AN EVALUATION OF MATRIX TRAINING TO TEACH PIANO NOTES AND
RHYTHMS TO COLLEGE STUDENTS

A Thesis

Presented to the faculty of the Department of Psychology
California State University, Sacramento

Submitted in partial satisfaction of
the requirements for the degree of

MASTER OF ARTS

in

Psychology

(Applied Behavior Analysis)

by

Emily Katherine Darcey

FALL
2016
Student: Emily Darcey

I certify that this student has met the requirements for format contained in the University format manual, and that this thesis is suitable for shelving in the Library and credit is to be awarded for the thesis.

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Lisa M. Bohon, Ph. D  Date

Department of Psychology
Abstract

of

AN EVALUATION OF MATRIX TRAINING TO TEACH PIANO NOTED AND RHYTHMS TO COLLEGE STUDENTS

by

Emily Katherine Darcey

The purpose of this study was to assess matrix training to teach twelve college students to play music notes and rhythms on the piano. We conducted two experiments using a multiple baseline design across participants. In Experiment 1, we taught participants to tact and play notes and rhythms on the piano when presented together as compound stimuli. After mastery, we tested to see if participants could tact and play the same notes and rhythms combined in different ways. We assessed whether participants could tact and play correctly when listening to audio clips with notes and rhythms, and play a musical piece with previously learned stimuli. In Experiment 2, we played a metronome in all conditions for three participants and faded out the metronome for the other participants. We tested to see whether participants could tact and play untrained compound stimuli before and after training and removed reinforcement before probes. We observed recombinative generalization, and novel piano play across all participants. During probes, no one played or tacted in the presence of audio clips proficiently. Results suggest that matrix training is an effective procedure to teach music skills to college students.

_________________________________, Committee Chair
Caio Miguel, Ph.D Date
ACKNOWLEDGEMENTS

I would like to humbly thank those who have patiently given me support and encouragement throughout my academic career. To my advisor, Dr. Caio Miguel, for setting the standard for all graduate students to become prominent researchers and clinicians in the behavior analysis community. His passion is demonstrated through the vast amount of time and energy producing quality verbal behavior research.

I would like to thank my committee members Dr. Megan Heinicke and Dr. Judah Axe, for their continuous feedback and dedication. Their suggestions have significantly enhanced these series of experiments.

To Jocelyn Diaz for dedicating an extensive amount of ongoing time and effort towards data collection. To Careen Meyer for assisting in the scientific development of the project, and for ongoing support during the editing process. I would also like to thank Maria Clara Cordeiro, Sukhvir Gill, and Svea Love for assisting with experimental development and data collection.

I am especially grateful for my fiancé and family’s understanding, love, and enthusiasm throughout the development of this project. It is their patience and support that helped make pursuing graduate school a reality.
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Chapter 1

INTRODUCTION

The emphasis on standardized testing in the areas of English, math, science, and history, compounded with recent budget cuts, has led to the removal of many music education programs in public schools (Major, 2013). Notwithstanding, there is evidence suggesting that music education supplements the overall intellectual development of children (Lim, 2010b; Lim & Draper, 2011; Hudziak et al., 2013; O’Connell, 1974). Music education has been shown to be correlated with improvements in several domains including, language acquisition (Brandt, Gebrian, & Slevc, 2012), math (Graziano, Peterson, & Shaw, 1999; Vaughn, 2000) reading (Zuk, Andrade, Andrade, Gardiner, & Gaab, 2013), social interactions and communication (Brown & Jellison, 2012; Gourgey, 1998; Jemison-Pollard, 2010; Sussman, 2009), IQ scores (Schellenberg, 2006; Kaviani, Mirbaha, Pournaseh, & Sagan, 2014), motor skills (Gilbert, 1983), joint attention (Kim, Wigram, & Gold, 2008), and decreases in vocal stereotypy in children with autism (Rapp, 2007). In addition, music may serve as an appropriate leisure skill (Hill, 2015). Given these many benefits, music instruction in schools should be required.

Various methodologies have been used to teach individuals basic musical, instrumental and/or vocal skills regardless of age or ability. The four most common procedures in music education are the Dalroze, Kodaly, Orff, and Suzuki methods (Farber, Anne & Parker, 1987; McRae, 1982; Russell-Smith, 1967; Suzuki Association of the Americas Inc., 2011). These methods vary in terms of their teaching structures (e.g.,
naturalistic versus structured) and prerequisite skills (i.e., body movements, auditory discrimination, rhythm) before exposing students to their instruments. For example, the Dalcroze method or *eurhythmics* is a developmental approach to music education in which rhythm, structure, and musical expressions are taught using body movements or kinesthetics (Farber et al., 1987). Body movements paired with rhythm (e.g., tapping feet, swaying arms, walk while singing) are taught to the students before they are exposed to traditional musical stimuli (i.e., notes on a staff). The objective is to expose students to music, develop their listener and motor skills to transition the student to an instrument or voice. Similarly, the Kodaly method teaches music through listening, singing, and rhythmic movement. Once children master these skills, they are introduced to their instrument of choice. The Orff approach capitalizes on captured incidental teaching opportunities to teach music behavior. Children learn music via exposure to singing, dancing, acting, and the use of percussion instruments as opportunities come up during active play (i.e., drums, xylophone; McRae, 1982). Finally, the Suzuki method uses a more structured approach (i.e., repetition) to teach music similarly to a parent teaching a child to speak. Students are taught how to properly clean and maintain their instrument, identify specifics of their instrument (i.e., correct finger placements), and discriminate between pitches. Then, students are required to listen to a pitch and reproduce that pitch on their specific instrument without looking at any visual materials. Through repetition, students are supposedly able to play their instrument. Even though many music students and teachers anecdotally report success with these different types of procedures, we have
not found any empirical studies aimed at evaluating and comparing the overall effectiveness of these various methods.

When learning music, a person must respond to the printed note (e.g., ‘c’) and a picture of the note (e.g., ) similarly. In other words, these two stimuli must be functionally equivalent, so individuals can respond the same way when presented with any of these stimuli. As an attempt to make music stimuli, such as textual, visual, and auditory representations of notes, acquire the same meaning, several studies have attempted to establish equivalence classes among textual, visual, and auditory stimuli using matching-to-sample procedures (MTS; Arntzen, Halstadt, Bjerke, & Halstad, 2010; Hayes, Thompson & Hayes, 1989; Perez & DeRose, 2010; Griffith, Ramos, Hill, & Miguel, in press; Hill, 2015).

For example, Griffith et. al (in press), used an auditory-visual MTS to establish three three-member equivalence classes consisting of the textual representation of a chord, its music notation, and the sound of the chord with eight typically-developing adult participants. First, researchers taught participants to identify the textual representation of the chord (e.g., c major), then to select the correct music notation (e.g., ) and play the chord on the piano when presented with the dictated chord name (e.g., ‘c major’). Researchers tested for the emergence of playing the chord on the piano in both the presence of the musical notation and textual representation of the chord. In addition, they tested whether participants could identify the correct music notation in the
presence of the textual representation (i.e., pointing to “C” in the presence of and the textual representation of the chord in the presence of the music notation (i.e., pointing to in presence of “C” as the sample. Participants were also tested on whether they could play the previously taught relations within a novel sequence of chords that made up a familiar musical piece on the piano. Results indicated that this procedure was effective in producing the emergence of all untrained relations, suggesting that the letters and notes became functionally equivalent to one another. These results were systematically replicated with four typically developing children and four children with autism (Hill, 2015).

In all of the studies mentioned above, researchers only trained one type of stimulus class (i.e., notes/chords, letters, note values). However, an effective musician must respond similarly in the presence of several arbitrary stimuli such as pitch, rhythm, dynamics, notes, articulation, and other related stimuli that demonstrate stimulus control over musical behavior when someone is performing a music piece. Accurate responding in the presence of music stimuli is essential to being a successful musician. Since there are several stimuli to be taught directly, matrix training may be an alternative to typical music instruction (Goldstein & Mousetis, 1989).

Matrix training is an instructional technique that relies on simple discrimination of compound stimuli (rather than conditional discrimination), to create a specified number of untaught responses with at least two individual components in the presence of
novel stimulus combinations (Pauwels, Ahearn, & Cohen, 2015). In most cases, matrix training includes direct training of only a few compound stimuli followed by tests of untaught responses in the presence of novel stimulus combinations. For example, in a 3 X 3 grid of three columns (i.e., colors) and three rows (i.e., objects), a person is taught to tact some, but not all the cells (i.e., color-object combinations). Once the person can reliably and accurately tact in the presence of a few compound stimuli, then the individual components (i.e., single stimuli) of the previously trained compounds are switched into six novel compounds. In other words, these components were never paired together before. Responding accurately in the presence of these recombinations has been defined as recombinative generalization (Goldstein, 1983a). Often, matrix training does not comprise of training individuals to respond to single stimuli (i.e., objects, colors), but teaching them to respond to entire combinations (Pauwels et al., 2015). Because of this teaching structure, matrix training has been shown to be an effective and efficient teaching tool (Axe & Sainato, 2010).

Matrix training may include non-overlap (NOV) and/or overlap (OV) procedural elements (Foss, 1968a). In the NOV, the cells (i.e., combinations) that fall along the diagonal of the matrix are taught directly. Each component is taught once in combination with other components without overlap. For example, if red boat and blue car are taught in a 2 X 2 matrix, each component (i.e., blue, red, boat, car) is presented only one time (i.e., no overlap). In the OV procedure, some components are presented more than once during training. For example, if red boat and red car are taught in a 2 x 2 matrix, red is
presented twice, whereas the objects are only presented once. If participants have no prior knowledge of the components, Goldstein (1983a) recommends using OV because it may aid them in forming the key discriminations required for recombinative generalization. This was confirmed by Foss (1968a) who found that none of their typically developing adult participants exposed to NOV could tact colors and shapes correctly in the presence of novel recombinative stimuli. After Foss incorporated OV training, participants’ tacted colors and shapes correctly when combined into compound stimuli. Goldstein (1983a) stated that in some cases, OV training may not be necessary for recombinative generalization to occur if participants have had previous exposure to some of the component stimuli. Based on Goldstein’s findings, NOV training is best suited for learners who already have previous knowledge of components in the matrix.

Despite Goldstein (1983a), Pauwels et al. (2015) sought to extend upon Foss (1968a) by comparing NOV and OV training structures to teach three children and adults with autism (ages 13-20) to tact object locations using prepositions. Their results were comparable to the aforementioned studies in that recombinative generalization was observed. However, the NOV procedure was sufficient to produce recombinative generalization even when some of the individual components (i.e., objects, locations, prepositions) were not in the participants’ tacting repertoire. These results contradicted Goldstein’s (1983a) conclusions who suggested that NOV training could be effective only if participants are familiar with some of the components prior to training.
Much of the research on matrix training have recruited participants with intellectual disabilities (Axe and Sainato, 2010; Frampton, Wymer, & Hansen, 2016; Goldstein, Angelo, & Mousetis, 1987; Goldstein and Brown 1989; Goldstein and Mousetis 1989; Karlan et al., 1982; Kinney, Vedora, & Stromer, 2003; Kohler and Malott, 2014; Light, Watson, & Remington, 1990; Pauwels et al., 2015; Remington, Watson, & Light, 1990; Riberio et al., 2015; Striefel, Wetherby, B., & Karlan, 1978) and employed either the NOV and/or the OV training structure as described by Foss (1968a) and Pauwels et al. (2015). Within those studies, target responses were either listener responses, such as instruction following (Axe and Sainato, 2010; Ribeiro et al, 2015; Striefel et al., 1978), tacts, such as noun-verb combinations (Frampton et al., 2016; Karlan et al., 1982; Light et al., 1990; Remington et al., 1990), or both tact and listener responses, such as tacting and identifying shape-pattern combinations (Goldstein et al., 1987; Goldstein and Brown, 1989; Goldstein and Mousetis, 1989).

