A Science for the Behavior of Music Learning: The Impact of Mnemonics for Acquisition and Fluency of Music Note Labeling with Adolescent Non-Musicians

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Introduction

"Can one be considered educated if one cannot read or write?" (Drobni, I., 2018, p. 21). Fluency in note labeling is paramount for students to communicate effectively within music performance, composition, and theory. Performers that still need to meet the functional criteria of musical knowledge, practice, and literacy often need to improve in music-related communication skills. Using music and rhythmic notation are fundamental concepts within music literacy. Instrumental and vocal music students must be fluent in abstracting notes and rhythms to meet performance criteria even at the most primary levels. With fluency in notation, students will show increased applied activity in the music classroom, preventing high-performance achievement in solo or ensemble performance settings.

This quantitative study aims to describe the effects of mnemonic devices on the acquisition and fluency of identifying textually written music notes for non-musically literate adolescents from a public high school general music appreciation class. More specifically, what is the impact of behavior analytic techniques that utilize mnemonic devices on the acquisition and fluency for learning novel treble clef musical note labeling by non-musically literate adolescents in a music appreciation class?

The information gained from this study may be utilized to improve the acquisition of music literacy skills of the Western tradition. The interventions applied during this research may also generalize to all age groups possessing various degrees of music literacy development. Additionally, the introductory music course participants will benefit from acquiring foundational music literacy skills.

Review of Literature

As music educators, diverse pedagogical concepts and frameworks are available for individual and ensemble application. With these varied techniques, students from all backgrounds and developmental levels can participate or be reinforced by the enjoyment of performing or appreciation as a listener. As the field of education becomes more of an evidence-based practice, music education needs to become aware of what efficacious practices are available to provide and promote effective pedagogical instruction. In order to accomplish this feat of such importance, music educators must adapt assessment, research, and decision-making practices based on empirical data to promote better efficacious and generalized pedagogical practice, not simply authoritatively, inspirationally, or intuitively. Since the cognitive revolution of the mid and late twentieth century, a myriad of studies on the aesthetics, affective response, and attitudinal shifts of music preference have been conducted. Unfortunately, little resulting evidence has been applicable or provides deterministic guidance for better performance practice from many of these observations. In addition to these subjective topics that have engulfed the majority of musical research, many academicians have begun to formulate and conduct research in the neurologic and physiologic domains in hopes of "saving" music education or finding a correlation or causation for intelligence, cognition, or other subjectively observed characteristic. In some instances and to some degree, these efforts dilute the enjoyment of the musical activity by attributing neurological pairing with other disciplines for more significant achievement in academic subjects. With advancing digital technologies, scientific research has begun to see the neurological activity of music in the central nervous system, but to what end is still being determined. While a correlation between music-related activity and cognitive enhancement may exist, it has yet to be definitively proven as the "golden goose" to improve cognition. In addition to a pairing of music and cognition, other music-related endeavors within the research spectrum have seen promising advancement with special needs and aging populations that improve observable behaviors. Music therapy for intellectually and developmentally divergent and aging populations are building momentum after research has yielded socially significant findings after evaluating music-related treatment. Much of the research in this scope of practice has been stringently monitored, implemented, and reported in publications like the Journal of Music Therapy. However, a technological approach to the acquisition and learning practices of music-related endeavors with the general population has yet to take flight. Current research practice in music psychology and education still debates the semantic definition of musical aesthetics accompanied with Likert scale surveys of preference and attitudinal changes. Unlike music therapy (and sports psychology), professional music educators and psychologists have yet to embrace analytic methodology that can provide data to support efficacious pedagogical practice.

Historically, music education research that implemented behavioral principles in a within-subject (or single-subject) research design with general population sample groups stands limited to almost nonexistent. Outside the scope of music therapy for neurologic and developmentally divergent populations, an analytic research design has yet to be occasioned or generalized to a public school music classroom. The following literature review will provide information supporting the problem statement, inform the reader of the conceptual skill acquisition target, and provide information for the intervention used in the present research study. Though not an exhaustive review, all articles are related to the scope of behavior analytic design, research, and treatment methodologies. Section one, the literature review, discusses a limited scope within the historical context of music-related behavioral research and provides the reader with a view of behavioral-related research within general and divergent music education populations. This section will also provide reference to sports psychology and their adoption of behavior analytic practice for comparison of replication, generalization, and applicability to the performing arts. The second section of this literature review will discuss the intervention used within this research study for skill acquisition – mnemonic devices as an effective strategy for acquiring, recalling, and applying information. Lastly, the third section of the literature review will discuss the pedagogical aim of this reseach - stimulus-equivalence and control.

Behaviorism and Music Education

Traditionally, behavioral psychology has focused on human (and nonhuman) observable (overt) behaviors. Many music educators may recall the late 19th-century physiologist Ivan Pavlov's experiment with dog salivation elicited by the sounding of a tone or of the early 20th-century psychologist John B. Watson's "The Little Albert " experiment, where a small child was conditioned to fear furry objects. These early behaviorists developed the principles known as classical conditional and began setting a foundation for modern behaviorist principles. Twenty years after Watson, the dedicated and rising psychologist, B.F. Skinner advanced research and applied relations of behaviorism. This new developmental construct, termed by Skinner as *operant conditioning*, has been incorporated in almost every facet of educational, commercial, personal, and social settings. Behaviorist principles and techniques have defined and guided the implementation of the Individualized Disabilities Education Act, special education services, Functional Behavior Assessment and Behavioral Intervention Plans within schools, Organizational Behavior Management, commercial advertising, gambling, aviation, pharmacology, business administration, ecology, conservation, and research practices within applied and perfomance psychology. Skinner envisioned the development of a science of human behavior to improve daily living and educational systems with positive reinforcement and eschew the punitive measures of the past by defining a technology that can describe all aspects of human life. Skinner devoted his entire adult life to developing and refining the science of human behavior. After Skinner died in 1990, psychologists, researchers, and educators continued the advancement of behaviorist principles and developed what is now known as Applied Behavior Analysis (ABA). In 1998, the Behavior Analyst Certification Board (BACB) became the collective governing body that certifies practicing applied behavior analysts and advances behavioral therapy and research across various human and nonhuman related environmental settings and conditions. The tenets of ABA and the BACB were defined in 1968 by Baer, Wolf, and Risley's seminal article in the *Journal of Applied Behavior Analysis*. The aims within the behavioral paradigm should be applied, behavioral, analytic, technological, conceptually systematic, practical, and generalize to various settings and situations (Baer et al., 1968). These principles guide the behavioral psychologist to maintain rigid research standards, make ethically guided decisions, and contribute to enhancing the human condition.

The latter half of the twentieth century saw changes in philosophical thought and educational trends. This "cognitive revolution" may have been formed as a response to the behavioristic majority of the first half of the 20th century. Like other artistic domains in education, music education was not left untouched by the attitudinal shifts of philosophy and continues to find a concise scientific model for inquiry into pedagogical practices in applied and experimental settings. To discuss the influences of educational psychology specific to music, one must consider the historical writings of music education researchers R. Douglas Greer and Clifford K. Madsen. In 1975, *Research in Music Behavior: Modifying Music Behavior in the Classroom* was published by Teachers College Press (Madsen et al., 1975). Within this compendium are twenty-two chapters dedicated to music research with an attempt to consolidate the definition and scope of behaviorist principles in music education.

> The fact that the teacher and the researcher deal with observable behaviors makes both need to use operational or behavioral terminology rather than relying solely on construct or conceptual. This procedure is more difficult in music education because of the frequent use of aesthetic or other phenomenological models…. Scientific methods are essential to successful objective educational practice, and the procedures of scientific methods are similar to those undertaken by a responsible teacher (Madsen et al., 1975, pp. 5-6).

The research of "aesthetic or other phenomenological models" were supported by the cognitive movement within education, which promoted the use of metaphorical verbiage without the ability to objectively quantify and verify findings of what was then referred to as mentalistic unobservable behavior. "Although teachers cannot observe cognition, many teachers are interested in theories of cognition and find a [behavioral] learning theory approach to be lacking in theoretical constructs about cognition" (Madsen et al., 1975, p. 8). Though unobservable behavior cannot be quantified in a classroom, supporters of this paradigm continued to develop metaphorical and allegorical constructs and paradigms. In stark contrast to these unobservable and speculative conditions, Greer recommends:

> Research that investigates music instruction as behavior modification deals with observable behaviors and assumes some responsibility commensurate with that at hand for learning. Continued research should increase that responsibility as more factors influencing music learning and the influence of much on other learnings are identified (Madsen et al., 1975, p.9).

In support of Greer, fellow professor, and colleague of music education, C. K. Madsen stated, "If aesthetic education, or any other general goal, can be operationally defined into specific observable behaviors, then these behaviors might be able to be learned and in some way measured" (Madsen et al., 1975, p.15).

Though published in 1975, during the formulation of ABA, one particular study within this compendium followed a model and method of research that would be closely related to the stringent considerations of the experimental analysis of behavior in an academic setting for modern times. This research was conducted by Helen Jorgenson and incorporated a single-subject research model: "The Use of a Contingent Music Activity to Modify Behaviors Which Interfere with Learning." Though called a "multiple baseline model" by the author, more specifically, in the modern era, we would define this model as a multiple baseline across behaviors (MBAB). The single participant for the study was a 9-year-old male who was considered "mildly" intellectually or developmentally divergent and whose parents wanted him to learn to play the piano while also diminishing the current rates of stereotypic behavior (i.e., hand-to-hand, hand-to-leg, hand-to-face). Additionally, the participant's parents desired better compliance by him when following directives during the piano lessons. Data was collected based on the frequency of stereotypic behavior and the percentage of following directives per session. The compounding reinforcement contingency stated that for every two directives that were followed within 5 s, he would have earned 30 s of preferred music listening after the lesson. He would also earn additional reinforcement if no stereotypical behaviors were observed between the directives. Data is presented in the form of a line graph, and the data points show a decreasing trend for the stereotypic target behavior and an increase in the compliance target behavior over the 24-session study. "Following directives" averaged approximately 70% during baseline conditions and improved to 99.5% during the following phases of treatment. For the second target behavior (stereotypy), baseline observations were approximately 26 instances per session. During the intervention, the average frequency declined to 1.8 instances per session. The investigator noted that the intervention "indicated that the music activity contingent on following directives and the absence of stereotyped behavior was an effective consequence" (Madsen et al., 1975, p.224). The author also notes, "The present study demonstrated the effectiveness of using a music activity to decrease two behaviors that interfered with learning. In addition, it provided an example of the multiple-baseline technique. Few such studies have been published…" (Madsen et al., 1975, p.224). This early example of behavior management while training a student in piano lessons contributed to the literature base by showing that techniques of operant conditioning were effective in using positive reinforcement through the implementation of praise and preferred reinforcement contingent on following directives and lessening the degree of what the parents considered a socially significant behavior, stereotypy.

