltenberger, R. G., Flessner, C., & Gatheridge, B. (2004). Teaching safety skills to children to prevent gun play. *Journal of Applied Behavior Analysis, 37*, 1-9.
- Ho, Y., Cheung, M., & Chan, A. S. (2003). Music training improves verbal but not visual memory: cross-sectional and longitudinal explorations in children. *Neuropsychology, 17*, 439-450.
- Hume, K. M., & Crossman, J. (1992). Musical reinforcement of practice behaviors among competitive swimmers. *Journal of Applied Behavior Analysis, 25*, 665-670.
- Ingvarsson, E. T. & Hanley, G. P. (2006). An evaluation of computer-based programmed instruction for promoting teachers' greeting of parents by name. *Journal of Applied Behavior Analysis, 39*, 203-214.
- Kaufman, D., Coddling, R. S., Markus, K. A., Tryon, G. S., & Kyse, E. N. (2013). Effects of verbal and written performance feedback on treatment adherence: Practical application of two delivery formats. *Journal of Educational and Psychological Consultation, 23*, 264- 299.



- Kazdin, A. E. (2010). *Single-case research designs: Methods for clinical and applied settings* (2<sup>nd</sup> ed.). Oxford University Press: New York, NY.
- Kern-Dunlap, L., Dunlap, G., Clarke, S., Childs, K. E., White, R. L., & Stewart, M. P. (1992). Effects of a videotape feedback package on the peer interactions of children with serious behavioral and emotional challenges. *Journal of Applied Behavior Analysis, 25*, 355-364.
- Kladopoulos, C. N., & McComas, J. J. (2001). The effects of form training on foul-shooting performance in members of a women's college basketball team. *Journal of Applied Behavior Analysis, 34*, 329-332.
- Langebin, J., Siebert, K., Nurenberg, G., & Manteuffel, G. (2007). The impact of acoustical secondary reinforcement during shape discrimination learning of dwarf goats (*capra Hircus*). *Applied Animal Behaviour Science, 103*, 35-44
- Lanovaz, M. J., Rapp, J. T., & Ferguson, S. (2012). The utility of assessing musical preference before implementation of noncontingent music to reduce vocal stereotypy. *Journal of Applied Behavior Analysis, 45*, 845-851.
- Lanovaz, M. J., Sladeczek, I. E., & Rapp, J. T. (2011). Effects of music on vocal stereotypy in children with autism. *Journal of Applied Behavior Analysis, 44*, 647-651.
- Lantz, M. E., & Stawiski, A. (2014). Effectiveness of clickers: Effect of feedback and the timing of questions on learning. *Computers in Human Behavior, 31*, 280-286.

- Lerman, D. C., Vorndran, C. M., Addison, L., & Kuhn, S. C. (2004). Preparing teachers in evidence-based practices for young children with autism. *School Psychology Review, 33*, 510-526.
- Marshall, M. T., & Wanderley, M. M. (2006). Vibrotactile feedback in digital musical instruments. *Proceedings of the 2006 International Conference on New Interfaces for Musical Expression, Paris, France, NIME06*, 226-229.
- Mathews, R. M. & Dix, M. (1992). Behavior change in the funny papers: feedback to cartoonists on safety belt use. *Journal of Applied Behavior Analysis, 25*, 769-775.
- McCall, C. A., & Burgin, S. E., (2002). Equine utilization of secondary reinforcement during response extinction and acquisition. *Applied Animal Behaviour Science, 78*, 253-262.
- Miltenberger, R. G., Flessner, C., Gatheridge, B., Johnson, B., Satterlund, M., & Egemo, K. (2004). Evaluation of behavioral skills training to prevent gun play in children. *Journal of Applied Behavior Analysis, 37*, 513-516.
- Miltenberger, R. G., Gatheridge, B. J., Satterlund, M., Egemo-Helm, K.R., Johnson, B. M., Jostad, C., . . . Flessner, C. A. (2005). Teaching safety skills to children to prevent gun play: An evaluation of in situ training. *Journal of Applied Behavior Analysis, 38*, 395- 398.
- Panyan, M., Boozer, H., & Morris, N. (1970). Feedback to attendants as a reinforcer for applying operant techniques. *Journal of Applied Behavior Analysis, 3*, 1-4.
- Rauscher, F. H., Shaw, G. L., Levine, L. J., Wright, E. L., Dennis, W. R., & Newcomb, R. L. (1997). Music training causes long-term enhancement of preschool children's spatial- temporal reasoning. *Neurological Research, 19*, 2-8.