For example, Goldstein and Mousetis (1989) taught six children with intellectual disabilities to combine known words into two (i.e., object-location) to three-word (i.e., object-preposition-location) utterances with the use of peer modeling. During baseline and training trials, the experimenter placed an object in a specific location and asked, “What did I do?” to either the peer model or the participant. Both children needed to describe the event with either a two (i.e., shoe speaker) or three-word utterance (i.e., shoe on speaker). Listener trials consisted of the experimenter asking participants, “Put the [object] [location]” or “Put the [object] [preposition] [location]” (e.g., put the pen in front
of the chair). Because of matrix training, recombinative generalization was demonstrated by participants’ tacting object-preposition-locations and placing objects in locations that have not been paired together before. Ribeiro et al. (2015) also conducted listener matrix training to teach five children with intellectual disabilities (auditory-visual) to select shapes and patterns and tested for recombinative generalization of tact and listener repertoires. Four out of the five participants demonstrated recombinative tact repertoires (i.e., speaker) and selection repertoires (i.e., listener). The participant who did not respond correctly during posttests appeared to lack prerequisite speaker and listener skills (Horne & Lowe, 1996). Frampton et al. (2016) stated recombination itself may serve as a higher order operant (i.e., behavioral cusp). Thus, participants who did not show recombinative generalization may not have demonstrated the appropriate prerequisite skills required for recombination to occur.

Previous studies evaluated the emergence of untrained tact and listener responses. For evaluating untrained tact responses, Kohler and Malott (2014) used video modeling and matrix training to teach speaker behavior (i.e., tacts) in the form of subject-verb-objects (SVO) to two 5-year old children diagnosed with autism. After pre-training, probes for the S-V-O sentences were conducted by the experimenter asking, “What” when presented with a video to ensure the participants could not tact known subjects, verbs, and objects as compound stimuli. After training, experimenters probed for tacts of untrained S-V-O sentences within the current matrix as well as novel matrices (i.e., unknown components). Results showed that both participants only needed to be trained
to tact a few sentences directly before demonstrating generalized responding within and across matrices. This suggests that teaching a few targets directly via speaker training alone can result in the emergence of numerous similar, untaught responses.

An equally important component of verbal behavior research is listener training. For example, Axe and Sainato (2010) taught four children with autism (ages four to five) to engage in different actions with writing utensils and pictures (i.e., listener responses) via matrix training. During probes, the researcher showed a piece of paper including targets from the matrix mixed with distractors, a cup filled with writing utensils, and gave the instruction, “Get ready, [action] the [item].” Untrained combinations (i.e., all other targets outside of the diagonal) were probed following training. Overall, three of the four participants performed the untrained actions (e.g., underline the deer) with familiar stimuli in novel combinations demonstrating recombinative generalization of instruction following. Emergence of a recombinative, generative repertoire may be explained by the establishment of stimulus control for individual parts of the instruction. Specifically, the action portion of the discriminative stimulus (e.g., highlight, underline, stamp) evoked selection of a certain writing instrument, the image evoked selection of a specific picture (e.g., pepper, deer, tape), and the action instruction evoked an action (e.g., grabbing the highlighter). After stimulus control was established with the individual components, they could be replaced with additional components to account for novel action-picture responses. This explanation is corroborated by Ribeiro et al. (2015), in which one participant did not demonstrate correct speaker behavior (i.e., tact) following listener
training. His performance during listener posttests for the individual components (i.e., shapes, patterns) led to the conclusion that his behavior was controlled by shapes, but not patterns. An explanation for Axe and Sainato’s (2010) participant who did not engage in responding in the presence of untrained combinations may have to do with the participant attending to irrelevant features of a stimulus or only attending to one component rather than the action and picture as a compound. This is not an uncommon outcome when attempting to teach compound stimulus control (e.g., Miguel et al., 2015; Ribeiro et al., 2015).

As evidenced by previous research, the advantage of matrix training can best be explained by its overall efficiency (Axe and Sainato, 2010). In NOV training, relations are taught directly from the diagonal of the matrix, but researchers may not necessarily have to teach each combination individually. For example, within a 6 x 6 matrix, if only six of those relations are taught directly, then a total of 30 new combinations could potentially emerge. Because of this, matrix training may potentially take fewer trials to teach a set of skills. When teaching a new skill in which participants have no previous knowledge of either components, an OV matrix training structure may better lead to a recombinative repertoire because it expedites discrimination of the individual components since each component is paired together at least twice (Foss, 1968a). To date, no one has attempted to apply matrix training to music education. Therefore, the purpose of this study was to assess matrix training in an OV format to teach college students to tact and play notes and rhythms on the piano.
Chapter 2

EXPERIMENT 1

Method

Participants

Participants were six typically developing college students (Neo, 25; Oracle, 32; Trinity, 21; Kali, 24; Persephone, 22; and Morpheus, 34), enrolled at California State University, Sacramento (CSUS). They had no prior formal musical training, experience playing an instrument, or prolonged exposure to musical stimuli such as notes, rhythms, articulations, dynamics, and/or the musical staff. Prior to the study, participants were given a questionnaire which assessed for general familiarity with musical terms (see Appendix A and description below). Participants had to score 33% or below on the questionnaire to be included in the study.

Setting and Materials

Sessions were all conducted in the Verbal Behavior Research Laboratory (3 x 5m) at CSUS. The laboratory contained three tables, three computers, and six chairs. Each session lasted between 90 to 120 min in duration with 5-min breaks approximately every 30 min. If a session lasted up to 120 min in duration before participants complete training, the experimenter scheduled additional 90 to 120 min sessions within the same week until participants completed all conditions.

Experimental materials were two white binders (21.59 x 29.54 cm), musical stimuli in clear binder sleeves (21.59 x 29.54 cm; see description below), a full-sized
Casio LK-165 piano keyboard, an On Stage Classic Single-X keyboard stand, a Pro Metronome android phone application, a Manhasset M48 Symphony music stand and a Sony Handycam CX405 video camera. The musical stimuli included notes on a music staff (e.g., C, D, E, F, G, and A) and rhythms (i.e., a whole-note, a half-note, a quarter-note, a group of eighth-notes, a group of sixteenth notes and a dotted half-note; see Fig. 1). For all conditions, participants sat in a chair with the piano and music stand in front of them. A binder containing the musical stimuli was placed on the music stand facing participants. During training conditions, the experimenter played a metronome which emitted short, steady tones at approximately 60 beats per minute. The primary researcher stood approximately 30 cm to the left of participants, and all experimental sessions were videotaped for data collection purposes. A secondary observer sat adjacent to the primary investigator and behind participants to collect interobserver agreement (IOA) data.
We used a nonconcurrent multiple baseline design across participants (Watson & Workman, 1981) to assess the effects of matrix training on the acquisition of speaker behavior (i.e., tacts) and piano playing. Participants were exposed to two tiers of the matrix consecutively (see figure 1). Experimental conditions were presented as follows: Pre-Training Probe, Training 1, Training 2, Remedial Training (if necessary), Component
Training (if necessary), Post-Training Probe 1, Post-Training Probe 2, Music Probe, Name/Play-By-Ear Probe and Follow-up Music Probe (see Table 1).

Table 1.

*Experiment 1 Relations. The letters represent music notes and the numbers represent rhythms (see figure 1).*

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Relations Tested</th>
<th>Trials per Block</th>
<th>Training and Testing Criterion</th>
<th>Feedback Provided</th>
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<tr>
<td>1. Questionnaire</td>
<td>N/A</td>
<td>N/A</td>
<td>33% or below</td>
<td>0%</td>
</tr>
<tr>
<td>2. Pre-Training Probe</td>
<td>C1, D1, D2, E2, E3, F3, F4, G4, G5, A5, A6</td>
<td>22</td>
<td>1 (or 3) at 33% or below</td>
<td>0%</td>
</tr>
<tr>
<td>3. Training 1</td>
<td>C1, D1, D2, E2, E3</td>
<td>10</td>
<td>2 at 100% w/ metronome; 1 at 100% w/o metronome</td>
<td>100%</td>
</tr>
<tr>
<td>4. Remedial Training 1*</td>
<td>C1, D1, D2, E2, E3</td>
<td>10</td>
<td>2 at 100% w/ metronome; 1 at 100% w/o metronome</td>
<td>100%</td>
</tr>
<tr>
<td>5. Note Component Training 1**</td>
<td>C, D, E</td>
<td>6</td>
<td>2 at 100%</td>
<td>100%</td>
</tr>
<tr>
<td>6. Rhythm Component Training 1**</td>
<td>1, 2, 3</td>
<td>6</td>
<td>2 at 100% w/ metronome; 1 at 100% w/o metronome</td>
<td>100%</td>
</tr>
<tr>
<td>7. Post-Training Probe 1</td>
<td>C2, C3, D3, E1</td>
<td>8</td>
<td>1 at 80%</td>
<td>0%</td>
</tr>
<tr>
<td>8. Name/Play-By-Ear Probe 1</td>
<td>C1, C2, C3, D1, D2, D3, E1, E2, E3</td>
<td>18</td>
<td>N/A</td>
<td>0%</td>
</tr>
<tr>
<td>9. Training 2</td>
<td>C1, D1, D2, E2, E3, F3, F4, G4, G5, A5, A6</td>
<td>22</td>
<td>2 at 100% w/ metronome; 1 at 100% w/o metronome</td>
<td>100%</td>
</tr>
<tr>
<td>10. Post-Training Probe 2</td>
<td>C4, C5, C6, D4, D5, D6, E4, E5, E6, F1, F2, F5, F6, G1, G2, G3, G6, A1, A2, A3, A4, A5, A6</td>
<td>42</td>
<td>1 at 80%</td>
<td>0%</td>
</tr>
<tr>
<td>11. Remedial Training 2*</td>
<td>C1, D1, D2, E2, E3, F3, F4, G4, G5, A5, A6</td>
<td>22</td>
<td>2 at 100% w/ metronome; 1 at 100% w/o metronome</td>
<td>100%</td>
</tr>
</tbody>
</table>
The dependent variables of interest were the percentage of correct responses during each probe and total number of trials to mastery criterion for tact and playing during Training. Data were collected for both tact and play responses to assess if a response component was acquired quicker than the other. Correct tact responses included vocally stating the correct note-rhythm combinations (e.g., saying “half note D” when given the visual representation of “half note D” on a music staff) when presented with experimental stimuli within 5s of the instruction. Correct play responses included placing fingers on the correct piano key, as well as depressing keys with the correct rhythm (e.g., playing whole note C when given the visual representation of ‘whole note C’ on a musical staff), when presented with experimental stimuli within 5 s of the instruction. Incorrect responses consisted of tacting in the presence of the visual representations of musical stimuli (i.e., notes and rhythms) that do not correspond with the experimenter’s
instruction, placing the fingers on the incorrect piano keys, playing the incorrect rhythm or not responding within 5 sec of the experimenter’s instruction. Responses were defined as trained and untrained. Trained responses were defined as tact and play responses that occurred in the presence of note-rhythm combinations derived from the diagonal of the matrix plus a few additional cells outside of the diagonal (i.e., OV). Untrained responses were defined as tact and play responses that occurred in the presence of note-rhythm combinations derived from all other cells in the matrix (i.e., blank cells; see Fig. 1 – Matrix).