Five years after the publication of *Research in Music Behavior*, R. Douglas Greer independently developed a blueprint for operant conditioning practice to be used in music classrooms and maintained congruence with the emerging vocabulary and methods of ABA (Greer, 1980). It is believed this is the only resource dedicated to behavioristic methodology for music education and proved to be a rare find to review for this study. After acquiring the text and digesting the content, it may be considered the foundation for a canon of music behavior. Titled, *Design for Music Learning*, Greer supports the notion that a philosophically divergent dyadic relationship of learning theories within psychology and education exists – behaviorist (e.g., Thorndike, Pavlov, Skinner, among others) and behavioristic (e.g., Freud, Piaget). "Behavioristic theories are concerned with lawful predictions of the relationship between behavior and the environment. Behavioralistic theories describe the behavior and environment to describe internal processes" (Greer, 1980, p.19). More simply stated, this philosophical dichotomy may have the behavioralist asking, "What do we teach?" and the behaviorist asking, "How do we teach?"

In Chapter 8 of the Greer blueprint, the author alludes to the discussion of the aesthetic movement within music education, much of which is still relevant 50 years hence:

> Most recently, it has been proposed that music education is to be aesthetic education. Most of the notions of what constitutes the nature of the aesthetic in music have been based on rationales that exclude human behavior, with the expectation of a few hinted at in the psychology of music texts. Perhaps Suzanne Langer's influence on music education philosophy in the fifties and sixties led to the exclusion of behavioral rationales since she dismissed their work out of hand. There seems to be sufficient need to redress this lack of representation, particularly when some theorists propose that the au courant position of absolute expressionism should be, indeed, proposed as the philosophy of American music education (Greer, 1980, p.113).

It is essential to note this observation from 1980 that still holds today. Thousands of music education-related studies are focused on unobservable and subjective topics (e.g., aesthetics, feelings, emotion, and others) and only sometimes generalize to a broader population. Additionally, these studies may have little relevance or do not offer pragmatic findings to enhance music education and performance practice. Stated, music education pedagogical practice

> …should make obvious the importance of the behavior change, its quantitative characteristics, the experimental manipulations which analyze with clarity what was responsible for the change, the technologically exact description of all procedures contributing to that change, the effectiveness of those procedures in making sufficient change for value, and the generality of that change (Baer et al.,1968, p. 97).

Greer's (1980) text has contributed a large amount of procedural and conceptual knowledge that covers many aspects of music in the public classroom setting. The foundational principles of

ABA have been described in great detail within this text, and how they generalize to music performance and learning. Though written in 1980, all of the conceptual frameworks delineated by Greer are still relevant today.

Sports Psychology

In addition to the aims of current music education trends in research attempting to quantify unobservable behavior, a competitive subdiscipline within the scope of extracurricular and leisure activity is "winning the race" at teaching skill acquisition – sports psychology. Sports performance and fitness continue to advance in research and technology, while music-related pedagogy, research, and psychology have not. Sports psychology has embraced behavior analytic techniques and methodology into its formalized subdiscipline within Applied Behavior Analysis. Meanwhile, music psychology and music education continue to survey subjective personal listening preferences of late 19th-century composers and what emotions may be elicited by comparing period performance practice to modern performance practice. As an alternative, music and other performance-related disciplines can look to sports-related research for a clear path to improve learning and teaching.

One such study that would apply to musical performance practice was conducted by McDougall in 2005. This study aimed to apply range-bound changing criteria to exercise performance. The subject was a middle-aged, overweight man who wanted to increase his daily exercise regimen, reduce weight, and improve his cardiovascular health and fitness levels. The research was collected over 213 days. A data point was added for the participants' minutes over seven intervention phases. The range-bound changing criterion (RBCC) can best be explained by McDougall (2005):

> The range-bound changing criterion design is a simple variation of the classic changing criterion design. The two designs are identical except for one crucial design feature. Unlike the classic design, in which investigators establish a single criterion within a specific intervention phase, the range-bound version establishes a lower and upper criterion within a specific intervention phase. The two criteria create a bounded range of performance. For example, one specifies the minimum level or floor, and the other specifies the maximum level, or ceiling, of performance for the target behavior (p. 130).

The dependent variable for this study was the number of minutes exercised by the participant (i.e., running). The independent variables used during treatment were “used goal setting and multiple behavioral self-management (BSM) components to increase the duration of daily exercise" (McDougall, 2005, p. 131). In the "first intervention phase, the participant aimed to run, on average, 20 min per day for six days a week. Moreover, the participant established, around this mean, a [plus or minus] 10% range to ascertain the minimum and maximum number of minutes he should run each day" (McDougall, 2005, p.131). For example, during the first intervention, the participant attempted 20 minutes per day; a range between 18 and 22 minutes was considered an accomplished goal for that daily run.

Results were recorded in minutes daily (six days on, one day off). Goals were achieved daily for the seven interventions. Percent was calculated using a percentage of data point (PCD) formula. "PCD is equal to the number of data points within intervention phases that 'conform' (i.e., reside within *a priori* criterion ranges for respective intervention phases), divided by the total number of data points within all range-bound intervention phases, multiplied by 100%" (McDougall, 2005, p.134). All seven subphases resulted in 100% of trials being reached. The author says the model "demonstrated strong experimental control over the target behavior" (McDougall, 2005, p. 134). Of particular note, the PCD, experimental control, and intervention efficacy will be weakened if the data points do not conform to the ranges of prescribed performance when using this research model. Based on the participant/author's criteria, the data points met 100% PCD and showed a high functional relationship between the independent variable and target behavior. According to the researcher, the reason for having this range is to help build endurance and not be overly fatigued during the training process, which may lead to injury or a decline in the activity. In addition, the article discusses the various applicable treatments and scenarios for including this changing criterion design.

This study is just one of many sports and fitness-related research studies incorporating behavior analytic techniques within a single-subject research model. A study was conducted with a collegiate women's lacrosse team in 2019. Its purpose was to "examine the use of prompting and an interdependent group negative reinforcement contingency to improve performance of 12 collegiate women's lacrosse players" (DePaolo et al., 2019, p. 407). Participants included twelve female lacrosse players (attackers and midfielders) from a university located in the southern United States. The participants ranged from 18 to 22 years old and had 4 to 10 years of lacrosse experience. Data were collected during the "last half hour of full practices on the team's practice field, 3-5 days per week, and data collation occurred in the second half of the team's season" (Depaolo et al., 2019, p. 408). "The team's two coaches requested assistance with improving pass naming during practices to increase awareness of intended receivers and potentially improve receptions and positioning during the catch" (Depaolo et al., 2019, p. 408). The dependent variable measured during baseline was the observance of improved reception and body positioning by using " 'named passes,' defined as a player saying the name of an intended receiver at least 1 s before the receiver made the catch" (Depaolo et al., 2019, p. 408). Interventions of coaching prompts and a negative reinforcer of sprint contingency were used to facilitate improvement. An A-B-A-B reversal design was used for data collection. The researchers collected data over 14 sessions (i.e., 4, 4, 4, 2 per respective phase). The final phase only consisted of two sessions due to the completion of the competitive season coming to completion. Players participated in scrimmage games for at least 30 minutes during each session. During the first intervention phase, participants were told the purpose of the study, and the coaches would implement a post-practice sprinting session of five lengths of 65 yards each. For every 20 times, the players performed the name passes, one of the five segments of sprints would be deducted from the post-practice run. The coaches also prompted the players every 4-6 minutes during the first intervention phase.

Prompting and sprints were removed for the second baseline. The interdependent negative reinforcement and prompting strategies returned for the second intervention phase. All data were presented in a line graph titled Figure 1 (Depaolo et al., 2019, p. 409). Each of the 14 sessions observed has a recorded data point on the graph. The ordinate is labeled as "Frequency of Names on Passes out of 100," and the abscissa is labeled as "Sessions [1-16]" (Depaolo et al., 2019, p. 409). The results indicated a functional relationship between baseline and intervention conditions. The initial baseline average number of named passes was 2.75 per 100. Named passes increased to 54.5 during the first intervention, dropped to 4.25 during the reversal phase, and increased to 72 during the second intervention. The data support a significant change in completed passes between baseline/reversal and intervention phases.

The design of this study was effective for using the type of negative reinforcement in a group setting. In addition to the specified variables being measured, a team must cooperate as a cohesive unit. Intervening with the presence and absence of group reinforcement is common among group training (i.e., athletics, music, military, among others). The absence of a conditioning reinforcement (i.e., sprints) can be a valuable motivation tool with any medium involving a collective consciousness of operation. Of interesting note, a Performance Diagnostic Checklist (PDC) was used to survey the players' possible options for reinforcement of lacrosse training. According to the authors, this was the first use of a PDC with a women's lacrosse team for research. Many coaches, teachers, and directors can benefit from the information gathered in a PDC to create reinforcement menus. This study focused on the functional communication skill of a group. It could be replicated with a competitive high school marching band, drumline, or any group-related endeavor reliant on improved communication skills to enhance performance. It can also be adapted to observe the relationship between motivating operations during rehearsals and group practice times to create a more efficient and streamlined approach for group performance enhancement.

Music Behavior

The literature review aims to show the historical conditions and limitations of research in music education of performance enhancement. The work of Greer in 1980 provided a paradigm of procedural techniques in congruence with behavior analytic principles and a vocabulary of scientific inquiry applicable to music education and performance. Currently, Dib and Sturmey have conducted only two research studies using informed practices within music education and behavior analytic techniques. Additionally, sports psychology has adopted many within-subject research methods for team and individualized performance improvement and enhancement and may generalize to other performance-related disciplines.

As previously stated, "The lack of ongoing research in musical behavior…is of great concern" (Greer et al., 1971, p. 34), and an emerging contingency of music educators are beginning to utilize the efficacious practices of ABA. The *Journal of Applied Behavior Analysis* began publishing research articles in 1968, a setting event in the development and organizational principles of Applied Behavior Analysis. To date, one article has been published in the journal related to enhancing music performance and music-related skill acquisition for the neurotypical student. This research would also be considered within the "standard practice" scope and generalized to many music learning settings.

Dib and Sturmey (2011) focused on enhancing sight-reading novel musical excerpts with flute players. The participants for this study were two females and one male, aged 14–17, and classified as advanced flute players by the New York State Music Association Festival scoring criterion. Participants were enrolled in weekly private lessons, and intervention was administered by the study's flute instructor and lead author (Dib & Sturmey, 2011). Trials were conducted in a classroom at the private music school containing two chairs, a video camera, a music stand, and a keyboard. The study aimed to observe if general-case training, instruction, and feedback decreased errors in sight-reading novel musical excerpts (Dib & Sturmey, 2011). Trials were conducted during weekly lessons spanning nine months.

Two dependent variables were identified for measurement (i.e., correct notes and correct rhythms). Researchers observed and recorded note errors, rhythm errors, repetitions, and hesitations during the sight-reading trials. Data were expressed as a percentage for note/rhythmic errors and frequency for observed repetition and hesitation. The independent variables used were verbal instruction of sight-reading procedures, feedback on the sight-reading performance within 10 seconds, and rehearsal if errors were detected. Fifteen selections of sight-reading excerpts were used during the training phase and only repeated if errors were noted during the sight-reading by the participant. A concurrent multiple baseline design was used consisting of training and post-training phases. Data are presented in the form of line graphs and mean scores.

Interobserver agreement for 75% of the trials was above 90%. Results indicate a functional relationship between the treatment package and increased mastery in sight-reading for all three participants. The study demonstrated that behavior analysis procedures could be effective pedagogical strategies for musical performance enhancement (Dib & Strumey, 2011). The intervention package included three I.V.s, and the authors recommend further research is required to determine if one specific treatment was more efficacious than another for a functional relationship.

In 2007, the same authors conducted another pragmatic research study to correct and reinforce posture with three novice flute players aged 8 to 9. This study's dependent variable was the participants' posture while performing the flute. The behavior for improvement was well-defined by the authors and very specific. A longitudinal multiple-baseline across-participant research model was used, and data were collected over 100 sessions. Independent variables implemented as a behavior skills training package included verbal instruction, modeling, rehearsal, and corrective feedback. The treatment package was efficacious by the line graph for all three participants. The posture was scored near 0% during baseline conditions to a cumulative average of 99.7% accuracy during the intervention and the months following during the probe sessions in maintenance. The authors provide a well-written description of the procedures, the target behavior, and the procedures for replication in future research. Additionally, the authors offer the following commentary:

> These results are consistent with previous studies findings in that behavioral skills training was robustly effective in teaching a variety of skills…The present study is important because it demonstrates a novel use for ABA teaching procedures (Dib & Sturmey, 2007, p. 387).

When many music educators and investigators think of music behavioral research, Clifford K. Madsen will appear dominantly in music psychology and behavioral searches from the 20th and early 21st centuries. Madsen was a professor of music at Florida State University and conducted over 300 published studies related to music behavior and music therapy. Many of these articles can be found in the journals of the National Association for Music Education, Music Therapy, and Education. Of particular interest is the compendium of research articles published as *Applications of Research in Music Behavior.* This collection of research was a starting attempt to consolidate topics that may be considered music behavior. While many of the studies provide interest and lean toward describing music behavior, they would only be considered a starting point of music behavioral research. The lack of rigid procedural demands of scientific study would compromise the validity and repeatability of replication for much of this research. Additionally, many of the topics discussed in the text were subjective in nature, relying on aesthetic preference or emotional preference of self-report or other subjective means.

However, skill acquisition research for the general population of music learners has yet to be conducted for discrete pedagogical operations in the body of research. Formal organization and practice of research procedures for behaviorists were not defined and consolidated until very recently. Madsen and his collaborative researchers were not so beholden to the prescribed scientific model used today for within-subject research, particularly in psychological and behavioral research. The trove of studies does provide a basis for future replication and relies on more practical "standard practice" interventions as opposed to many hypothetically related modes of experimental research.

As artists and educators, we must become aware of what efficacious practices will improve and advance the students in their classrooms. Behaviorism describes measures and classifies all facets of human activity, including the behavior of music performance and related literacy for neurotypical and neurodivergent-developed individuals. Additionally, Skinner (1974) cites, "There is no reason why a behavioristic account could not list the reinforcing effects of works of art, music, and literature and deal with them as such." As shown in the aforementioned research, principles of behavior analysis can be effective strategies for performance enhancement by Dib and Sturmey (2007, 2011), as well as a developed framework for defining and measuring musical behavior by pioneering behaviorists like Greer (1980) and Madsen (1975).

Mnemonics as an Intervention

Mnemonic strategies have been used for acquiring and recalling information from antiquity to the present. In addition to Skinner's references to music throughout many of his verbal commentaries, he references mnemonic devices as a form of self-instruction and self-management. In *Technology of Teaching*, chapter "Learning How To Learn," Skinner (1968) describes the function of a mnemonic device in behaviorist terms:

> Mnemonic devices play a role in studying. By definition, a mnemonic is easier to learn than the material it helps to recall. By reproducing a mnemonic, verbal or perceptual, the student generates stimuli, usually as formal or thematic prompts, which aid in either word-for-word or paraphrased recall. Some mnemonics are constructed on the spot while studying; others are learned in advance and connected with current material. Fragmentary mnemonics play a more substantial role in studying than is commonly supposed (Skinner, 1968, p. 131).

Transferring novel information into our memory requires repetition and rehearsal before knowledge can be applied to later situations. Recall of information can be triggered in many different ways and by various forms of similarly encountered stimuli, particularly mnemonics. Mnemonics are utilized as a learning strategy for remembering and recollection. An effective mnemonic device "creates structure…easy-to-remember memory record…and helps to facilitate a future retrieval process" (Rainey & Larsen, 2002, as cited in Moore et al., 2007, p. 310). Mnemonics may even assist with memory recall weeks or months after the strategies have been learned (Moore et al., 2008) and encoded.

Rowlison & Merta (1993) compared the effect of two treatments with world geography facts within an Alternating Treatment Design (ATD). Eight students from a rural community were used in the study. This study was conducted as geography enrichment for students identified as gifted (Rowlison & Merta, 1993) during their differentiated teaching time. Mnemonic devices (IV) and traditional lectures (IV) constituted the two alternating treatments used for the acquisition of world geography facts (DV). The specific mnemonic strategy was not specified or described within the article. Results showed that the mnemonic intervention was more effective than traditional lecture delivery when students were assessed (Rowlison & Merta, 1993). The graphed data supports the conclusion as mentioned earlier, but the author noted a limitation to the functional relationship between mnemonics and the DV. "If time had permitted, the researchers would have initiated a third phase using mnemonics to strengthen the support for the hypothesis. During the course of the inquiry, the ATD used actually turned out to be more of a B.C. model comparing two instructional techniques, mnemonics, and lecture" (Rowlison & Merta, 1993). The author recommended further "research should be conducted in the use of mnemonics in areas other than world geography facts" (Rowlison & Merta, 1993, p. 12).

Similar to the Rowlison and Merta study (1993), Erin Whitescarver (2018) conducted a reversal design research study using mnemonics and vocabulary acquisition with neurodivergent high school students (Whitescarver, 2018). The research was conducted with 6 participants during pull-out sessions from a history class. In contrast to the previous study, these students received special education services for Attention Deficit Hyperactivity Disorder (ADHD), written expression, mathematics, and language-specific learning disabilities. Utilization of mnemonic strategies for acquisition and retention of high school vocabulary was the IV and DV, respectively. New vocabulary words were paired with a contrived mnemonic during both treatment phases. Results showed that mnemonic devices were effective for acquisition and retention compared to traditional methods of instruction (Whitescarver, 2018). The data showed a functional relationship between DV and IV. Limitations of the study are described by the investigator as non-researcher treatment implementation and timeframe (holiday breaks and student attendance) and "may have had an impact on the fidelity of the implementation" (Whitescarver, 2018).

Additional mnemonic research was conducted as an alternative treatment design with four public high school students (grades 7–9) with special needs (Hayden et al., 2017). As specified by the investigator, two different dependent variables were observed during the trials (i.e., on-task behavior and correct responses). The alternating IV consisted of choral responding (C.R.) alone and choral responding paired with mnemonic devices (CR+). Results support the use of mnemonics as a viable instructional strategy for students classified as intellectually and developmentally divergent (Hayden et al., 2017). The data appears to support the hypothesis of a functional relationship between the mnemonic intervention and the correct response-dependent variable. Limitations to the study include the small sample size, the novelty of the strategies, and the variability of the on-task target behavior.

Most recently, Attar et al. (2022) conducted trials related to verbal communicative skills and music. Three male children from Lebanon (age 6) participated in the study. Two participants were identified as non-verbal, and one participant was identified as verbal. A licensed neurologist identified all subjects as having Autism Spectrum Disorder (ASD). The study aimed to decrease the latency of verbal expression with target words paired with simplistic unfamiliar songs (Attar et al., 2022). The DV for the study consisted of verbal expression for non-verbal and verbal students identified with ASD. An additional variable measured was an index of happiness (Attar et al., 2022) rating scale adapted from the Dunlap and Koegel index. After a pre-baseline phase of introduction to the new songs, the three independent variables used during the intervention were "singing," a paired activity of "music and singing," or "listening" only. Songs were either from an audio recording or performed by the teacher. Each IV was administered in 6-minute increments in delayed multiple baselines across subjects designs embedded with changing conditions. Trials were conducted 14 times over eight weeks, each session lasting approximately 20 minutes. Each song of the interventions contained pauses for two target words to be spoken by the participant. Time was measured in seconds with a maximum response time of 6 seconds. Each intervention was administered every session in 6-minute increments before moving to the following condition. Results "demonstrated a differential effect among the three musical interventions for the three participants" (Attar et al., 2022, p. 9). No participants scored the interventions in the lowest tier on the happiness scale, indicating neutral or happiness for all three interventions.

The authors comment that speech alone may not be as reinforcing for an individual with ASD as a neurotypical child displays. Pairing verbal operants with a more sensory-stimulating activity may enhance communicative performance and be more reinforcing. Limitations to data may have been confounded by the small number of participants, the population from which the sample was taken, and the redirection strategies used to maintain control of challenging behaviors from the three participants.

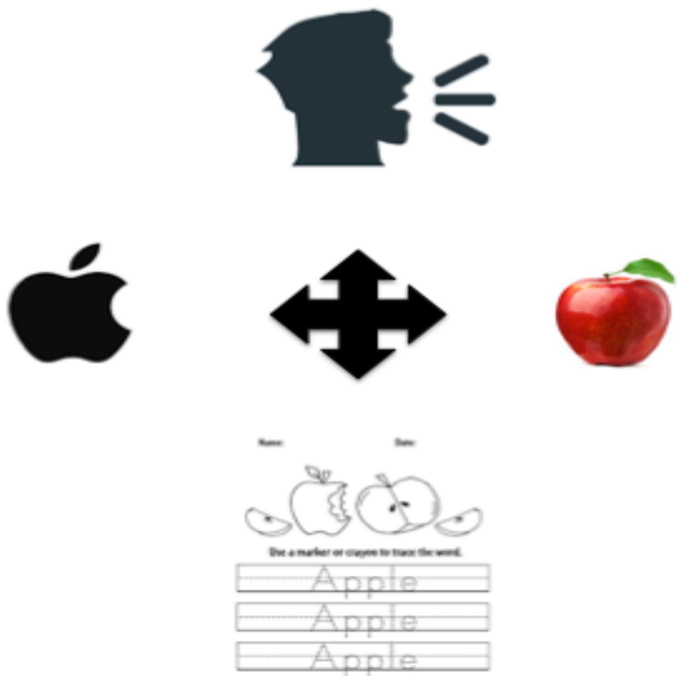
This research shows mnemonics are effective instructional strategies between a variety of neurotypical (Whitescarver, 2018), gifted (Rowlison & Merta, 1993), and neurodivergent (Attar et al., 2022; Hayden et al., 2017) student populations. Whether remembering specific dates, essential stages of a framework, or topographical information, mnemonics can be a valuable strategy for learning, storing, and retrieval of various forms of information.

Acquiring Stimulus Discrimination and Response Differentiation

Stimulus-equivalence is a conceptual framework for learning and discriminating stimuli. Reflexivity, symmetry, and transitivity define the equivalence relationship between stimuli of related classes. When a person has red apples in both hands, they will respond similarly to both. The red apple in the right hand is very similar to the red apple in the left hand. Therefore, both are considered examples of the same stimuli class. If we observed the three-dimensional red apple in one of our hands, then spoke aloud "apple," this would be considered a symmetric association of stimuli – speaking the descriptor aloud and seeing the object. Transitivity would be associating the word "apple," seeing a three-dimensional apple, and a drawing or picture of an apple. The three stimuli have different topographical features. However, they refer to the same object.

Figure 1

Stimulus Relations of Apple



At first glance, the field of behavior analysis may be intimidating to the untrained educator due to the heavy use of the proprietary technical jargon used in behavioral psychology. The principles of behavior analysis are based on operant conditioning, or rather, activities that *operate* in and in the environment. In the most basic of explanations, operant behavior focuses on a three-term contingency consisting of an antecedent event, a response, then a consequence. If one decides to have a practice session on their instrument, they practice scales; the result is they improve the fluency of the scale, resulting in a more confident performance and skill acquisition. If a compliant child is asked to pick up their toys from the floor and place them in the appropriate location, they may be praised or given a cookie. The antecedent of a three-term contingency is referred to as a stimulus. A stimulus can also be defined as any event, action, or vocalization that can evoke a response. If one is driving down the street with a stop sign on the corner of the block, it will evoke the driver to stop the car briefly before continuing with the standard driving operations. When the driver stops the car at a stop sign, it is said to be under the control of the stimulus. One step further in describing what can be learned from this driving scenario is when the same driver approaches a different intersection with a red traffic *light* and stops the vehicle. Stopping at a stop sign or traffic light evokes the same response, referred to as stimulus-equivalence. For novice musicians, learning the symbolic language is a requisite skill for performance enhancement and becoming proficient singers or instrumentalists. Music notation is a symbolic language that can evoke synonymous or differentiated responses depending on the rule-governed behavior built into the system.

In 1989 one of the few music-related articles published in the *Journal of Applied Behavior Analysis* discussed behavior-analytic techniques of stimulus-equivalence and rule-following while using music notation and piano. The research was conducted for experimental purposes only and was designed to report on two conditions. Hayes et al. (1989) conducted two experiments to see if emerging relations of stimulus-equivalence would generalize with music notation and a piano with undergraduate students. The authors defined the dependent variables measured for the study as "timing" and "placement" classes. These stimuli were used to train the non-musicians to perform the correct response when shown visual stimuli (i.e., unique music notation). The description of the procedures is compounded with the various versions of the stimuli for the participants in an alternating fashion. According to the authors, there was much variability between participants in the observed data. The experimental conditions and procedures described by the researchers in the article are written in an unwieldy manner. They would not generalize to a classroom setting or be considered "standard pedagogical practice" in studio or ensemble instruction. The data reported may have shown a functional relationship to the independent variables. However, more congruent data may have been obtained if the research had focused on discrete match-to-sample (i.e., fewer stimuli with less class variation). Though the research lacks "standard practice" for a music educator, the study attempts to describe music-related stimuli and responses for future research and focuses on neurotypical sampling participants.

More recently, three research studies were conducted by graduate-level students from the Department of Psychology, University of California, Sacramento, and are similar in scope and methodology. The first of these studies was conduted by Griffith et al. in 2018. Like the replicated model that Langton et al. (2020) employed and will be later discussed, the dependent variable consisted of visual and performance relations of chords instead of single notes on a piano by sight with six untrained college students. Results showed that equivalence-based instruction (EBI) effectively trained the participants to pair the visual notation of a chord, the vocalized chord name, and the correct placement of fingers on a piano.

Hill et al. (2020) conducted an EBI study with four typically developing children and four children diagnosed with autism spectrum disorder, ages 6 to 11. This peer-reviewed research study was conducted to "evaluate the effects of EBI on learning to play individual notes and simple songs on the piano" (Hill et al., 2020, p.189). The study aimed to "establish equivalence relations between auditory-musical stimuli and musical notation" (Hill et al., 2020, p.189). The implementation of the independent variable consisted of a matching-to-sample (MTS) procedure for visual and auditory stimuli (i.e., A = B, B = C, C= A). The research model employed a two-tier nonconcurrent multiple baseline design incorporating eleven training and assessment steps over multiple phases. EBI is a teaching design described as developing emerging relationships between stimulus classes with direct training. To explain this concept in simple terms, if one is taught to speak "apple" when seeing a picture of an apple and they are taught to say "apple" when holding an apple, then typically, after a history of exposure, they will infer the picture and the apple are spoken with the same descriptor, "apple."

Hill et al. (2020) state that after the 8 participants were divided into three heterogeneous groups (e.g., 4, 2, 2), MTS procedures were employed under three conditions: the vocalization of note names to pictures of single notes written on the treble clef; playing the corresponding key on a piano to the written treble clef note; playing the correct key on the piano when a spoken note of the treble clef is prompted to the participant by the researcher. Unlike Hayes et al. (1989), the research model and procedures used in this study are more discrete and promote focused attention for the participants. Three music notes (C4, D4, E4) were the music stimuli for all three equivalence conditions. According to the authors, "EBI was effective in establishing three 3-member equivalence classes and produced novel piano playing" (Hill et al., 2020, p. 202). The study showed relations between visual letter names, vocalized letter names, and written note pitches with neurodivergent and neurotypical students in a within-subject research design.

The third study from the University of California, Sacramento, was conducted by Langton et al. (2020). Like Hill et al. (2020), this research conducted stimulus-equivalence training that incorporated matrix training tandem pitches and rhythmic values. The article provides evidence of the equivalence relationship between note names, pictures, values, and pitch production. These symmetrical derivatives are required from every type of formally trained music student; however, due to the current trend of curriculum within our "standard" practice of music training in the classroom, introducing putative stimuli has been presented in more discrete manners than the experimental research interventions described in the Langton et al. (2020) research. Similar to Hill et al. (2020), the model of implementation is experimental and would not be incorporated into the "standard practice" of most music educators in a classroom or private instruction setting. However unorthodox the pedagogical practices from these studies may seem, Hill et al. (2020) alludes to a salient statement within music education research: "Although there are numerous theories on how to teach music…the field of music education remains relatively unexplored by behavior analysts" (Hill et al., 2020, p. 188). Like the previous three studies in this literature review section, the lead investigators may not have been a music educator who was aware of informed pedagogical practice, but rather demonstrating a behavior analytic technique with human subjects in a music-related medium.

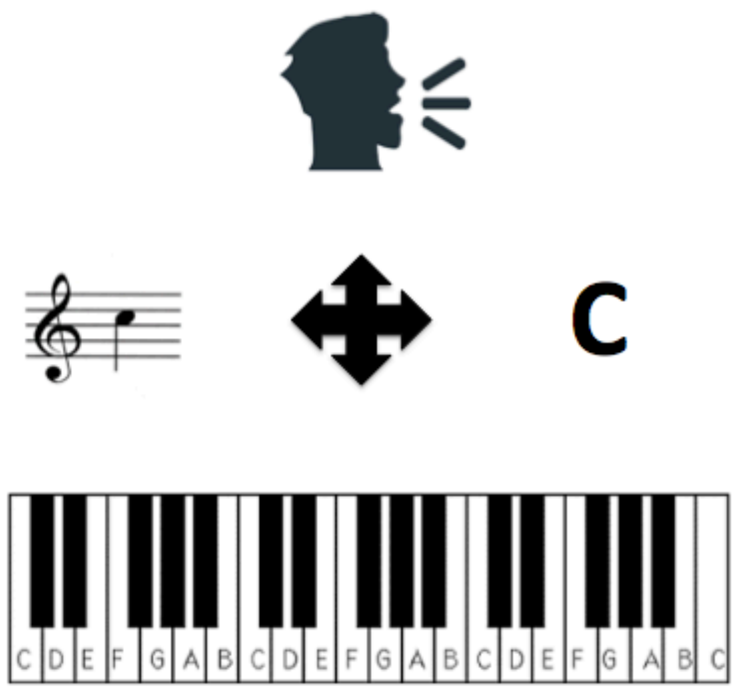
While this research does contribute to the knowledge base of behavior analytics and music-related activities, from the perspective of a professional music educator, one would not consider the procedures used as pragmatic, efficacious, parsimonious, or practical within a music classroom. All four studies conducted in this section of the literature review may not have been designed by professional music educators but by musicians as performers. Though the research contributes to music-related activity and behavior analytic techniques, professionals trained in music education would benefit from adopting a science of music education research and using the framework to investigate more efficacious and parsimonious pedagogical practices.

Conclusion

Music-realted stimulus-equivalence occurs when trained vocalization of a note name, textually written note name, textually written letter of note name, and sounding the note can all be understood. Association two different relations (i.e., vocalizing a note name and sounding the note on a piano) is a symmetric relationship between two stimuli. Association between three or more stimuli is a transitive relationship.

Figure 2

Music-Related Stimulus Relations



The studies reviewed within this section all contribute to a better understanding of how stimulus-equivalence can be trained and reinforced. The aim of every music educator is to promote fluency of these stimulus relations and shape the learner for a better appreciation of music-related activity.

Methods

Participants

The location for the study is in a large inner-city high school from downtown Las Vegas, NV. 100% of students receive Title 1 funding, and 93% are classified as a minority. A diagnostic note-naming multiple-choice assessment of 9 note names will be administered to 40 high school music appreciation students (grades 9-11). The diagnostic assessment pretest will be administered through the Canvas by Instructure platform, labeled "Diagnostic Note Naming Quiz," and found on their classroom accounts. Students will be spatially isolated to ensure the validity of the diagnostic assessment. Participants for the study were selected from the sample of underperforming (i.e., 20% or less of correct responses) students after the diagnostic assessment was administered. After a determination was made of proficient versus non-proficient, eligible research participants were ranked from lowest to highest scoring in order of receiving treatment intervention.

After parental permission and student assent forms were verified, three participants were selected for this research study from the larger population of the music appreciation class. Additionally, IRB approval was obtained at the university and school district levels. Participant 1 (P1) was 16 years of age, from the general education population, Hispanic, identified as female, did not require teaching modifications, and had a cumulative 3.06 grade point average. Participant 2 (P2) was 14 years of age, from the general education population, African American, identified as female, did not require teaching modifications, and had a cumulative 2.97-grade point average. Participant 3 (P3) was 16 years of age, from the general education population, Hispanic, identified as male, did not require teaching modifications, and had a cumulative 2.33

grade point average. None of the selected participants had prior music instruction according to self-report, and all had achieved 0% correct responses on the treble clef note labeling diagnostic assessment.

Setting and Materials

Treatment was administered to students in a ten ft. by ten ft. practice room adjacent to the rehearsal classroom. The treatment room contained two chairs, two music stands, a piano, a dry-erase board, and a small window in the door (see appendix b). In addition to the researcher administering treatment and collecting data, participants were recorded using an iPhone video application mounted on one of the music stands for viewing by the interobserver at a later time. Nine flash cards purchased from Alfred Music Publishing that display single notes of the treble clef staff were used to test the dependent variable (i.e., E4, F4, G4, A4, B4, C5, D5, E5, F5), available in Appendix C. Data was recorded using a pen, paper scoring sheet, and clipboard (see appendix d and e). No other materials were used with the treatment of the participants. Responses were recorded as correct or incorrect. A multiple baseline across subjects within-subject research design was used. The model contains A-B-C-D-A′ phases and includes a final probe session for maintenance. Baseline conditions required a minimum of 3 sessions to show a stable response. Intervention phases required a minimum of 3 sessions for trend identification. Each participant attempted multiple trials per each of the five sessions in the research study.

Procedures for Baseline Conditions

During the baseline data collection phase (A), participants were asked to accompany the observer to the treatment room individually. Scripted instructions for the baseline condition were as follows:

> Welcome to the baseline phase of the research. This research will be in four phases: Baseline, Phase 2, Phase 3, and Phase 4. In baseline, we test what knowledge you already have. In Phases 2 and 3, we teach the note names in two groups, lines then spaces. During the last phase, we will check to see if the interventions helped you learn all of the note names. I will show you nine flashcards for today's session, each containing a single musical note. After I turn over the card, you may say the correct name of the note, the incorrect name of the note, no response, or by saying the word "pass." If you say multiple responses, they will be recorded as incorrect responses. This is not for a grade. Just be honest and do the best you can. Do you have any questions before we begin?

The participants were shown a flash card with a single note and given 5 seconds (s) to respond (see Appendix A). After the card was visible to the participants, the observer silently counted to five (i.e., one, two, three, four, five). Correct responses were marked as correct; no response, incorrect response, or multiple responses will be marked as incorrect. Nine unique note-name flash cards were shown to each participant, and none were repeated. Data was recorded as correct or incorrect for the nine opportunities. No prompts or feedback were given during baseline trials and continued until a stable baseline was established. At the end of each session, the investigator said, "Thank you, you may leave the room and go back to your class."

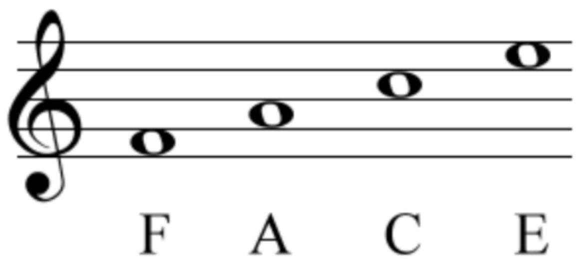
Procedures for Treatment Conditions

During the first session of the treatment phase (B), after the participants entered the room and sat down in the appropriate location, a scripted sequence of instruction was delivered. This sequence required the participant to repeat the mnemonic device while viewing the notation on the treble clef music staff located on the dry-erase board in the treatment room.

Nine flashcards containing a single note on a staff in treble clef were used to test the dependent variable (e.g., E4, G4, B4, D5, F5, F4, A4, C5, E5). Phase B incorporated the music notation that resided on the spaces of the treble clef staff and the mnemonic "FACE on the space."

Figure 3

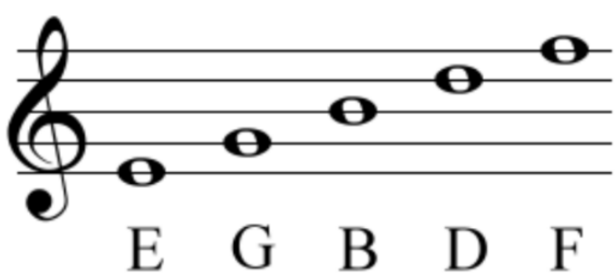
Treble Clef Notes of the Spaces



Phase C incorporated the music notation that resided on the lines of the treble clef staff and the mnemonic “Every Good Bear Deserves Fudge.”

Figure 4

Treble Clef Notes of the Lines



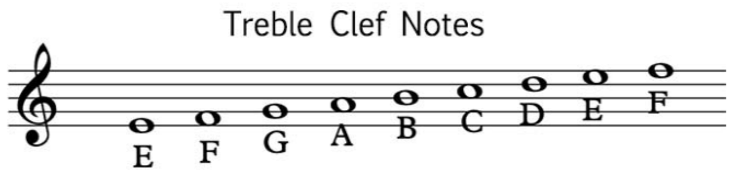
The participants were given five seconds to respond after the flash card had been shown. The flashcard remained visible the entire time until a correct response, no response, multiple responses were given, or the 5-second interval had expired. The correct responses were marked as correct; no response, incorrect response, or multiple responses were marked as incorrect. Scripted instructions were used to support treatment fidelity with all participants during all phases of the study. Scripted instructions for all phases can be found in Appendix F.

Treatment Design and Data Collection System

A multiple baseline across subjects (A-B-C-D-A′) with a maintenance probe was the sequence of intervention phases. Assessment data was based on the frequency of correct responses and recorded as a percentage data point. Baseline (A) consisted of a minimum of 3 sessions for trend stability. The first intervention phase (B) consisted of 3 or more treatment sessions until a stable criterion was exhibited in the participants' responses. This phase implemented the lines of the treble clef staff and the accompanying mnemonic ("FACE on the space"). Each card was shown once, resulting in 4 opportunities for response per trial. The second intervention phase (C) consisted of 3 or more treatment sessions until a stable criterion was exhibited in the participants' responses. This phase will focus on the spaces of the treble clef staff and the accompanying mnemonic ("Every Good Bear Deserves Fudge"). Each card was shown once, resulting in 5 opportunities for response per trial. The last treatment phase (D) focused on the combination of both mnemonic devices used for the lines and spaces of the treble clef.

Figure 5

Treble Clef Notes of Lines and Spaces



All flashcards were randomly shuffled and shown once, resulting in 9 opportunities for response per trial. Additionally, the criteria of 5s during all phases were assessed. The return to baseline (A′) did not require the participants to vocalize the taught mnemonics before responding to the same conditions as Phase D. Due to the end-of-year scheduling conditions, one probe during the maintenance phase was conducted a week after the conclusions of Phase A′.

Figure 6

Sequence of Training and Assessment

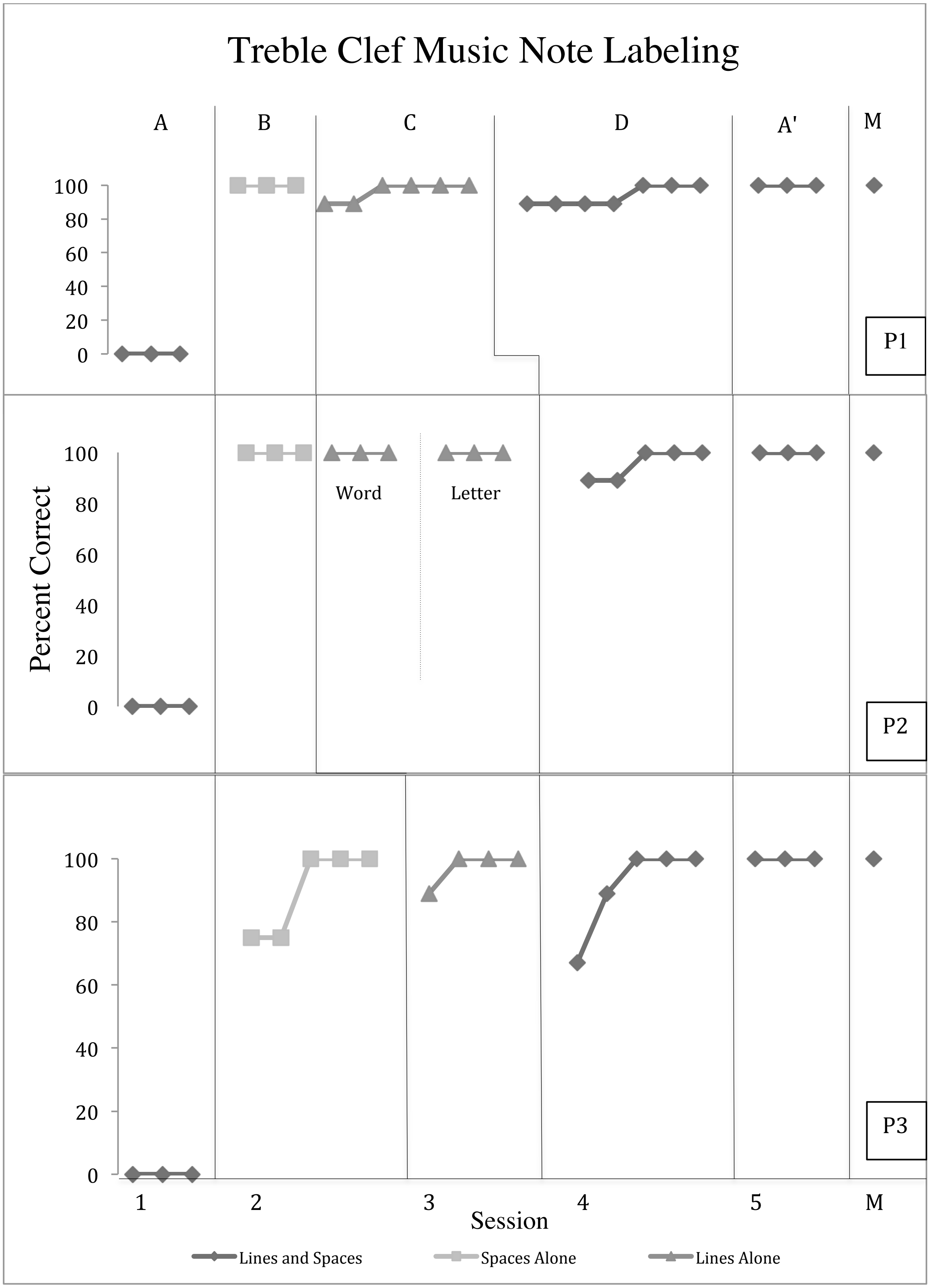
Phase	Stimulus	MinimumTrials Required	Criterion
1. Pretest	Diagnostic	1	-
2. Baseline (A)	Spaces, Lines (9)	3	-
3. Mnemonic 1 (B)	Spaces (4)	3	100%
4. Mnemonic 2 (C)	Lines (5)	3	100%
5. Mnemonic 1,2 (D)	Spaces, Lines (9)	3	100%
6. Non-vocalization (A)	Spaces, Lines (9)	3	100%

Results

Five treatment sessions were conducted with the participants. All three participants were assessed individually during the same sessions. Results from the baseline (A) phase corroborated the diagnostic examination used to find participants lacking any music note labeling knowledge prior to the study. During baseline, all three participants were shown all nine flashcards without verbal prompting or reinforcement for three trials, all resulting in 0% correct answers. The first instruction phase consisted of tact training instruction by modeling and textual/verbal prompts paired with vocalization of the mnemonic device repeatedly. Participants were required to verbalize the appropriate learned mnemonic before every flash card was revealed and answer correctly within 5 s. Accomplished mastery required three consecutive trials with no errors. Results from the first instruction phase (B) utilized the mnemonic "FACE on the space" to denote the four-spaced treble clef flash cards. During this phase, P1 required five trials to meet the criterion; P2 required six trials to meet the criterion; P3 required four trials to meet the criterion. Results from the second instruction phase (C) utilized the mnemonic "Every Good Bear Deserves Fudge" to denote the lined treble clef flash cards. P1 and P2 required three trials to meet the criterion; P3 required five trials. Phase D incorporated both mnemonics (lines and spaces) in random order. Criterion included correct verbal responses before 5 s, three consecutive trials at 100% correct. To aid in knowledge application, the participants were allowed to speak the mnemonics verbally before a flash card was revealed. Six trials were required to meet the criteria for P1 and P3; five trials were required to meet the criterion for P2. The criterion for the concluding phase (E) required participants to answer three consecutive trials of all nine randomly sorted flash cards without verbalizing the mnemonic and correctly speaking the answer within 5 s. Participants 1 and 2 met the criteria in 3 trials with no errors. Participant 3 required five trials to meet the criterion. A maintenance probe was administered to the participants individually seven days after the conclusion of the study. Criterion was maintained for all participants in one trial. All data were collected and recorded on a line graph. Data points were displayed as percent correct per trial.

Figure 7

Treble Clef Music Note Labeling Line Graph



During the instruction phases, each participant was required to vocalize the specific mnemonic being used during the trial echoically. Phase B and C mnemonics were repeated back to the investigator eight times in total during the scripted instruction portion of the session and contributed to the rehearsal of each self-instructed prompt for knowledge acquisition.

Figure 8

Number of Mnemonic Prompts Vocalized by Participants During Assessment

Participant	Phase A	Phase B	Phase C	Phase D	Phase A’	Probe
P1	0	12	25	15	0	0
P2	0	12	30	14	0	0
P3	0	20	16	15	0	0

Total trials to meet the criterion for all three participants yielded a similar number of trials to meet the criterion. All participants met the criterion of 100% correct responses per trial for three trials in the return to baseline phase at the conclusion of the study. No additional trials were required.

Figure 9

Trials to Criterion

Participant	Phase B	Phase C	Phase D	Phase A'
P1	3	6	7	3
P2	3	3+3	5	3
P3	5	4	5	3

In addition to the frequency of correct responding, data was collected on the intervallic duration of responding during each trial. The data reported for Phases B, C, and D included the vocalization of the mnemonic, revealing the flash card, and the response for spaces, lines, or both based on the respective criterion. "Face on the space," card is turned over, response, repeat sequence until all cards have been revealed. Phase D required the participants to vocalize both mnemonics for lines and spaces, resulting in 9 opportunities for response. The return to baseline conditions in Phase A' required the same sequence without vocalizing the mnemonic aloud. Data indicates the participants were acquiring fluency in responding between Phase D and Phase A metrics. P1 averaged 75 s in Phase D, which decreased to 47.3 s during the nontreatment conditions. P2 averaged 65.8 s, which decreased to 50 during the nontreatment conditions. P3 averaged 59.4 s in Phase D, which decreased to 38.4 s during the nontreatment conditions. This data shows the trend in fluency of responding correctly to music notation.

Figure 10

Mean Duration in Seconds by Phase

Participant	Phase B (s)	Phase C (s)	Phase D (s)		Phase A' (s)
P1	20.3	29	75	→	47.3
P2	14	24	65.8	→	50
P3	21.5	15.8	59.4	→	38.4

Interobserver Agreement

All trails were video recorded. The participants' identities were not in view of the recording device at any point during the research study. The video recorded all aspects of the sessions, from the entrance to the treatment room, scripted instruction, intervention responses, and treatment room verbal deportment. The cooperating interobserver (IOA), a licensed music education specialist, was able to verify no deviation from scripted instructions, the scored responses from participants, or the open-ended self-reporting discussions. IOA reliability was scored at 100% for all trials and phases.

Discussion

Initially, scripted procedures and instructions were used to assuage any confounding or extraneous variables during the research phases. In addition to the use of mnemonic devices, the task analysis for instruction resulting in scripted instruction may have provided an efficacious form of instructional delivery. Throughout all phases of the study, participants did not require clarification or repeated instruction on the task being learned, applied, or assessed. Extraneous variables that may have confounded the validity of the study may have included home study or tutoring (peer, parent, other). To address the aforementioned confounding variables during the study, participants were instructed in the script to "do not study reading note names or practice with other classmates" at the conclusion of each session. The concluding self-report indicated that no participant had knowingly rehearsed or been aided by outside factors during the research period.

Multiple participant replication with different aged populations may provide better verification of a functional relationship between the mnemonic devices and knowledge acquisition of music note name labeling. Replication over various settings, maturation, and ages may contribute to more efficient and effective instruction practices in pedagogical settings.

The behavior analytic construct of this research utilized a skill acquisition plan to develop stimulus control in novice adolescents within the field of music. Within the construct, discrete trial training developed generic tact labeling of treble clef note names. By incorporating the use of a mnemonic device, the students were able to respond with accuracy by vocalization and then fading to non-vocalized verbal operants to deduce the correct note label. During the maintenance phase, fluency in note-labeling was observed by the limited inter-response time required for correct responding. In addition to the mnemonic, the teacher's requirement of instruction was limited to modeling the use of the mnemonic device while providing gestural prompting during the instruction period of phases B and C. After acquiring the note-labeling skill; instrumental music, students will begin the next step of stimulus-equivalence training by producing the correct sound with their respective instruments. Music note-labeling is a requisite skill for accomplished instrumental and vocal musicians alike (e.g., vocalizing, writing, singing, instrument tone production). In order to begin the process of abstracting meaning from the symbolic language of music, the acquisition of the fundamental components of the vocabulary is crucial to shaping novice consumers of the music performance activity. As shown within this research model, simple and effective mnemonic strategies can be beneficial for novel skill acquisition and contribute to a heuristic of self-instruction and self-management. If a student learns to utilize and develop strategies of learning and recall, the vocabulary within their repertoire may generalize to multiple domains or provide an efficient means to master other skills.

At the conclusion of Phase A', an open-ended discussion was conducted with each participant. All three participants indicated that the use of the mnemonics was enjoyable and a fast way to aid in an application for the correct answers. Additionally, the three participants indicated the spaces (F4, A4, C5, E5) were easier to label than the lines (E4, G4, B5, D5, E5). The participants' self-report indicated that the inner lines (G4, B5, D5) required acute discrimination for effective response. Not vocalizing the mnemonics during Phase A' was required to assess if the mnemonic had served its function to aid in the fluency of response application. Results show that fluency in responding was present in P1 and P2, each only requiring the three trials to meet the criterion within 1 second. P3 began with the below criterion for the first two trials but concluded with the criterion for the next three and averaged the lowest time response of the three participants. Additionally, P3 also indicated during the self-report that instead of using "Every Good Bear Does Fine," they had amended the mnemonic temporarily to "All Good Bears Do Fine" before correcting responses on the third, fourth, and fifth trials. Incorrect responses recorded across all participants during Phase D were reported as follows: P1 errors (E4, B5, D5); P2 (G4, B5, D5, F5); P3 (F5, F4, E5). Eight of the ten incorrect responses during Phase D were music notes located on the lines of the treble clef staff. This may corroborate the self-report from the participants that the five lines required more acute monitoring to respond with the correct answer. Only P3 provided incorrect responses to space-related note labeling (F4, E5). The only common errors reported during the trials of this phase were B5 and D5, shared by P1 and P2, and F5, shared between P2 and P3. Only one participant had a repeated error between trials for a specific note label. P1 incorrectly responded to E4 in two different trials. All other errors for all participants were unique and not repeated.

The mnemonics target different stimulus classifications (i.e., lines and spaces). When learning to discriminate between the two stimulus classes, the mnemonic prompts the respondent toward the correct response, subsequently reinforcing the behavior of answering correctly. Learning to discriminate between similar stimuli is reliant upon differentiating topographical dimensions. Initiating the discriminative process of note labeling begins by observing if the note has been marked on a space or a line. Once that operation has resulted in satisfactory completion, the specific line or space will be analyzed. Respondents may begin this second step in the procedure by using the mnemonic that categorizes the note names in order from lowest placement on the staff. Much like learning to discriminate odd numbers from even numbers, tacting a lined or spaced music note on a music staff requires the participant to acquire knowledge of the sequencing pattern. In addition, requisite knowledge of the English alphabet is a necessary skill within a respondent's repertoire. After seeing a note placed on the bottom space of the treble clef (F4), the respondent will answer "F." Though the actual letter "F" is not written, the placement of the inked circular form becomes a discriminative stimulus (S.D.) that evokes the respondent to vocalize the letter F of the English alphabet. Additionally, a respondent may not only vocally respond to the correct answer, but if asked to complete the note naming assignment on a written test, they would be able to textually respond by writing the letter F. We use these abstractions in everyday life when learning to categorize various objects, words, and topographies within stimulus classification. This abstraction is a learned behavior and is an example of the transitive-derived relations of stimulus-equivalence training.

The fluency of the participants averaged less than 3 s per response during the maintenance probe. Another self-report discussion was conducted at the conclusion of the probe. When asked if they used the same learned mnemonic to respond to the flash card, Participants 1 and 2 said they did not need the learned mnemonic; Participant 3 said he did use the learned mnemonic. Interestingly, Participant 1 described how she modified and adapted to answer correctly when shown the flash card. Participant 1 said that she did use the learned mnemonics of the intervention to provide the correct answers for the intervention phases but adapted to the procedure: " If the note shown was on a space, I used 'FACE on the space.' If the notes were either E or G (E4, G4), I used 'Every Good' from the mnemonic. If the notes shown on the card were lines above A (A5), I said the letters alphabetically." For Participant 1, using the learned mnemonic of the intervention helped to train the sequence of notes. However, after the sequence was learned by the participant, she developed a novel strategy for deducing the correct answer, a spontaneous mnemonic. After consultation with Michael Domjan, Professor of Psychology, University of Texas, it was decided to refer to this naturalistic and incidental strategy as a spontaneous mnemonic device. “Mnemonics can be things participants come up with on their own to help them remember something. It need not be something they were instructed to use” (M. Domjan, personal communication, May 31, 2023).

Participant 2 reported her strategy for musical notation problem-solving procedure. Participant 1 used the 'FACE on the space' learned mnemonic for any musical note on a space and utilized the same deductive procedure of E4 and G4 by remembering "Every Good" of the mnemonic device for lines. Where they differ in strategy is how to address the lines of B5, D5, and F5. Participant 2 said that she automatically recalled that the top line of the staff was F (F5). If the flash card denoted the middle line (B5) or the fourth line (D5), she would look at the top line (F) and say the alphabet backward until she arrived at the correct line.

The participants were asked individually if they had conferred with each other about these strategies, and both responded, "No." The third participant indicated that he only used the learned mnemonic but was becoming faster in fluency from repetition. These emerging strategies proved beneficial and supported faster correct responses during the maintenance phase for all three participants. Participants 1 and 2 developed a spontaneous strategy that may continue to develop if more trials were available, and it would be interesting to learn how they modify their personal prompting to recall and apply the information. Of interest, these individual problem-solving procedures described by the participants create a specialized *order-of-operations* (OOO). Ron Martelle, an authority in the field of Applied Behavior Analysis and Professor of Education, University of Colorado, provided this explanation, “I would consider the order of operations to be a chained task with a smaller task analysis for each operation" (R. Martelle, personal communication, June 11, 2023). In essence, Participants 1 and 2 developed two procedural OOO, one for lines and one for spaces. Within each stimulus class (line or space), an independent task analysis was used for deduction. For spaces, all three participants continued to use the learned verbal prompt "FACE on the space." For lines, the task analysis for lines could be one of two operations: the bottom two lines (E4, G4) required the learned verbal prompt "Every Good," while the middle line and top two lines were sequentially spoken alphabetically, either ascending or descending. In the case of Participant 1, she began with A and sequentially ascended alphabetically to the correct note name. Participant 2 began with the top line F and descended alphabetically to the correct note name. The ascending and descending deductive procedure acts as a paired-associate learning mechanism. According to Domjan (2010, p. 359), once one is aware that A is followed by B and C is followed by D, it would only be necessary to be aware of a specific starting point for the staff to move forward or backward and arrive at the correct conclusion. If the self-reports of the participants are considered valid, the OOO utilized two learned mnemonics, a spontaneous mnemonic, and applied a paired-associate learning mechanism for deducing the correct result for both stimulus classes of lines and spaces and paired associations for stimulus-equivalence between vocalized verbal stimuli (e.g., A, B, C, D, E, F, G) and textual music notation stimuli on the flash card (see appendix e).

As Skinner stated in *The Technology of Teaching*, "The skilled typist, tennis player, lathe operator, or musician is, of course, under the influence of reinforcing mechanisms which generate subtle timing, but many people never reach the point at which these natural contingencies can take over" (1968, p. 83). Learning to navigate and produce the appropriate response within the musical language takes millions of trials before one can be considered a master of the art. The subtleties of performance disciplines require near perfection of discrete responses honed over many years to be considered "proficient." To reinforce the discussion of the difficulties of proficient musical development, Skinner goes on to say, "Even children who are encouraged to play with objects of different sizes, shapes, and colors and given a passing acquaintance with musical patterns are seldom exposed to the precise contingencies needed to build subtle discriminations. It is not surprising that most of them move into adulthood with largely undeveloped 'abilities'" (Skinner, 1968, p.87).

The aim of this research was to show how behavioral analytic procedures and concepts can be applied to music-related learning procedures for knowledge acquisition and application. Behavioral analytics can provide an efficient description of procedural technology for describing, assessing, and delivering conceptual knowledge that can facilitate self-instruction, self-management, and automatic reinforcement. These applications can also generalize to a broader scope of populations and promote higher levels of fluency in performance and shared cultural repertoire of skills. Specific examples of behavior analytic techniques used throughout the study include: tact training, stimulus-equivalence, match-to-sample, prompting, extinction, self-management, errorless learning, shaping, positive reinforcement, automatic reinforcement, discrimination training, differentiated responding, repetition, modeling, imitation, and within-subject design to monitor and evaluate data. Techniques of behavior analysis have been proven to be efficacious and provide a systematic approach toward self-management and automatic reinforcement.

These findings may contribute to understanding the number of vocalizations for the acquisition of novel mnemonic devices to aid knowledge application. The three participants encompassed different ethnic, cultural, gender, age, socioeconomic, and achievement histories. Additionally, the three participants were not associated socially inside or outside of the music appreciation class, nor were they on a familiar basis (i.e., knowledge of the other participants' names, social backgrounds, or preferences).

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Appendix A

Pre Baseline: Class Diagnostic Assessment, Canvas Platform

Question 1 5 pts

What is this note (choose your instrument's clef)?

- F
- D
- B
- A

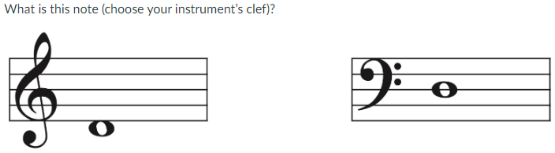
Question 2 5 pts

What is this note (choose your instrument's clef)?

- B
- A
- D
- C

Question 3 5 pts

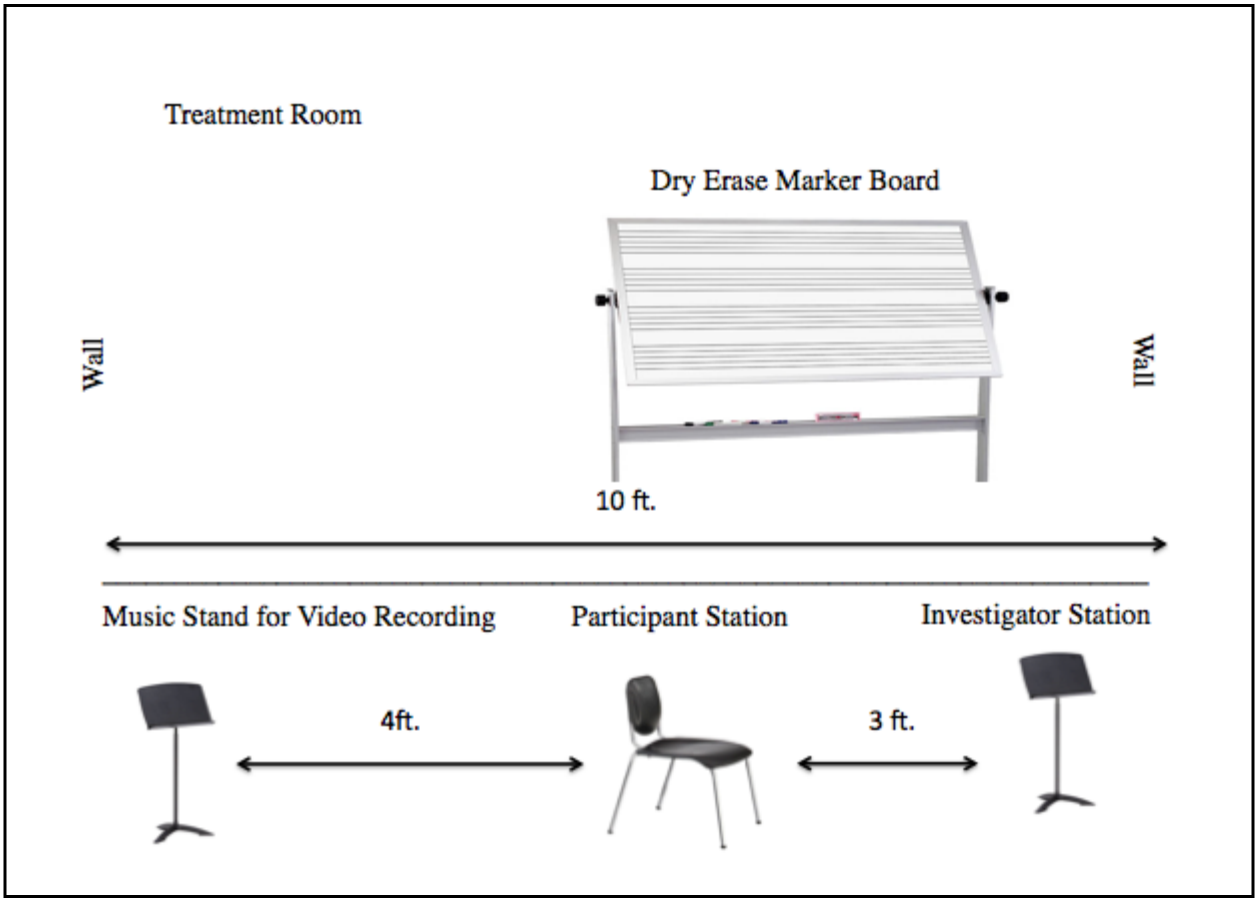
What is this note (choose your instrument's clef)?



- D
- F
- B
- A

Appendix B

Treatment Room Diagram



Appendix C

Baseline Condition Data Collection

Student Identifier_______________________________ **Date(s)**_________________________________

Class Period___________________________________ **Location**________________________________

Observer 1________________________________**Observer 2**___________________________________

(+): Correct Response **(-)**: Incorrect/Multiple Responses

Session	**E**	**G**	**B**	**D**	**F**	**F**	**A**	**C**	**E**
1									
2									
3									

Session 1: Correct__________________________ **Incorrect**____________________________

Session 2: Correct__________________________ **Incorrect**____________________________

Session 3: Correct__________________________ **Incorrect**____________________________

Interobserver Agreement:____

Appendix D

Intervention Condition Data Collection

Student Identifier______________________________ **Date(s)**_________________________________

Class Period_________________________________ **Location**_______________________________

Observer 1__________________________________**Observer 2**______________________________

(+): Correct Response **(-)**: Incorrect/Multiple Responses

Session	**E**	**G**	**B**	**D**	**F**		**F**	**A**	**C**	**E**
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

Session 1: Correct________________________ **Incorrect**___________________________
Session 2: Correct________________________ **Incorrect**___________________________
Session 3: Correct________________________ **Incorrect**___________________________
Session 4: Correct________________________ **Incorrect**___________________________
Session 5: Correct________________________ **Incorrect**___________________________
Session 6: Correct________________________ **Incorrect**___________________________
Session 7: Correct________________________ **Incorrect**___________________________
Session 8: Correct________________________ **Incorrect**___________________________
Session 9: Correct________________________ **Incorrect**___________________________
Session 10: Correct_______________________ **Incorrect**___________________________

Interobserver Agreement:____

Appendix E

Music Note Card C5

Appendix F

Scripted Instructions

Phase A: Baseline Instructions

Attendant: "Welcome to the baseline phase of the research. This research will be in four phases: Baseline, Phase 2, Phase 3, and Phase 4. In baseline, we test what knowledge you already have. In Phases 2 and 3, we teach the note names in two groups, lines then spaces. During the last phase, we will check to see if the interventions helped you learn all of the note names. For today's session, I will show you nine flashcards, each containing a single musical note. After I turn over the card, you may say the correct name of the note, the incorrect name of the note, no response, or by saying the word "pass." If you say multiple responses, they will be recorded as incorrect responses. This is not for a grade. Just be honest and do the best you can. Do you have any questions before we begin?"

Phase B: "FACE on the space" Instructions

1. **Attendant:** "This is Phase 2 of the research. I will show you four flash cards, each containing a single musical note. After I turn over the card, you may say the correct name of the note, the incorrect name of the note, or no response by saying the word 'pass.' If you say multiple responses, they will be recorded as 'incorrect.' This is not for a grade. Just be honest and do the best you can. But first, I want to show you a saying to help you answer the questions."
2. **Attendant:** "Repeat after me, 'FACE on the space'" (x 3)
3. **Attendant:** Write the corresponding letter on the staff line (order: F, A, C, E)
4. **Attendant:** "Repeat after me, 'FACE on the space'" (point to the corresponding letter on staff)
5. **Attendant:** Add words to the existing letter to complete "FACE on the space."
6. **Attendant:** "Repeat after me, 'FACE on the space'" (point to the corresponding letter on staff)
7. **Attendant:** Write the statement "FACE on the space" in a clear area under the staff
8. **Attendant:** "Repeat after me, 'FACE on the space'" (point to the corresponding letter on staff)
9. **Attendant:** Erase Board
10. **Attendant:** "Repeat after me, 'FACE on the space'"
11. **Attendant:** Draw corresponding quarter notes on the staff lines (order: F, A, C, E)
12. **Attendant:** "Repeat after me, 'FACE on the space'" (point to corresponding quarter note on staff)
13. **Attendant:** "Do you understand how the spelling of "face" corresponds to the letters of the ascending treble clef notes in the spaces?"
14. **Attendant:** "Do you also see how F, A, C, and E are related to the saying 'FACE on the space'?"
15. **Attendant:** "Would you like me to explain this again?"

(if answering in the affirmative, move to the assessment condition; if not answering in the affirmative, repeat the sequence of instructions)

16. **Attendant:** Erase the board
17. **Attendant:** "Before I show you a flash card, I want you to say 'FACE on the space' out loud to help you answer correctly. After you say it out loud, I will turn over the card and wait for you to answer. We will do this sequence four times per trial. Do you have any questions before we begin?"
18. **Attendant:** "Repeat after me, 'FACE on the space'"; turn over the card
19. **Attendant:** Show the four unique cards of (F, A, C, E) and repeat until the criterion is met
20. **Attendant:** "Congratulations! You are finished with the session! Please do not study by reading note names or practicing it with the other classmates. We are tracking how fast it takes for you to learn the notes while you are in the sessions. Thanks again, and you may return to class."

Phase C: Every Good Bear Does Fine Instructions

1. **Attendant:** "During this is Phase 1 of the research. I will show you five flash cards, each containing a single musical note. After I turn over the card, you may say the correct name of the note, the incorrect name of the note, or no response by saying the word 'pass.' If you say multiple responses, they will be recorded as 'incorrect.' This is not for a grade. Just be honest and do the best you can. But first, I want to show you a saying to help you answer the questions."
2. **Attendant:** "Repeat after me: 'Every Good Bear Does Fine'"(x 3)
3. **Attendant:** Write the corresponding letter on the staff line (order: E, G, B, D, F)

4. **Attendant:** “Repeat after me: 'Every Good Bear Does Fine'" (points to the corresponding letter on staff)
5. **Attendant:** Add words to the existing letter to complete "Every Good Bear Does Fine."
6. **Attendant:** “Repeat after me: 'Every Good Bear Does Fine'"(points to the corresponding letter on staff)
7. **Attendant:** Write the statement "Every Good Bear Does Fine" in a clear area under the staff
8. **Attendant:** “Repeat after me: 'Every Good Bear Does Fine'"(points to the corresponding letter on staff)
9. **Attendant:** Erase Board
10. **Attendant:** “Repeat after me: ‘Every Good Bear Does Fine’”
11. **Attendant:** Draw corresponding quarter notes on the staff lines (order: E, G, B, D, F)
12. **Attendant:** “Repeat after me: ‘Every Good Bear Does Fine’” (point to corresponding quarter note on staff)
13. **Attendant:** “Do you understand how the first letter of each word is the same name of which line is on the music staff?”
14. **Attendant:** “Do you see how E, G, B, D, and F are related to the saying ‘Every Good Bear Does Fine’?”
15. **Attendant:** “Would you like me to explain this again?”

(if answering in the affirmative, move to the assessment condition; if not answering in the affirmative, repeat the sequence of instructions)

16. **Attendant:** Erase the board
17. **Attendant:** "Before I show you a flash card, I want you to say 'Every Good Bear Does Fine' out loud to help you answer correctly. After you say it out loud, I will turn over the card and wait for you to answer. We will do this sequence five times for each trial. Do you have any questions before we begin?"
18. **Attendant:** “Repeat after me: 'Every Good Bear Does Fine'"; turn over the card
19. **Attendant:** Shuffle and reveal the five unique cards randomly (E, G, B, D, F) one card per response, repeat until the criterion is met
20. **Attendant:** "Congratulations! You are finished with the session! Please do not study by reading note names or practicing it with the other classmates. We are tracking how fast it takes for you to learn the notes while you are in the sessions. Thanks again, and you may return to class."

Phase D: Lines and Spaces Instructions

1. **Attendant:** “Do you remember the mnemonic sayings from the previous session?”
2. **Attendant:** “Can you say them out loud for me?”

(if they answer in the affirmative, move to assess the cards, if not, repeat the entire sequence of instructions from Phase B and C)

3. **Attendant:** “Before I show you a flash card, I want you to say ‘FACE on the space’ and ‘Every Good Bear Does Fine’ out loud to help you come up with an answer. Do you have any questions before we begin?”
4. **Attendant:** "Say, 'FACE on the space' and 'Every Good Bear Does Fine'; turn over the card
5. **Attendant:** Shuffle and show the nine unique cards (F, A, C, E; E, G, B, D, F) until criteria are met per trial
6. **Attendant:** "Congratulations! You are finished with the session! Please do not study by reading note names or practicing it with the other classmates. We are tracking how fast it takes for you to learn the notes while you are in the sessions. Thanks again, and you may return to class."

Phase A′, Probe: Non-Vocalized Mnemonic Instructions

1. **Attendant:** "This is the last phase of our research; congratulations, you made it! We will be combining the previous two strategies together. I will show you nine flash cards, each containing a single musical note. After I turn over the card, you may say the correct name of the note, the incorrect name of the note, or no response by saying the word 'pass.' If you say multiple responses, they will be recorded as 'incorrect.' This is not for a grade. Just be honest and do the best you can. Do you have any questions before we begin?"
(after answering any questions, begin)

2. **Attendant:** (Show cards)
3. **Attendant:** "Congratulations! You are finished with the session! Please do not study by reading note names or practicing it with the other classmates. We are tracking how fast it takes for you to learn the notes while you are in the sessions. Thanks again, and you may return to class."

Appendix G

Duration of Response Data

Participant	Phase	Trial	Session	Time		Average
P1	B	1	2	21 s		
		2	2	20 s		
		3	2	20 s		
					MS	**20.3 s**
	C	1	2	39 s		
		2	2	26 s		
		3	2	20 s		
		4	2	30 s		
		5	2	30 s		
					MS	**29 s**
	D	1	3	123 s		
		2	3	77 s		
		3	3	62 s		
		4	3	60 s		
		5	3	68 s		
		6	3	60 s		
					MS	**75 s**
	A’	1	4	42 s		
		2	4	50 s		
		3	4	50 s		
					MS	**47.3 s**
P2	B	1	2	15 s		
		2	2	15 s		
		3	2	12 s		
					MS	**14 s**
	C	1	2	28 s		
		2	2	22 s		
		3	2	21 s		
		4	2	25 s		
		5	2	23 s		
		6	2	25 s		
					MS	**24 s**
	D	1	3	76 s		

		2	3	70 s		
		3	3	69 s		
		4	3	58 s		
		5	3	56 s		
					MS	**65.8 s**
	A’	1	4	50 s		
		2	4	51 s		
		3	4	49 s		
					MS	**50 s**
P3	B	1	2	28 s		
		2	2	20 s		
		3	2	20 s		
		4	2	18 s		
					MS	**21.5 s**
	C	1	2	20 s		
		2	2	15 s		
		3	2	14 s		
		4	2	16 s		
		5	2	14 s		
					MS	**15.8 s**
	D	1	3	72 s		
		2	3	62 s		
		3	3	59 s		
		4	3	55 s		
		5	3	61 s		
		6	3	60 s		
					MS	**59.4 s**
	A’	1	4	41 s		
		2	4	37 s		
		3	4	37 s		
		4	4	36 s		
		5	4	41 s		
					MS	**38.4 s**