- Roke, C., Melhuish, C., Pipe, T., Drury, D., & Chorley, C. (2012). Lump localization through a deformation-based tactile feedback system using a biologically inspired finger sensor. *Robotics and Autonomous Systems, 60*, 1442-1448.
- Roscoe, E. M., Fisher, W. W., Glover, A. C., & Volkert, V. M. (2006). Evaluating the relative effects on of feedback and contingent money for staff training of stimulus preference assessments. *Journal of Applied Behavior Analysis, 39*, 63-77.
- Rubí, F. C., Montilla-Salas, X., & Sureda-Garcia, B. (2014). Pedagogical innovation and music education in Spain: Introducing the Dalcroze method in Catalonia. *Paedagogica Historica, 50*, 320-337.
- Ruckmich, C., A. (1914). The psychology of piano instruction. *The Journal of Educational Psychology, 5*, 185-198.
- Schega, L., Bertram, D., Fölsch, C., Hamacher, D., & Hamacher, D. (2014). The influence of visual feedback on the mental representation of gait in patients with THR: A new approach for an experimental rehabilitation strategy. *Applied Psychophysiology and Biofeedback, 39*, 37-43.
- Schonwetter, S. W., Miltenberger, R., & Oliver, J. O. (2014). An evaluation of self-monitoring to improve swimming performance. *Behavioral Interventions, 29*, 213-224.
- Scott, D., Scott, L. M., & Goldwater, B. (1997). A performance improvement program for an international-level track and field athlete. *Journal of Applied Behavior Analysis, 30*, 573- 575.

- Simmons-Morton, B. G., Bingham, C. R., Ouimet, M. C., Pradhan, A. K., Chen, R., Barretto, A., & Shope, J. T. (2013). The effect on teenage risky driving of feedback from a safety monitoring system: A randomized controlled trial. *Journal of Adolescent Health, 53*, 21- 26.
- Skaggs, H. G. (2004). The very young beginner. In D. Agay, & H. G. Skaggs, (Eds.), *The art of teaching piano: The classic guide and reference book for all piano teachers* (pp. 247- 252). New York, New York: Yorktown Music Press, Inc.
- Smith, S. L., & Ward, P. (2006). Behavioral interventions to improve performance in collegiate football. *Journal of Applied Behavioral Analysis, 39*, 385-391.
- Southgate, D. E., & Roscigno, V. J. (2009). The impact of music on childhood and adolescent achievement. *Social Science Quarterly, 90*, 4-21.
- Thomas-Lee, P., M. (2003). Piano pedagogy for four-and five-year olds: An analysis of selected piano methods for teaching preschool children (Doctoral Dissertation). Retrieved from <http://www.getd.libs.uga.edu/>
- Thresher, M. J. (1964). The contributions of Carl Orff to elementary music education. *Music Educators Journal, 50*, 43-48.
- Vaughn, K., & Winner, E. (2000). SAT scores of students who study the arts: What we can and cannot conclude about the association. *Journal of Aesthetic Education, 34*, 77-88.
- Ward, P., & Carnes, M. (2002). Effects of posting self-set goals on collegiate football players' skill execution during practice and games. *Journal of Applied Behavior Analysis, 35*, 1- 12.

Yu, E., Moon, K., Oah, S., & Lee, Y. (2013). An evaluation of the effectiveness of an automated observation and feedback system on safe sitting postures. *Journal of Organizational Behavior Management*, 33, 104-127.