**Interobserver agreement (IOA) and Treatment Integrity (TI)**

Trial-by-trial IOA data and TI data were either scored in vivo or via video by a trained second observer. IOA was calculated for each session by dividing the number of agreements by the total number of agreements and disagreements and converting the result to a percentage. For Neo, data were collected on 97.2% of sessions, with a mean agreement of 96.7% (range, 80% to 100%). For Oracle, data were collected on 98.1% of sessions, with a mean agreement of 97.9% (range, 84.2% to 100%). For Trinity, data were collected on 100% of sessions, with a mean agreement of 99.1% (range, 83.3% to 100%). For Kali, data were collected on 100% of sessions, with a mean agreement of 98.9% (range, 90% to 100%). For Persephone, data were collected on 100% of the sessions, with a mean agreement of 97.6% (range, 80% to 100%). For Morpheus, data were collected on 100% of the sessions, with a mean agreement of 97.6% (range, 84.2% to 100%).
TI was either scored in vivo or via video by a trained second observer. A checklist was developed that outlined each step of the procedures for each condition. The second observer observed a trial, then recorded a plus if the step was completed as outlined or a minus if any deviations from the outlined procedures were observed. The TI score was calculated by dividing the number of steps completed with integrity (scored as a plus) by the total number of steps and converting the result to a percentage. For Neo, TI data were collected on 97.2% of sessions, with a mean score of 98.3% (range 86.7% to 100%). For Oracle, TI data were collected on 98.1% of sessions, and TI was 97.9% (range 80% to 100%). For Trinity, TI data were collected on 100% of sessions, with a mean score of 99.8% (range, 96.3% to 100%) TI. For Kali, TI data were collected on 100% of sessions, with a mean score of 99.9% (range, 98.4% to 100%) TI. For Persephone, TI data were collected on 100% of sessions, with a mean score of 98.6% (range, 90% to 100%) TI. For Morpheus, TI data were collected on 100% of sessions, with a mean score of 99.7% (range, 93.3% to 100%) TI.

**Procedures**

**Music Assessment.** We asked participants to complete an assessment containing ten questions regarding musical knowledge (i.e., “what note is it”, “circle the note c”, “draw a whole note”; see Appendix A) to rule out any previous formal exposure or history with musical stimuli (Griffith et al., in press).

Participants included in the study scored 33% or below to move on to the next condition (i.e., three or less questions correct).
**Pre-Training Probe.** The purpose of this condition was to measure participants’ tact and play responses to relations targeted for training (i.e., C1, D1, D2, E2, E3, F3, F4, G4, G5, A6; see figure 1) to rule out previous history with the experimental stimuli. Eleven cells from the full matrix were presented twice in one 22-trial block or three 22-trial blocks for the second participant in the dyad prior to training specific cells directly.

Before each trial block, the experimenter provided the following instructions on how to complete the task:

I’m going to show you a binder with pictures of music. When I show you a picture, I will ask you, ‘What is it?’ Then, I will give you some time to answer. Once you answer, I will ask you to ‘Play it’ on the piano. I will give you time to play. I will not tell you how you did, but the harder you try the faster you will go. So please give your best answer. Can you tell me what the instructions are? Do you have any other questions? Let’s begin.

During each trial, the experimenter presented a binder with a picture of one of the cells from the matrix (i.e., C1, D1, D2, E2, E3, F3, F4, G4, G5, A6). For each trial, the experimenter presented the binder with the picture along with the instruction, “What is it?” Once participants responded, the experimenter started the second half of the trial by asking participants to look at the same picture and to “Play it” on the keyboard. Once participants finished playing the piano, the experimenter immediately presented the next trial. To score a trial as correct, participants needed to correctly and independently tact the name of the picture and play the note and rhythm (i.e., current picture in the binder) on the keyboard. No programmed consequences followed any response (i.e., correct, incorrect, no response after 5s). Noncontingent praise (i.e., “Keep it up” “Almost there”)
unrelated to participants’ performance was provided every two trials during intertrial intervals. All participants scored below 33% and moved onto training.

**Matrix Training.** The aim of this condition was to teach participants to tact in the presence of compound stimuli (i.e., note-rhythm combination), to use the correct finger placement on the piano keys, play the correct rhythmic sequence (e.g., playing a c note for four counts) when presented with the visual of the musical note-rhythm combination (e.g., whole note c) and an instruction (e.g., “What is it?”). The cells targeted for Training 1 were C1, D1, D2, E2, and E3 (i.e., diagonal cells plus two additional cells from S1). These five cells were presented twice in 10-trial blocks. The cells targeted for Training 2 were C1, D1, D2, E2, E3, F3, F4, G4, G5, A5, and A6 (i.e., full matrix diagonal cells plus five additional cells from S2). These eleven cells were presented twice in 22-trial blocks. The cells from Training 1 were included in Training 2 in a mixed training format to maintain responding for the individual components taught directly from Training 1. Prior to the first block (with assistance), the experimenter provided instructions on how to complete the task:

Now, I’m going to show you a binder with pictures of music. When I show you a picture, I will tell you what it’s called. Then I will ask you, ‘What is it?’ Once you repeat my answer, I will show you how to play it on the piano and have you play after me. This time, I will let you know if you did it right. Can you tell me what the instructions are? Do you have any other questions? Let’s begin.

Before each trial block, the experimenter turned on the metronome which played short, steady tones throughout at 60 beats per minute. A training trial consisted of presenting a visual representation of the note-rhythm combination from the binder,
followed by the experimenter immediately telling the participant the correct answer (e.g., “This is called whole note C”). Contingent on the participant vocally imitating the experimenter’s response, the experimenter provided praise (e.g., “That’s correct!”). Then, the experimenter demonstrated how to play the note-rhythm combination on the piano (e.g., “This is how you play quarter note E”, then the experimenter plays quarter note E on the piano). Contingent upon participants performing the correct note-rhythm sequence, the experimenter provided praise, and immediately presented the next trial. After two blocks with assistance, the experimenter provided instructions on how to complete the task:

Just like before, I’m going to show you a binder with pictures of music. When I show you a picture, I will ask you, ‘What is it?’, then I will give you some time to answer. Next, I will ask you to play it on the piano and give you time to play the piano. I will tell you if you answered the question correctly. If you answered it wrong, I will tell you no, then tell you or show you the right answer. Once you hear the correct answer, repeat after me. Can you repeat the instructions back to me? Do you have any other questions? Let’s begin.

If participants correctly tacted the name corresponding with the visual stimulus and/or played the note-rhythm combination correctly within 5s, the experimenter delivered praise. For example, the experimenter asked, “What is it?”. Contingent upon participants’ tacting “whole note C”, the experimenter said “That’s correct”. For each trial to be considered correct, participants needed to both independently tact and play the note-rhythm combination.

An incorrect response (i.e., tacting the incorrect stimulus; playing the incorrect note, rhythm [or both], engaging in a response other than the target response in between
the instruction and the prompt or no response within 5s of the instruction) was followed by the experimenter saying, “no it’s ____” (for tact) or “no, you play ____ like this” followed by playing the correct response. Once participants imitated the experimenter’s model, the experimenter moved on to the next trial. Mastery criterion was two blocks (both tacting and playing) at 100% correct independent responding with a metronome playing, and one block at 100% correct independent responding without a metronome. Regression criterion was three consecutive trials within a trial block. If the session ended during training, then the experimenter conducted one review block with assistance at the start of the next session prior to testing.

**Post-Training Probes 1 and 2.** The purpose of these conditions was to measure participants’ tact and play responses immediately after each training to assess if matrix training was effective in teaching notes and rhythms via tact and play training. Following Training 1 and Training 2, the experimenter probed untrained cells (e.g., combinations of trained musical stimuli that were never paired together during training) from either tier 1 or tier 2. For example, when participants were trained to tact and play cells C1 (e.g., whole-note C) and D2 (e.g., half-note D) directly, cells C2 (e.g., half-note C) and D1 (whole-note D) were probed (See figure 1).

Before each trial block, the experimenter provided the following instructions on how to complete the task:

I’m going to show you a binder with pictures of music. When I show you a picture, I will ask you, ‘What is it?’ Then, I will give you some time to answer. Once you answer, I will ask you to ‘Play it’ on the piano. I will give you time to play. I will not tell you how you did, but the harder you try the faster you will go. So please give your best
answer. Can you tell me what the instructions are? Do you have any other questions? Let’s begin.

During each trial, the experimenter presented the binder with a picture of one of the untrained cells from a submatrix (i.e., S1 – C2, C3, D3, E1; S2- C4, C5, C6, D4, D5, D6, E4, E5, E6, F1, F2, F6, G1, G2, G3, G6, A1, A2, A3, A4, A5). Post-training Probe 1 included all S1 untrained cells twice in 8-trial blocks. Post-training Probe 2 included all S2 untrained cells twice in 42-trial blocks. For each trial, the experimenter presented the binder with the picture along with the instruction, “What is it?” Participants had 5s to respond, after which, the experimenter started the second half of the trial by asking participants to look at the same picture and to “Play it” on the keyboard. Participants had 5s to respond, after which the experimenter presented the next trial. To score a trial as correct, participants needed to correctly and independently tact the name of the picture and play the note and rhythm (i.e., current picture in the binder) on the keyboard. No programmed consequences followed any response (i.e., correct, incorrect, no response after 5s). Noncontingent praise (i.e., “Keep it up” “Almost there”) unrelated to participants’ performance was provided approximately 2 sec after the end of every two trials. If participants said, “I don’t know” during a trial, the experimenter vocally prompted them, “Please give your best answer”.

Passing criterion was one block at 80% or above. Scoring below 50% lead to Remedial Training (see Remedial Training condition for details). If participants scored above 50% and below 80%, the experimenter conducted an additional block. If there was an increasing trend (i.e., participants score higher than their previous score) the
experimenter conducted additional blocks until responding stabilized. After three blocks (i.e., S1 - 8-trial blocks; S2 – 42-trial blocks), if participants continued to score below 80% correct responding, Remedial Training was conducted.

**Remedial Training.** If participants failed either Post-Training Probe, the experimenter retaught the previously trained cells (i.e., matrix training). Remedial Training had the same prompting procedure, and mastery criterion as the training condition described above. Once the mastery criterion was met, the experimenter conducted the same Post-Training Probe.

**Component Training.** If participants failed the probe following Remedial Training, they received Component Training on either notes or rhythms depending on their performance during Post-Training Probes. For example, if participants incorrectly tacted (e.g., said ‘whole note D’ in the presence of the visual representation of whole note C) or played (i.e., played whole note D in the presence of the visual representation of whole note C) notes, then they were exposed to Note Component Training. If participants incorrectly tacted (e.g., said ‘whole note C’ in the presence of the visual representation of half note C) or incorrectly played (e.g., played ‘whole note C’ in the presence of the visual representation of half note C) rhythms, then they were exposed to Rhythm Component Training. If there was not a significant difference in incorrect responses between the notes and rhythms, then the experimenter automatically defaulted to Note Component Training.
Prior to the beginning of Component Training with assistance (two trial blocks), the researcher gave specific instructions on how to proceed through the task:

This time, I’m going to show you a binder with pictures of notes (or rhythms). When I show you a picture, I will tell you what it’s called. Then I will ask you, ‘What is it?’ Once you repeat my answer, I will show you how to play it on the piano and have you play it after me. This time, I will let you know how you did. Can you tell me what the instructions are? Do you have any other questions? Let’s begin.

Prior to each rhythm trial block, the experimenter turned on the metronome which played short and steady tones throughout. Note Component Training was conducted without a metronome. A training trial with assistance consisted of presenting a visual of a note (or rhythm) in the binder, followed by the experimenter immediately telling the participant the correct answer (e.g., “This note is C”). Contingent on the participant vocally imitating the experimenter’s response, the experimenter provided praise (e.g., “That’s correct!”). Then, the experimenter demonstrated playing the note on the piano (e.g., “This is how you play E”). Contingent upon participants playing the correct note, the experimenter provided praise, and immediately presented the next trial. After two blocks with assistance, the researcher gave specific instructions on how to proceed through the task:

Just like before, I’m going to show you a binder with pictures of notes (or rhythms). When I show you a picture, I will ask you, ‘What is it?’, then I will give you some time to answer. Next, I will ask you to play it on the piano and give you time to play the piano. I will tell you if you answered the question correctly. If you answered it wrong, I will tell you no, then tell you or show you the right answer. Once you hear the correct answer, repeat after me. Can you repeat the instructions back to me? Do you have any other questions? Let’s begin.
If the participants correctly tacted in the presence of the note (or rhythm) within the 5s of the instruction, the experimenter delivered praise. For example, the experimenter asked, “What is it?”. Contingent upon participants’ tacting the correct note or rhythm (e.g., ‘C’, ‘Half note’), the experimenter said, “That’s correct”. In order for each trial to be considered correct, participants needed to both independently tact and play the correct note (or rhythm). If participants’ incorrectly tacted in the presence of the note or rhythm (e.g., ‘C’ in the presence of the visual for ‘D’, ‘Half note’ in the presence of the visual representation for ‘Whole note’), played the incorrect note or rhythm (e.g., played ‘Half note C’ in the presence of the visual representation for ‘Whole note C’) or did not respond when presented with the visual within 5s, the experimenter vocally modeled the correct response and/or played the correct response, as explained below.

An incorrect response (i.e., tacting the incorrect stimulus; playing the incorrect note, rhythm, engaging in a response other than the target response in between the instruction and the prompt, or no response within 5s of the instruction) was corrected in the same manner as Training and Remedial Training.

Rhythm Component Training had the same mastery and regression criteria as Training. Mastery criterion for Note Component Training was two blocks at 100% correct responding. Once the mastery criterion was met, the experimenter conducted an additional Post-Training Probe.

Music Probe. The purpose of this condition was to test for generalization of previously taught and untaught cells within the novel context of an unfamiliar musical
piece (Hill, 2015). Participants were shown a sequence of note-rhythm combinations and were asked to play the sequence on the piano. The sequence was unfamiliar to participants. In other words, the experimenter did not ask them to play any musical selections that may be familiar to participants (i.e., Mary had a little lamb).

Prior to the beginning of the probe, the researcher gave specific instructions on how to proceed through the task:

Now you are going to play a musical piece. I will not tell you if you played it correctly or incorrectly, but the harder you try, the faster you will go, so do your best. Please repeat the instructions. Do you understand? Let’s begin.

No programmed consequences followed all responses (correct, incorrect, or no response). Noncontingent praise was delivered approximately 2 sec after the end of every two trials regardless of participants’ performance.

Passing criterion was one block at 70% or above. Scoring below 50% lead to Remedial Training (see Remedial Training condition for details). If participants scored above 50% and below 70%, the experimenter ran an additional block. If there was an increasing trend (i.e., participants score higher than their previous score) the experimenter ran additional blocks until responding stabilized. After three blocks, if participants continued to score below 70% correct responding, Remedial Training was conducted.

**Name-/Play-By-Ear Probes 1 and 2**. The purpose of this condition was to test for generalized responding in the form of auditory to vocal responding (i.e., name-by-ear) and auditory to piano playing (i.e., play-by-ear) using similar procedures to Hill (2015). Name-By-Ear and Play-By-Ear Probe 1 consisted of S1 relations (i.e., C1, C2, C3, D1,
Name-By-Ear and Play-By-Ear Probe 2 consisted of S2 relations (i.e., C4, C5, C6, D4, D5, D6, E4, E5, E6, F1, F2, F3, F4, F5, F6, G1, G2, G3, G4, G5, G6, A1, A2, A3, A4, A5, A6). Participants were asked to listen to a sound clip of a note-rhythm combination then say the name of the sound they heard. Participants were expected to score low because absolute pitch (i.e., perfect pitch), the ability to identify a note by hearing it, is considered to be a rare, innate ability that only 1 in 10,000 individuals possess (Van-Hedger, Heald, Koch and Nusbaum, 2015). Therefore, even with practice, auditory discrimination between notes is a difficult skill for musicians to acquire.

Prior to the condition, the instructor provided instructions on how to complete the task:

Now, you are going to listen to some sound clips. First, I will ask you, ‘What is it?’, then immediately play a sound clip. Once you hear the sound, tell me what it is. After you’ve answered, I will ask you to ‘play it’ then I will play the same sound and give you time to play. I will not tell you if you’re correct or not, but the harder you try, the faster it will go, so give your best answer. Please repeat the instructions. Do you understand? Let’s begin.

In a probe trial, the experimenter asked “What is it?” then immediately played a sound clip of a cell from the matrix. Following all participant responses (i.e., correct, incorrect, no response), the experimenter asked “Play it” then immediately played the same sound clip. Following all participant responses (i.e., correct, incorrect, no response), the experimenter moved onto the next trial. No visual stimuli were presented to avoid inadvertent prompting.
No programmed consequences were provided for any response (i.e., correct, incorrect, no response). There was no passing or failure criteria for this condition.

**Follow-up Music Probe.** The purpose of this condition was to assess if previously taught and untaught participants’ responses would maintain over a duration of time. One week following the last training session, a follow-up session was conducted for two participants selected randomly (Trinity, Kali, Smith, and Cas) for approximately ten min around the same time as previous training session(s). Procedures and the passing criterion were identical to the Music Probe condition.

**Social Validity**

Upon completion of the study, participants were provided with a debriefing form that described the purpose, procedures, and intended outcomes of the study. Participants were asked to fill out a short survey using the 7-point Likert scale ranging from strongly disagree to strongly agree (Axe & Sainato, 2010; see Appendix B).

The scale contained close-ended statements about the procedures and outcomes (i.e., I learned notes, I learned rhythms, I feel more prepared to learn music, I would recommend the teaching strategies for others, etc.) and provided open-ended questions about the participants’ preferences (e.g., what did you like about our teaching methods; what didn’t you like about this condition, how could this condition be improved).
Results

Figures 2, 3, and 4 show the percentage of correct tact and play responses across all probe conditions for all participants. Table 2 depicts the total number of training trials required by each participant to meet mastery criteria across Training 1 and 2. Participants completed the experimental conditions in approximately two to four hours total. Prior to training, none of the participants tacted or played correctly in the presence of visual notes and rhythms (0/22 trials). All participants mastered Training 1 within 60 to 180 trials (see table 2). They all met passing criterion at 80% or above for Post-Training Probe 1 for tact (88%-100%) and play (88%-100%). Neo passed Post-Training Probe 1 for both tact and play in 7/8 trials (88%). Oracle passed Post-Training Probe 1 for tact in 7/8 trials (88%) and play in 8/8 trials (100%). Trinity passed Post-Training Probe 1 for tact and play in 8/8 trials (100%). Kali passed Post-Training Probe 1 for both tact and play in 8/8 trials (100%). Persephone passed Post-Training Probe 1 for tact in 8/8 trials (100%) and play in 7/8 trials (88%). Morpheus passed Post-Training Probe 1 for tact and play in 8/8 trials (100%).
Figure 2. Results for Neo and Oracle.
Figure 3. Results for Trinity and Kali.
Figure 4. Results for Persephone and Morpheus.
Table 2.

*Experiment 1 Trials to Criterion.*

<table>
<thead>
<tr>
<th></th>
<th>Training 1</th>
<th>Training 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neo</td>
<td>140</td>
<td>352</td>
</tr>
<tr>
<td>Oracle</td>
<td>180</td>
<td>638</td>
</tr>
<tr>
<td>Trinity</td>
<td>60</td>
<td>396</td>
</tr>
<tr>
<td>Kali</td>
<td>130</td>
<td>176</td>
</tr>
<tr>
<td>Persephone</td>
<td>180</td>
<td>352</td>
</tr>
<tr>
<td>Morpheus</td>
<td>60</td>
<td>242</td>
</tr>
</tbody>
</table>

Participants demonstrated little to some emergence of Name-By-Ear Probe 1 responses (0%-78%) and Play-By-Ear Probe 1 responses (22%-67%). Chance level is 17%. Neo scored below chance for Name-By-Ear Probe 1 in 2/18 trials (11%) and above chance Play-By-Ear Probe 1 in 5/18 trials (28%). Oracle scored above chance for Name-By-Ear and Play-By-Ear Probe 1 in 4/18 trials (22%). Trinity scored below chance for Name-By-Ear Probe 1 in 0/18 trials (0%) and above chance for Play-By-Ear Probe 1 in 7/18 trials (39%). Kali scored above chance for Name-By-Ear Probe 1 in 9/18 trials (50%) and above chance for Play-By-Ear Probe 1 in 10/18 trials (56%). Persephone scored above chance for both Name-By-Ear Probe 1 in 10/18 trials (56%) and Play-By-Ear Probe 1 in 12/18 trials (67%). Morpheus scored above chance for Name-By-Ear Probe 1 in 14/18 trials (78%) and Play-By-Ear Probe 1 in 12/18 trials (67%).

All participants mastered Training 2 within 176 to 638 total trials. They all met passing criterion for Post-Training Probe 2 at 80% and above for tact (93%-100%) and
play (93%-100%). Neo passed Post-Training Probe 2 for tact in 42/42 trials (100%) and play in 39/42 trials (93%). Oracle passed Post-Training Probe 2 for tact and play in 39/42 trials (93%). Trinity passed Post-Training Probe 2 for tact in 41/42 trials (98%) and play in 42/42 trials (100%). Kali passed Post-Training Probe 2 for tact in 42/42 trials (100%) and play in 40/42 trials (95%). Persephone passed Post-Training Probe 2 for tact in 41/42 trials (98%) and play in 42/42 trials (100%). Morpheus passed Post-Training Probe 2 for tact and play in 40/42 trials (95%).

Participants demonstrated little emergence for Name-By-Ear Probe 2 (2%-41%) and Play-By-Ear Probe 2 (16%-44%). Chance level is at 8%. Neo scored above chance for Name-By-Ear Probe 2 in 12/54 trials (22%) and Play-By-Ear Probe 2 in 13/54 trials (24%). Oracle scored above chance for Name-By-Ear Probe 2 in 16/54 trials (30%) and Play-By-Ear Probe 2 in 18/54 trials (33%). Trinity scored above chance for Name-By-Ear Probe 2 in 22/54 trials (41%) and Play-By-Ear Probe 2 in 24/54 trials (44%). Kali scored above chance for Name-By-Ear Probe 2 in 17/54 trials (31%) and above chance for Play-By-Ear Probe 2 in 19/54 trials (35%). Persephone scored above chance for Name-By-Ear and Play-By-Ear Probe 2 in 9/54 trials (17%). Morpheus scored below chance for Name-By-Ear Probe 2 in 1/54 trials (2%) and above chance for Play-By-Ear Probe 2 in 20/54 trials (37%).

Subsequently, all participants met the passing criterion of 70% or higher correct responding for the Music Probe (72-94%) without Remedial Training. Neo passed the Music Probe in 14/19 trials (72%). Oracle passed the Music Probe in 17/19 trials (89%).
Trinity passed the Music Probe in 18/19 trials (95%). Kali passed the Music Probe in 16/19 trials (84%). Persephone passed the Music Probe in 15/19 trials (79%). Morpheus passed the Music Probe in 19/19 trials (100%). Trinity and Kali both passed the Follow-Up Probe in 18/19 trials (95%) one week following the last Music Probe trial block.

Table 3 displays the questions and average ratings across participants on the social validity questionnaire. Overall, participants rated the procedures and outcomes favorably. Five out of the six participants stated they would learn music with matrix training again. Participants stated they would have preferred more feedback throughout training in terms of how to utilize the metronome and how to place their hands on the piano correctly.

Table 3

*Experiment 1 Social Validity Results*

<table>
<thead>
<tr>
<th>Question</th>
<th>Average Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I learned how to name notes.</td>
<td>6.5</td>
</tr>
<tr>
<td>2. I didn’t learn how to name notes. *</td>
<td>1.7</td>
</tr>
<tr>
<td>3. I learned how to identify rhythms.</td>
<td>4.7</td>
</tr>
<tr>
<td>4. I learned how to play notes.</td>
<td>6.2</td>
</tr>
<tr>
<td>5. I learned how to play rhythms.</td>
<td>4.8</td>
</tr>
<tr>
<td>6. I didn’t learn how to play rhythms. *</td>
<td>3.2</td>
</tr>
<tr>
<td>7. The music was difficult to learn. *</td>
<td>3.3</td>
</tr>
<tr>
<td>8. The music was easy to learn.</td>
<td>5</td>
</tr>
<tr>
<td>9. I wouldn’t recommend this teaching strategy for others. *</td>
<td>2.8</td>
</tr>
<tr>
<td>10. I feel more prepared to learn music.</td>
<td>5.5</td>
</tr>
<tr>
<td>11. I do not feel prepared to learn music. *</td>
<td>2.3</td>
</tr>
</tbody>
</table>
12. I want to learn more about music after the study. 5.3
13. I don’t want to learn about music after the study. * 1.7
14. I would recommend this type of music lesson to other people. 5.3
15. I had no formal knowledge of music. 6
16. I learned to play a song. 4.2

*Note: Items were rated on a Likert-type scale of 1 (strongly disagree) to 7 (strongly agree). Items 2, 6, 7, 9, 11, and 13 were reverse coded.*
**Discussion**

None of the participants could play or name stimuli during the Pre-Training Probes and had no formal music training prior to the study. All six participants met passing criterion for Post-Training Probes 1 and 2 at 80% or above correct responding following training. Although all six participants passed Post-Training Probes, not all of them equally tacted and played correctly in the presence of visual recombined stimuli. For instance, after Training 1, Oracle tacted correctly in 8/8 trials (100%), whereas only played correctly in 7/8 trials (88%). In contrast, Persephone tacted correctly in 7/8 trials (88%), whereas played correctly in 8/8 trials (100%). This suggests that the product of participants’ tacting was not always an S\(_D\) for playing the correct note. In other words, this type of verbal mediation was not observed (Miguel, 2016).

During Name-By-Ear and Play-By-Ear Probes, all participants performed below proficiency defined as 79% or lower correct responding. However, Trinity scored significantly higher during Play-By-Ear Probe 1 (39%) compared to Name-By-Ear probe (0%). Trinity’s errors were due to tacting the incorrect name of the note (i.e., saying “Whole note E” in the presence of Whole note C), but he would still play on the piano correctly in the presence of the compound stimulus. Similarly, Morpheus scored significantly higher for Play-By-Ear Probe 2 (37%) compared to Name-By-Ear Probe 2 (2%). His tacts were scored incorrectly because he omitted the note name, but would still play correctly in the presence of the compound stimulus. In other words, when presented with whole note D, he would say, “whole note”, but would play whole note D on the
piano correctly. All participants passed Music Probe in which they were asked to play a sequence of note-rhythm combinations. Trinity and Kali participated in Follow-Up Music Probe and scored above 70% without Remedial Training.

These results suggest that the current procedures were effective in teaching college students to play piano notes and rhythms. Furthermore, college students demonstrated recombinative generalization in the form of tacting and playing in the presence of visual, recombined compound stimuli (i.e., notes and rhythms). This is in line with previous matrix training research (Axe and Sainato, 2010; Frampton et al., 2016; Goldstein et al. 1987; Goldstein and Brown 1989; Goldstein and Mousetis 1989; Karlan et al. 1982; Kinney et al., 2003; Kohler and Malott, 2014; Light et al., 1990; Pauwels et al., 2015; Remington et al., 1990; Ribeiro et al., 2015; Striefel and Wetherby, 1973; Striefel et al., 1976, 1978; Tanji and Noro, 2011) in which participants demonstrated recombinative generalization with tacting and playing in the presence of recombined visual representations of compound stimuli (i.e., notes and rhythms). To our knowledge, this was the first successful application of matrix training to music education.

Participants showed minimal emergence of play-by-ear responding, but this was expected, as this is a difficult skill even for trained musicians. A possible explanation for tacting and playing below proficiency could be participants’ difficulty in discriminating between notes that were closer together in pitch. For example, C and D are closer together in pitch whereas C and A are further apart. Therefore, C and A are easier to discriminate than C and D. In other words, when hearing the auditory sample of the note
C, participants would often tact and play D, whereas when participants hear the auditory sample of the note A (after previously hearing C from a previous trial), they might be more likely to correctly tact in the presence of the auditory sample. In the Name-By-Ear and Play-By-Ear Probes, Oracle (in Probe 1) and Persephone (in Probe 2) provided the same answer for playing in the presence of the auditory sample. For instance, if they said ‘whole note D’, they would also play whole note D’ on the piano. This suggests that their tacts served as a $S^D$ for playing on the piano during those conditions. For the remaining participants, their Name-By-Ear and Play-By-Ear Probe scores were not equal. In other words, sometimes when participants said, ‘whole note D’, they would play ‘half note D’ on the piano. This suggests that their tacts did not always serve as an $S^D$ for playing on the piano.

Consistent with previous music education research, participants demonstrated generalized responding by applying their previously learned piano skills within the context of a musical piece (Arntzen et al., 2010; Hayes et al., 1989; Perez & DeRose, 2010; Griffith, et al., in press; Hill, 2015). Furthermore, the two participants who completed Follow-Up Music Probes continued to display previous learned skills after one week. When interviewed, both participants self-reported not practicing their skills or looking up additional information regarding music. This is of particular interest for music educators as students usually take weekly lessons with a private instructor because teachers often tell students to practice their music skills daily. However, our results show practicing daily was not necessary to maintain those skills.
One potential limitation of the current procedure was the fading of the metronome. Although it may be desirable to fade the metronome throughout teaching, removing it in an experimental setting increases the risk of experimenter drift, in which an experimenter alters their behavior (i.e., praise, data collection) over time. This threatens treatment integrity and internal validity because the experimenter may inadvertently reinforce participants’ play responses that would have been counted as an incorrect response if the metronome was playing. Although musicians may practice playing their instrument with a metronome, they typically do not use it during a concert or a recital. In many cases, musicians may rely on the gestures made by a conductor, sounds made by a drummer, or their own behavior such as tapping their feet to provide tempo (i.e., timing). In a performance setting, these gestures guide a group of musicians to play together with proper timing. The tempo (i.e., timing) a conductor or drummer creates seems to be based on their own covert behavior and history of reinforcement. To illustrate, if one were to play a metronome to see if its timing matches the timing a conductor provides with their gestures, it is unlikely their gestures will perfectly line up with a metronome. Therefore, our fading of the metronome seemed appropriate for simulating a musician’s natural environment (i.e., concert, recital).

Another potential limitation of Experiment 1 was that reinforcement was not faded prior to Post-Training Probes. In other words, independent, correct responses were praised every time during training, while praise was removed during Post-Training Probes. Thus, it is impossible to rule out the possibility that incorrect responses during
probes were due to lack of reinforcement. Participants may have inadvertently performed worse during the probes than they had during training conditions due to their behavior being placed on extinction.

Third, during Pre-Training Probes, we only assessed for relations that were targeted for Training, rather than the new relations tested during Post-Training Probes. Although is unlikely that participants could respond to novel combinations prior to Training, experimenters were not assessing the same relations between Pre-and Post-Training Probes.

Thus, during Experiment 2, we addressed the aforementioned limitations by exposing three participants to the same metronome conditions as in Experiment 1 (i.e., fade the metronome prior to Post-Training Probes), while the remaining three participants went through all of the experimental conditions with the metronome present. In addition, for all participants, reinforcement was faded prior to Post-Training Probe conditions to ensure they could respond accurately in the absence of reinforcement prior to testing conditions. Finally, the same novel stimulus combinations were presented during Pre- and Post-Training Probes.
Chapter 3

EXPERIMENT 2

Method

Participants, Settings, and Materials

Participants were six typically developing college students (Switch, 22; Ice, 23; Smith, 22; Niobe, 26; Cas, 25; and Maggie, 22), enrolled at CSUS. Criteria for participating in the study, settings, and materials were the same as described in Experiment 1. All participants received course credit for completing the study.

Experimental Design and Dependent Variables

As in Experiment 1, we used a two-tier nonconcurrent multiple baseline design across participants. The experimental conditions included: Pre-Training Probe 1 (i.e., Post-training Probe 1 from Experiment 1), Pre-Training Probe 2 (i.e., Post-Training Probe from Experiment 1), Training 1, Post-Training Probe 1, Post-Training Probe 2, Name-By-Ear/Play-By-Ear Probe 1, Training 2, Remedial Training (if necessary), Component Training (if necessary), Post-Training Probe 2, Post-Training Probe 1, Music Probe, Name-By-Ear/Play-By-Ear Probe 2 and Follow-Up Music Probe (see Table 4). The dependent variables were the same as described in Experiment 1.

Table 4.

Experiment 2 Relations. The letters represent music notes and the numbers represent rhythms.

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Relations Tested</th>
<th>Trials per Block</th>
<th>Training and Testing Criterion</th>
<th>Feedback Provided</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Questionnaire</td>
<td>N/A</td>
<td>N/A</td>
<td>33% or below</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>2. Pre-Training Probe 1</td>
<td>C2, C3, D3, E1</td>
<td>8</td>
<td>1 (or 2) at 33% or below</td>
<td>0%</td>
</tr>
<tr>
<td>3. Pre-Training Probe 2</td>
<td>C4, C5, C6, D4, D5, D6, E4, E5, E6, F1, F2, F5, F6, G1, G2, G3, G6, A1, A2, A3, A4</td>
<td>42</td>
<td>1 (or 2) at 33% or below</td>
<td>0%</td>
</tr>
<tr>
<td>4. Training 1</td>
<td>C1, D1, D2, E2, E3</td>
<td>10</td>
<td>2 at 100% w/ metronome or 1 at 100% w/ metronome and 1 at 100% w/o metronome</td>
<td>100%</td>
</tr>
<tr>
<td>5. Remedial Training 1*</td>
<td>C1, D1, D2, E2, E3</td>
<td>10</td>
<td>2 at 100% w/ metronome or 1 at 100% w/ metronome and 1 at 100% w/o metronome</td>
<td>100%</td>
</tr>
<tr>
<td>6. Note Component Training 1**</td>
<td>C, D, E</td>
<td>6</td>
<td>2 at 100%</td>
<td>100%</td>
</tr>
<tr>
<td>7. Rhythm Component Training 1**</td>
<td>1, 2, 3</td>
<td>6</td>
<td>2 at 100% w/ metronome or 1 at 100% w/ metronome and 1 at 100% w/o metronome</td>
<td>100%</td>
</tr>
<tr>
<td>8. Post-Training Probe 1</td>
<td>C2, C3, D3, E1</td>
<td>8</td>
<td>1 at 80%</td>
<td>0%</td>
</tr>
<tr>
<td>9. Post-Training Probe 2</td>
<td>C4, C5, C6, D4, D5, D6, E4, E5, E6, F1, F2, F5, F6, G1, G2, G3, G6, A1, A2, A3, A4</td>
<td>42</td>
<td>1 at 33% or below</td>
<td>0%</td>
</tr>
<tr>
<td>10. Name-/Play-By-Ear Probe 1</td>
<td>C1, C2, C3, D1, D2, D3, E1, E2, E3</td>
<td>18</td>
<td>N/A</td>
<td>0%</td>
</tr>
<tr>
<td>11. Training 2</td>
<td>C1, D1, D2, E2, E3, F3, F4, G4, G5, A5, A6</td>
<td>22</td>
<td>2 at 100% w/ metronome or 1 at 100% w/ metronome and 1 at 100% w/o metronome</td>
<td>100%</td>
</tr>
<tr>
<td>12. Post-Training Probe 2</td>
<td>C4, C5, C6, D4, D5, D6, E4, E5, E6, F1, F2, F5, F6, G1, G2, G3, G6, A1, A2, A3, A4</td>
<td>42</td>
<td>1 at 80%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td><strong>13. Post-Training Probe 1</strong></td>
<td>C2, C3, D3, E1</td>
<td>8</td>
<td>1 at 80%</td>
<td>0%</td>
</tr>
<tr>
<td><strong>14. Remedial Training 2</strong></td>
<td>C1, D1, D2, E2, E3, F3, F4, G4, G5, A5, A6</td>
<td>22</td>
<td>2 at 100% w/ metronome or 1 at 100% w/ metronome and 1 at 100% w/o metronome</td>
<td>100%</td>
</tr>
<tr>
<td><strong>15. Note Component Training 2</strong></td>
<td>C, D, E, F, G, A</td>
<td>12</td>
<td>2 at 100%</td>
<td>100%</td>
</tr>
<tr>
<td><strong>16. Rhythm Component Training 2</strong></td>
<td>1, 2, 3, 4, 5, 6</td>
<td>12</td>
<td>2 at 100% w/ metronome or 1 at 100% w/ metronome and 1 at 100% w/o metronome</td>
<td>100%</td>
</tr>
<tr>
<td><strong>17. Music Probe</strong></td>
<td>Varied</td>
<td>Varied</td>
<td>1 at 70%</td>
<td>0%</td>
</tr>
<tr>
<td><strong>18. Name-/Play-by-Ear Probe 2</strong></td>
<td>C4, C5, C6, D4, D5, D6, E4, E5, E6, F1, F2, F3, F4, F5, F6, G1, G2, G3, G4, G5, G6, A1, A2, A3, A4, A5, A6</td>
<td>54</td>
<td>N/A</td>
<td>0%</td>
</tr>
<tr>
<td><strong>19. Follow-Up Music Probe</strong></td>
<td>Varied</td>
<td>Varied</td>
<td>1 at 70%</td>
<td>0%</td>
</tr>
<tr>
<td><strong>20. Survey</strong></td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>0%</td>
</tr>
</tbody>
</table>

*Participants will only be exposed to this condition if they fail the probe.

**Participants will only be exposed to this condition if they fail the probe following Remedial Training.

**IOA and TI**

Trial-by-trial IOA data and TI data were also collected as described in Experiment 1. For Switch, data were collected on 100% of sessions, with a mean agreement of 99.5% (range, 87.5% to 100%). For Ice, data were collected on 100% of sessions, with a mean agreement of 97.8% (range, 83.3% to 100%). For Smith, data were collected on 100% of sessions, with a mean agreement of 97.5% (range, 84.2% to 100%). For Niobe, data were collected on 100% of sessions, with a mean agreement of 98.1% (range, 80% to 100%).
For Cas, data were collected on 100% of the sessions, with a mean agreement of 97.4% (range, 85.2% to 100%). For Maggie, data were collected on 97.5% of sessions, with a mean agreement of 98.7% (range, 87.5% to 100%).

For Switch, TI data were collected on 100% of sessions, with a mean score of 99.8% (range, 96.7% to 100%). For Ice, TI data were collected on 100% of sessions, and TI was 99.7% (range, 93.3% to 100%). For Smith, TI data were collected on 100% of sessions, with a mean score of 99.7% (range, 96.7% to 100%) TI. For Niobe, TI data were collected on 100% of sessions, with a mean score of 99.8% (range, 93.3% to 100%) TI. For Cas, TI data were collected on 100% of sessions, with a mean score of 99.8% (range, 96.7% to 100%) TI. For Maggie, TI data were collected on 97.5% of sessions, with a mean score of 99.6% (range, 93.3% to 100%) TI.

Procedures

All procedures were conducted as described in Experiment 1 apart from Pre- and Post-Training Probes 1 and 2 conditions, as described below. In addition, we kept the metronome playing throughout all experimental conditions for Switch, Ice, and Cas and faded out the metronome at the end of each training condition for Smith, Niobe, and Maggie, similarly to Experiment 1.

Pre- and Post-Training Probes 1 and 2. We probed participants’ tacting and playing in the presence of the visual representation of untrained note-rhythm combinations from both submatrices (i.e., S1 – C2, C3, D3, E1; S2- C4, C5, C6, D4, D5,
D6, E4, E5, E6, F1, F2, F6, G1, G2, G3, G6, A1, A2, A3, A4, A5; see figure 1) prior to training and after each training condition.

Mastery criterion with the metronome constantly playing was one block (both tacting and playing) at 100% correct independent responding with a metronome playing, and one block at 100% correct independent responding without experimenter feedback. Mastery criterion with the fading of the metronome was one block at 100% correct independent responding with a metronome playing, and one block at 100% correct independent responding without the metronome and without experimenter feedback (i.e., no reinforcement).

Except for these conditions, the presence of the metronome, and the fading of reinforcement, all other conditions were conducted in the same way as described in Experiment 1.
Results

Figures 5, 6, and 7 show the percentage of correct tact and play responses across all probe conditions for all participants. Table 5 depicts the total number of training trials required by each participant to reach mastery criterion during Trainings 1 and 2. Participants completed the experimental conditions in three to four and a half hours. None of the participants passed Pre-Training Probe 1 tact and play in 0/8 trials (0%) and Pre-Training Probe 2 tact and play in 0/42 trials (0%) prior to Training 1. All participants mastered Training 1 within 70 to 190 trials (see table 4). Switch failed Post-Training Probe 1 tact and play in 4/8 trials (50%) following Training 1. After Remedial Training 1, Switch passed Post-Training Probe 1 tact and play in 8/8 trials (100%). Ice and Maggie passed Post-Training Probe 1 tact and play in 7/8 trials (88%). Smith failed Post-Training Probe 1 tact and play in 0/8 trials (0%). After Remedial Training 1, Smith passed Post-Training Probe 1 tact and play in 7/8 trials (88%). Niobe failed Post-Training Probe 1 tact in 1/8 trials (13%) and play in 0/8 trials (0%). After Remedial Training 1, Niobe passed Post-Training Probe 1 tact in 8/8 trials (100%) and play in 7/8 trials (88%). Cas passed Post-Training Probe 1 tact and play in 8/8 trials (100%). Switch, Ice, Smith, Niobe, and Maggie did not respond correctly for Pre-Training Probe 2 tact and play in 0/42 trials (0%) prior to Training 2. Cas did not pass Pre-Training Probe 2, but she did respond correctly for tact in 7/42 trials (17%) and play in 6/42 trials (14%).
Figure 5. Results for Switch and Ice.
Figure 6. Results for Smith and Niobe.
Figure 7. Results for Cas and Maggie.
Table 5.

*Experiment 2 Trials to Criterion*.

<table>
<thead>
<tr>
<th></th>
<th>Training 1</th>
<th>Remedial 1</th>
<th>Training 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switch</td>
<td>70</td>
<td>40</td>
<td>506</td>
</tr>
<tr>
<td>Ice</td>
<td>160</td>
<td>N/A</td>
<td>330</td>
</tr>
<tr>
<td>Smith</td>
<td>100</td>
<td>40</td>
<td>154</td>
</tr>
<tr>
<td>Niobe</td>
<td>80</td>
<td>50</td>
<td>154</td>
</tr>
<tr>
<td>Cas</td>
<td>190</td>
<td>N/A</td>
<td>242</td>
</tr>
<tr>
<td>Maggie</td>
<td>140</td>
<td>N/A</td>
<td>330</td>
</tr>
</tbody>
</table>

All participants demonstrated little to minimal emergence of Name-By-Ear Probe 1 (0%-67%) and Play-By-Ear Probe 1 (17%-78%). Chance is defined at 17%. Switch scored above chance for Name-By-Ear and Play-By-Ear Probe 1 in 12/18 trials (67%). Ice scored above chance for Name-By-Ear Probe 1 in 4/18 trials (22%) and at chance for Play-By-Ear Probe 1 in 3/18 trials (17%). Smith scored above chance for name-by-ear and Play-By-Ear Probe 1 in 10/18 trials (56%). Niobe scored below chance for Name-By-Ear Probe 1 in 1/18 trials (6%) and above chance for Play-By-Ear Probe 1 in 14/18 trials (78%). Cas scored below chance for Name-By-Ear Probe 1 in 0/18 trials (0%) and above chance for Play-By-Ear Probe 1 in 12/18 trials (67%). Maggie scored above chance for Name-By-Ear Probe 1 in 7/18 trials (39%) and Play-By-Ear Probe 1 in 8/18 trials (44%).
Participants mastered Training 2 within 154 to 506 trial blocks. They all passed Post-Training Probe 2 tact (95%-100%) and play (81%-98%) conditions after Training 2. Switch passed Post-Training Probe 2 tact in 40/42 trials (95%) and play in 39/42 trials (93%). Ice passed Post-Training Probe 2 tact in 41/42 trials (98%) and play in 34/42 trials (81%). Smith passed Post-Training Probe 2 tact in 42/42 trials (100%) and play in 41/42 trials (98%). Niobe passed Post-Training Probe 2 tact in 42/42 trials (100%) and play in 41/42 trials (95%). Cas passed Post-Training Probe 2 tact in 41/42 trials (98%) and play in 39/42 trials (93%). Maggie passed Post-Training Probe 2 tact in 42/42 trials (100%) and play in 37/42 trials (88%). All participants passed Post-Training Probe 1 tact (88%-100%) and play (88%-100%) conditions after Training 2. Switch, Smith, Niobe, and Cas passed Post-Training Probe 1 tact and play in 8/8 trials (100%). Ice passed Post-Training Probe 1 tact in 7/8 trials (88%) and play in 8/8 trials (100%). Maggie passed Post-Training Probe 1 tact in 8/8 trials (100%) and play in 7/8 trials (88%).

Participants demonstrated little to minimal emergence of Name-By Ear Probe 2 (0%-44%) and Play-By-Ear Probe 2 (20%-59%). Chance is defined at 8%. Switch scored above chance for Name-By-Ear Probe 2 in 24/54 trials (44%) and Play-By-Ear Probe 2 in 23/54 trials (43%). Ice scored above chance for Name-By-Ear Probe 2 in 7/54 trials (13%) and Play-By-Ear Probe 2 in 11/54 trials (20%). Smith scored above chance for Name-By-Ear Probe 2 in 19/54 trials (35%) and Play-By-Ear Probe 2 in 21/54 trials (39%). Niobe scored below chance for Name-By-Ear Probe 2 in 1/54 trials (2%) and above chance for Play-By-Ear Probe 2 in 32/54 trials (59%). Cas scored below chance for
Name-By-Ear Probe 2 in 0/54 trials (0%) and above chance for Play-By-Ear Probe 2 in 28/54 trials (52%). Maggie scored above chance for Name-By-Ear Probe 2 in 13/54 trials (24%) and Play-By-Ear Probe 2 in 17/54 trials (31%).

Subsequently, participants met passing criterion at 70% or above for Music Probe (74%-95%) without Remedial Training. Switch passed in 16/19 trials (84%). Ice passed in 14/19 trials (74%). Smith passed in 17/19 trials (89%). Niobe passed in 15/19 trials (79%). Cas passed in 14/19 trials (74%). Maggie passed in 16/19 trials (84%). Smith, and Cas passed Follow-Up Music Probe (74%-95%) one week following the last Music Probe trial block. Smith passed in 14/19 trials (74%) and Cas passed in 18/19 trials (95%).

Table 6 displays the questions and average ratings across participants on the social validity questionnaire. Overall, participants rated the procedures and outcomes favorably. All participants stated they would learn music with matrix training again. Participants noted they would have liked for the trainings to be shorter. Sessions lasted anywhere from two hours and 15 minutes to four hours.

Table 6

Experiment 2 Social Validity Results

<table>
<thead>
<tr>
<th>Question</th>
<th>Average Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I learned how to name notes.</td>
<td>6.7</td>
</tr>
<tr>
<td>2. I didn’t learn how to name notes. *</td>
<td>1</td>
</tr>
<tr>
<td>3. I learned how to identify rhythms.</td>
<td>5</td>
</tr>
<tr>
<td>4. I learned how to play notes.</td>
<td>6.7</td>
</tr>
</tbody>
</table>
5. I learned how to play rhythms. 4.3
6. I didn’t learn how to play rhythms. * 2.3
7. The music was difficult to learn. * 3.8
8. The music was easy to learn. 4.7
9. I wouldn’t recommend this teaching strategy for others. * 1.3
10. I feel more prepared to learn music. 6.2
11. I do not feel prepared to learn music. * 1.2
12. I want to learn more about music after the study. 5
13. I don’t want to learn about music after the study. * 1.5
14. I would recommend this type of music lesson to other people. 6
15. I had no formal knowledge of music. 6.2
16. I learned to play a song. 3.7

*Note: Items were rated on a Likert-type scale of 1 (strongly disagree) to 7 (strongly agree). Items 2, 6, 7, 9, 11, and 13 were reverse coded.*
Discussion

The purpose of Experiment 2 was to examine the effects of keeping the metronome across all conditions versus gradually fading it on participants’ performance at the end of each training condition. In addition, we addressed the limitations from Experiment 1 by probing untrained relations prior to training, and removing reinforcement prior to Post-Training Probe conditions. Potential experimenter drift, in which the experimenter alters their behavior over time, was ruled out by having the metronome present for Switch, Ice, and Cas, while the metronome was gradually faded out for Smith, Niobe, and Maggie at the end of each training. Results showed that the presence of the metronome made no difference between each triad of participants’ performances during all probes. In addition, removing reinforcement prior to Post-Training Probe conditions did not make a difference for participants’ performance.

None of the participants could play or name stimuli during Pre-Training Probes 1 and 2. All participants had no formal music training prior to the study. Similar to Experiment 1, three participants (Ice, Cas and Maggie) met passing criterion (80%) for Post-Training Probe 1 following Training 1. In contrast to Experiment 1, Switch, Smith, and Niobe required Remedial Training 1. One possible explanation for this may be due to participants attending to irrelevant features of the stimuli (i.e., faulty stimulus control).

After Remedial Training 1, Switch, Smith, and Niobe met passing criterion for Post-Training Probe 1. For Niobe, she did not equally tact and play correctly in the presence of recombined, visual, compound stimuli during Post-Training Probe 1.
Specifically, during Post-Training Probe 1, she correctly tacted in 8/8 trials (100%) and played correctly on the piano in 7/8 trials (88%). She played the incorrect rhythm during one of the trials during Post-Training Probe 1. For example, when presented with half note C (2 beats), she played a quarter note C (1 beat) which is not the correct duration of time. None of the participants met passing criterion for Pre-Training Probe 2 tact and play after Training 1, but Cas demonstrated minimal emergence of correct responding. During Pre-Training Probe 2, Cas sometimes tacted and played correctly in the presence of the visual representation of recombined notes and rhythms after Training 1. She correctly tacted and played in the presence of the visual representation of the note F when combined with previously trained rhythms components (e.g., whole note F, half note F) which had not been directly taught. One possible explanation for Cas’s performance during Pre-Training Probe 2 prior to Training 2 is the fact that notes are represented by letters of the alphabet. The notes progress on a music staff in the same manner as letters progress in the alphabet. For example, notes progress in the following sequence: A, B, C, D, E, F, G, A and so on. Since notes C, D, and E were taught during Training 1, it is possible that Cas learned that F was the next note in the sequence, based on her previous learning history with the alphabet. As a result of matrix training, all participants passed Post-Training Probe 2 (80%) following Training 2 with no need for Remedial Training 2. These results show that participants who needed Remedial Training 1 (Switch, Smith, Niobe) did not need Remedial Training 2 because they started to attend to all relevant features of the stimuli (i.e., note, music staff, rhythm). In addition, all participants
maintained their performance when tested on Post-Training Probe 1 relations after Training 2.

Like Experiment 1, all participants demonstrated minimal correct responding during Name-By-Ear and Play-By-Ear Probes. Participant errors were similar to participant errors from Experiment 1. For example, Niobe and Cas scored below chance for both Name-By-Ear Probes 1 and 2 and above chance for both Play-By-Ear Probes 1 and 2. Niobe and Cas made an error on the name of the note in the presence of the auditory compound stimulus, but still played on the piano correctly in the presence of the auditory compound stimulus. In other words, when presented with Half Note E, they would say half note, but still played half note E on the piano correctly. These results show some evidence that absolute pitch, a supposedly innate skill in which a person can label notes, could actually be taught to music students (Van-Hedger et al., 2015).

All participants met passing criterion for Music Probe at 70% or above and demonstrated generalization by playing piano notes and rhythms in the form of a musical piece (Hill, 2015; Griffith et al., in press). Smith and Maggie passed Follow-Up Music Probe one week following their last training session. Identical to Experiment 1, participants reported no practice or exposure to musical stimuli during the week.
Matrix training was effective in teaching college students to play piano note-rhythm combinations that were never presented together during training, replicating results from previous matrix training research (Axe and Sainato, 2010; Foss, 1968a; Frampton et al., 2016; Goldstein et al. 1987; Goldstein and Brown 1989; Goldstein and Mousetis 1989; Karlan et al. 1982; Kinney et al., 2003; Kohler and Malott, 2014; Light et al., 1990; Pauwels et al., 2015; Remington et al., 1990; Ribeiro et al., 2015; Striefel et al., 1978; Tanji and Noro, 2011). Recombinative generalization was observed for all 12 participants possibly because of the OV training structure. Foss (1968a) and Ribeiro et al. (2015) showed that OV training was sufficient to produce recombinative responding for their participants. OV training seems ideal for teaching novel skills to individuals because they are exposed to each of the components at least twice. NOV training is typically preferred in the matrix training literature for skills in which participants have some previous history with the components because the components have acquired discriminative control over individuals’ responses. In OV training, untrained components do not serve as discriminative stimuli for individuals’ responses. Therefore, NOV training (i.e., diagonal training) is more efficient than OV training). For instance, if participants’ all knew the names of notes or rhythms before the study, NOV training would have been used over OV training because NOV training involves experimenters teaching participants fewer relations directly. Alternatively, future researchers could pre-
train components via speaker or listener training (i.e., notes, rhythms) prior to introducing matrix training. Specifically, experimenters could train participants to tact and play in the presence of notes (i.e., C, D, E, F, G, A) or to select the correct visual representation of a note in an array of three when presented with a visual, sample stimulus (i.e., note) in an MTS format. If a pretraining is added, future researchers could compare whether it takes fewer trials to pre-train and use a NOV matrix, rather than using an OV matrix from the beginning. Matrix training may be more efficient because experimenters are teaching participants fewer relations directly.

Across both experiments, participants completed Training 1 in 60 to 190 trials and Training 2 in 154 to 638 trials. Across all participants, Training 2 took additional trials to meet mastery criterion than Training 1. This may be explained by the fact that Training 2 incorporated all 11 relations targeted for training from the matrix, whereas Training 1 used only five relations targeted for training from S1. Perhaps future studies should only conduct one training condition with all 11 relations targeted for training from the matrix. It is possible that Training 2 relations may require fewer trials to reach mastery overall than separating the matrix into two training conditions. Thus, it is unclear whether it is necessary to divide the matrix into two separate trainings (i.e., submatrices) as it was done in the current study.

During Experiment 2, three participants (Switch, Smith, and Niobe) failed Post-Training Probe 1 for either tact and play responses following Training 1. In other words, they did not demonstrate recombinative generalization with stimuli presented in novel
combinations. Therefore, Switch, Smith, and Niobe underwent Remedial Training 1. In particular, the type of errors these three participants made during Post-Training Probe 1 is worth mentioning. Switch tacted D when presented with the visual representation of C notes, and Smith only tacted and played in correspondence with previously taught relations (i.e., C1, D1, D2, E2, E3) in the presence of visual novel recombinations. In other words, when presented with the visual representation of whole note E, he would tact ‘whole note D’. For Niobe, when she was presented with the visual representation of half note C, she responded with “it’s a half note something”. She either omitted the rhythm or the note in her answer. One common error among these three participants is that they consistently tacted incorrectly in the presence of the visual representation of the note C. The note C has a line through it \( \overline{\text{C}} \) which may have not been salient to participants. Thus, these results suggest specific components lacked discriminative control over participants’ responses when those components were paired with other components in novel combinations (Miguel et al., 2015).

A possible limitation is that participants’ errors may have been due to limited exposure to the note C. During Training 1, the note C is only presented once as a trained relation (e.g., whole note C), whereas notes D and E are presented twice (e.g., whole note D, half note D, half note E, quarter note E). It is possible that participants needed additional learning opportunities to attend to compounds consisting of note C. Future studies could add half note C to Training 1 in order to include the note C for at least two relations in order to increase the number of learning opportunities.
The purpose of Name-By-Ear and Play-By-Ear Probes was to assess for the possible emergence of tacting and playing in the presence of sound clips following matrix training alone. During Name-By-Ear and Play-By-Ear Probes, minimal to some emergence was observed across all participants across both experiments. This was to be expected as absolute pitch, the ability to label a note after hearing it, is considered a rare, innate ability (Van-Hedger et al., 2015). Interestingly, some participants almost scored to proficiency (80%) during Name-By-Ear and Play-By-Ear Probes. For example, Niobe performed significantly better on Play-By-Ear Probes versus Name-By-Ear Probes. During these probes, Niobe would occasionally hum the pitch of the note after the experimenter played the sound clip. This particular behavior may have helped Niobe attend to and select the correct key on the piano. While Morpheus and Cas also scored significantly higher on playing than tacting during these probes, the experimenters did not observe them engage in any other mediating behaviors like Niobe. It is possible they were covertly rehearsing the pitch to themselves. Future researchers should explore the feasibility of the claim that “perfect pitch” is innate. Based on our results, auditory discrimination training between pitches could be a skill worth attempting to teach to music students.

As stated above, Morpheus, Niobe, and Cas’s percentage of correct play responses were significantly higher than their percentage of correct tact responses. Playing and tacting may be two functionally independent repertoires (i.e., speaker and listener behavior; Skinner, 1957). Playing may be considered a form of listener behavior,
and for these two participants, the auditory compound stimuli exerted stronger
discriminative control over playing the piano during Play-By-Ear Probes than tacting in
the presence of the auditory stimuli during Name-By-Ear Probes (i.e., speaker). For
Persephone, she responded correctly during Name-By-Ear and Play-By-Ear 2 in 9/54
trials (17%). This suggests, in this particular condition, tacting served as an SD for
playing. In some cases, correctly tacting in the presence of the visual compound stimulus
did not help with playing performance. For example, Morpheus and Ice tacted correctly
slightly more than he played correctly during Name-By-Ear and Play-By-Ear Probe 1.
Conversely, all participants with the exception of Morpheus and Ice during Name-By-
Ear and Play-By-Ear Probe 1 and all participants with the exception of Persephone during
Name-By-Ear and Play-By-Ear Probe 2 played correctly despite tacting incorrectly.
These data suggest that the product of participants’ tacting did not always serve as an SD
for playing the note. In other words, this type of verbal mediation was not observed
(Miguel, 2016). However, it is possible that if participants had been directly trained to
play note-rhythm combinations in the presence of their respective auditory samples
(listener training), prior to learning to tact note-rhythm combinations (speaker training),
that the auditory product of their tact would have served as a more efficient SD for
playing. Ribeiro et al. (2015) found that participants’ emergence of tacts may have
occurred due to the emission of overt or covert self-echoic behaviors controlled by
auditory samples presented during listener training. For example, when provided with
three pictures of shapes (i.e., dash arbelos, grid decagon, mosaic heptagram) and a sample
auditory stimulus (i.e., dictated ‘dash arbelos), participants may have echoed overtly or covertly ‘dash arbelos’ while selecting the shape. Future studies should assess the effects of listener matrix training (i.e., playing the piano) on tacting and playing in the presence of compound stimuli. If the interaction between speaker and listener behaviors (i.e., bidirectional naming) serves to mediate performances, then the presence of both listener and speaker behaviors would be correlated with improved playing (e.g., Lee, Miguel, Darcey, & Jennings, 2015; Miguel, Pettursdottir, Carr, & Michael, 2008).

During Music Probe, all participants demonstrated generalization in the form of playing on a piano in the presence of a visual representation of a musical piece. This is in line with previous music research in which generalization was demonstrated in the form of playing a musical piece on a piano with typically developing adults, children, and children diagnosed with autism (Hill, 2015; Griffith et al., in press); however, the previous studies did not conduct Follow-Up Music Probes. To our knowledge, this is the first music study to do conduct a Follow-Up Music Probe. In the current study, four participants (Trinity, Kali, Smith, and Cas) agreed to come back for a Follow-Up Music Probe one week following their last training session. All four participants passed with no need for Remedial Training. Of interest, participants reported not having practiced during the week. These results suggest that consistent practice may not be required to maintain music skills for at least a week. An alternative explanation is that since we only taught a sample of six notes and six rhythms from the matrix, and trained each participant to tact and play in the presence of visual compound stimuli to mastery (100%), the visual
representation of the compound stimuli exerted discriminative control over participants’
tact and play responses.

Another limitation is that we did not teach timing (Hill, 2015). In other words, we
did not require participants to play at a specific tempo when performing in the presence
of a visual representation of a musical piece. Participants could take as much time as they
needed to play. Playing with timing is an important component of music and would add
to the external validity of the current procedures (Hill, 2015). Future researchers could
teach participants to play sequences (i.e., a short musical piece) with proper timing prior
to introducing Music Probe.

The third limitation is that we did not teach participants to respond correctly in the
presence of visual rests. Rests are music symbols that represent the absence of playing.
When performing, rests are incorporated into a musical piece and musicians should be
counting to themselves (i.e., covertly) when they see rests on their sheet music. Rests
were not targeted in our procedures because it would be difficult to tell from the
experimenter’s point of view if they rested for the correct duration of time (i.e. rhythm).
Participants could simply sit at the piano when presented with a whole rest, half rest,
quarter rest, and other rhythms. Regardless of the combination, they would score a
correct trial. Therefore, we chose not to incorporate rests into our matrix. Future music
research could explore how to teach rests via matrix training.

Fourth, we only taught six notes and six rhythms. This is not sufficient to teach
someone all of the necessary skills to become a proficient piano player. There are more
complex notes and rhythms to teach, as well as other components such as articulation, hand placement, and dynamics to name a few. However, we were successful in teaching participants to tact and play the notes and rhythms provided. This may serve as a solid foundation in which future researchers can systematically replicate our procedures by expanding the size of the matrix in terms of number of notes and rhythms taught.

The current study provides the first successful application of matrix training to music education. To disseminate these findings to the music community, future research should compare matrix training procedures to traditional music education methods (i.e., Orff, Kodaly, Suzuki) to compare their efficiency and effectiveness. Our procedures may also be adapted to other instruments (i.e., guitar, trumpet, flute). Stringed and woodwind instruments require a different set of skills (i.e., embouchure, finger placement, placement of the bow, blowing air into the instrument). Thus, there may be additional barriers to address in the procedures such as teaching individuals how to blow air into their instruments with proper embouchure (i.e., mouth placement on an instrument).

In conclusion, matrix training was successful in teaching college students a creative or leisurely skill in two to four and a half hours. This is a procedure that could be implemented by teachers in the context of music education. Teachers would be able to utilize matrix training as an instructional technique to teach components of key music skills efficiently. Furthermore, matrix training can be incorporated as part of a comprehensive education plan.
Finally, music may be considered a form of language or verbal behavior. Skinner (1957) termed verbal behavior as any behavior that has been reinforced via the mediation of a listener. Verbal behavior is categorized based on stimuli that evoke, and reinforce specific response forms. Playing music may fit Skinner’s definition because when learning music, the teacher (i.e., listener) has been trained specifically to respond to the behavior of the speaker (i.e., the player). For example, when a student plays music notes on a music sheet, this behavior may be considered a form of codic behavior (Michael, 1982) since the response form (i.e., playing the note ‘c’ after seeing \(\text{\textbullet}\)) shares point-to-point correspondence with the controlling verbal stimulus (i.e., textual representation of the note), and there is no formal similarity between stimulus and response product.

Likewise, when a student plays a rhythm, seeing the textual representation of the rhythm on a sheet of music evokes the response of playing a rhythm on the piano (i.e., quarter notes) based on the number of beats in a musical phrase. In contrast, if the student plays the same piano note as his or her instructor, this response may be considered a form of duplic behavior, since it has formal similarity because the discriminative stimulus (i.e., the note ‘a’)) and the response product (i.e., playing the piano note) resemble each other. Also, musical stimuli evoke specific responses (i.e., playing notes on the piano) because piano playing has resulted in reinforcement through the mediation of the listener (i.e., piano teacher) who has been conditioned to reinforce those specific behaviors from the speaker (i.e., “yes, that is ‘c’!”). In addition, piano playing has been shaped and sustained by a piano teacher, an audience, and other members of the musical (verbal) community.
Even though a student may practice his or her music alone, a history of socially mediated consequences is responsible for the initial development of the musical repertoire, which can now be maintained as the speaker (player) serves as his or her own listener (Horne & Lowe, 1996). If music is in fact verbal behavior, then the same procedures used to teach other forms of verbal responding could be employed to advance research in music education.
APPENDIX A

Music Questionnaire

Please answer the following questions the best you can. Ask the experimenter if you have any questions.

1. What rhythm is this? _________________________

\[ \frac{3}{4} \]

2. Circle the note ‘c’.

\[ \text{c} \]

3. What note is this? _________________________

\[ \text{d} \]

4. Draw a quarter note. _________________________

\[ \text{quarter note} \]

5. What notes are these?

\[ \text{quarter notes} \]

6. Draw the note ‘d’ on the staff.

\[ \text{d on staff} \]
7. What is this note? _________________________

\[ \text{[\text{Musical notation}] } \]

8. What rhythms are these?

\[ \text{[\text{Musical notation}] } \]

\[ \text{[\text{Musical notation}] } \]

\[ \text{[\text{Musical notation}] } \]

\[ \text{[\text{Musical notation}] } \]

\[ \text{[\text{Musical notation}] } \]

9. What is this rhythm? _________________________

\[ \text{[\text{Musical notation}] } \]

10. Circle the half note.

\[ \text{[\text{Musical notation}] } \]

\[ \text{[\text{Musical notation}] } \]

\[ \text{[\text{Musical notation}] } \]

\[ \text{[\text{Musical notation}] } \]

\[ \text{[\text{Musical notation}] } \]
APPENDIX B

Music Survey

Please read each item carefully and respond honestly using the scale provided below each question. This information will be kept confidential and used to evaluate our teaching procedure.

1. I learned how to name notes.

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2. I didn’t learn how to name notes.

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3. I learned how to identify rhythms.

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4. I learned how to play notes.

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5. I learned how to play rhythms.

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6. I didn’t learn how to play rhythms.

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7. The music was difficult to learn.

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8. The music was easy to learn.

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9. I wouldn’t recommend this teaching strategy for others.

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10. I feel more prepared to learn music.

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11. I do not feel more prepared to learn music.

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12. I want to learn more about music after this study.

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13. I don’t want to learn about music after this study.

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14. I would recommend this type of music lesson to other people.

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15. I had no formal knowledge about music before the study.

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16. I learned how to play a song.

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17. What did you like about our teaching methods?

18. What didn’t you like about our teaching methods?

19. How could we improve our teaching methods?

20. Would you learn music this way again? Why or why not?
References