## **APPENDICES**

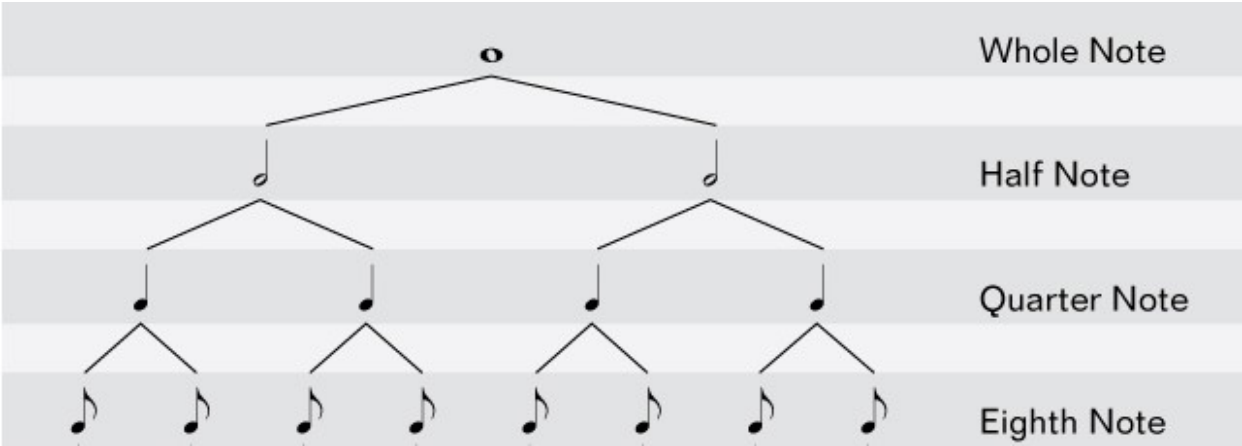
Appendix A: Instruction Materials

The image displays three piano scale exercises, each consisting of a treble and bass clef staff with fingerings indicated by numbers 1-5. The first exercise is for C major, the second for E-flat major, and the third for C-sharp harmonic minor. Each exercise is presented in a two-measure format, with the first measure showing the ascending scale and the second measure showing the descending scale. The C major exercise starts on middle C (C4) and ends on C5. The E-flat major exercise starts on E-flat4 and ends on E-flat5. The C-sharp harmonic minor exercise starts on C-sharp4 and ends on C-sharp5. The fingerings are as follows: C major (T: 1-3-1-3-1-3-1-3-1-3-1-3-1-4; B: 5-3-1-3-1-3-1-3-1-3-1-3-1-3); E-flat major (T: 3-1-4-1-3-1-4-1-3-1-4-1-3-1-4; B: 3-1-4-1-3-1-4-1-3-1-4-1-3-1); C-sharp harmonic minor (T: 3-1-1-3-1-3-1-3-1-4-1-3-1-4-3; B: 3-1-4-1-3-1-4-1-3-1-4-1-3-1).

Figure 7: C-Major, E flat-Major, and C sharp-harmonic minor scales

**Table 2:** Hand/finger position task analysis

<input type="checkbox"/> Slight bend in the wrist
<input type="checkbox"/> Curvature of fingers
<input type="checkbox"/> Proper hand placement
<input type="checkbox"/> Correct Fingering pattern



**Figure 8:** Rhythmic notation



## Appendix B: Treatment Integrity

**Table 3:** Treatment integrity checklist

Attempt number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
PI standing behind and to the left of participant	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
PI clearly indicates beginning of trial	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Remote control not visible to participant	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
PI activates feedback after correct performance	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
PI does not give any other feedback during trial	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
PI does not give any other feedback after trial	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
PI activates visual metronome (tempo only)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
PI deactivates visual metronome at appropriate time (tempo only)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

## Appendix C: Social Validity

**Table 4:** Social validity questionnaire

I feel like I have a greater knowledge of music than when I began this study	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
I found the tactile feedback to be very effective in improving my performance	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
I found the process of learning through tactile feedback to be enjoyable	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
I found this whole process to be a positive experience	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
I would recommend this approach be used in conjunction with traditional piano teaching methods	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree