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Scaffolding Autonomy in the Practice Room: A Mixed Methods Study Examining the Impact of Digital Scaffolds on High School String Musicians' Self-Correction and Improvement of Pitch and Rhythmic Accuracy During Independent Music Practicing

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SCAFFOLDING AUTONOMY IN THE PRACTICE ROOM: A MIXED METHODS STUDY EXAMINING THE IMPACT OF DIGITAL SCAFFOLDS ON HIGH SCHOOL STRING MUSICIANS' SELF-CORRECTION AND IMPROVEMENT OF PITCH AND RHYTHMIC ACCURACY DURING INDEPENDENT MUSIC PRACTICING

by

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The purpose of this study was to gain insight into the deficiencies and capabilities of high school string players in the practice room, through a mixed methods within-subjects experiment exploring the impact of digital scaffolds on pitch and rhythmic accuracy growth, self-assessment, self-correction, and other self-regulatory behavior during independent music practicing. Sixty high school string students individually completed a 30-minute practice session divided into four practice conditions with the order randomly assigned (1.Model, 2.Model+Playback, 3.Model+Playback+Feedback, and 4.Control). During each practice condition, performances at sight-read (pretest), during practicing (formative), and after practicing (posttest) were assessed for pitch and rhythmic accuracy by computer software *SmartMusic*. While participants practiced, they spoke their thoughts out loud, self-assessed their progress, and answered questions about their experiences. A two-factor mixed ANOVA revealed significantly greater accuracy gains when students practiced with the aural model (Model) and with the visual evaluative feedback (Model+Playback+Feedback). Integration of qualitative and quantitative data illuminated deficiencies in audiating an aural goal image from written notation, detecting errors by ear, and self-assessing performance deterioration; capabilities included strategy use and technique adjustment.

Keywords: practice, self-regulation, string players, music, digital scaffolds

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Chapter 1: Introduction

Introduction and Problem

Emma holds back tears as she reads the grading report of her latest playing test. She spent a week practicing the excerpt and had felt confident about her performance of the music, but her grade turned out to be much worse than expected. Since she could not pass the test after really practicing, Emma decides that she will not waste her time practicing anymore. Convinced that she simply does not have any musical talent and will never become a competent musician, Emma soon closes her violin case for the last time. What went wrong?

The first in her family to take up an instrument, Emma knows that learning an instrument requires practice, but feels ineffective when practicing on her own. Although her aural skills have improved in the last five years of school orchestra, she still has trouble figuring out what the music is supposed to sound like just by looking at the notes on the page, and if what she is playing is correct. Because her aural skills are still developing, Emma does not notice that her F-natural is consistently sharp when she is practicing for her test. As a result, she plays the mistake repeatedly until the incorrect version of the music becomes automatic, making the practice session counterproductive. When Emma takes the playing test on the music she practiced, she does poorly. She loses motivation to practice in the future because her effort did not result in the competency for which she was striving. The problem with Emma's practicing was not her effort, but rather her inability to accurately evaluate her performance and give herself proper feedback in the moment.

Deliberate practicing increases musical skills (Ericsson, Krampe, & Tesch-Romer, 1993; McPherson & Renwick, 2011; Sloboda, Davidson, Howe, & Moore, 1996;

Lehmann, Sloboda, & Woody, 2007). However, deliberate music practicing is difficult for students to learn to do effectively because it requires constant self-regulation, including goal setting, progress monitoring, self-assessment, self-feedback, error correction, and strategy use (Ericsson, 1997; Hyllegard & Bories, 2008; Krampe & Ericsson, 1996; McPherson & Renwick, 2011; Meinz & Hambrick, 2010; Nielsen, 2001). All of these requirements rely heavily on aural skills, defined here as the abilities to recognize pitch and discern intonation, which may not yet be proficient in a student musician. Because novice musicians have not yet developed the necessary aural schemata to hear, pinpoint, and correct their mistakes (Barry & Hallam, 2002), students like Emma spend almost all of their independent practice time playing through music from beginning to end, mistakes and all, without employing any strategies to improve their performance (McPherson, Davidson, & Faulkner, 2012; McPherson & Renwick, 2000; Pitts et al., 2000). The problem is that when a student's aural skills are underdeveloped, inability to accurately self-assess performance results in an inability to practice effectively in an independent setting.

Theoretical Foundations of Practice

Deliberate practice is a highly structured effortful activity, specifically designed to systematically target critical components of skill in order to incrementally improve one's current level of performance by strategically overcoming weaknesses pinpointed through self-monitoring and informative feedback (Ericsson, et al., 1993; Ericsson & Harwell, 2019). Although practice might look like simple repetition of an isolated skill, pure repetition alone will not lead to improved performance (Hallam, 1997; Ericsson, et al., 1993; Mornell, Osbourne, & McPherson, 2020). In productive deliberate practice, each repetition is a strategically specific variation representing an incremental approximation to the desired goal. If the strategy guiding the series of incremental variations is incompatible with the specific desired goal, the effort will result in lack of improvement. In order to ensure improvement, learners should be given explicit instructions about the best strategic methods to employ for various goals, and should be supervised in their practice so errors will be diagnosed through informative feedback, ideally by a teacher (Ericsson, et al., 1993).

When deliberate practice is done in solitary isolation, it becomes necessary for the individual to monitor and regulate these complex processes independently for oneself. Therefore, solitary practice begins with analysis of the task, followed by the creation of specific goals to maximize improvement on the task (Nielsen, 2001; Hatfield et al., 2017). Specific strategies are selected to target those specific goals, and those strategies are acted on through deliberate effortful performance. The performance is self-monitored to diagnose errors and self-evaluated to illicit feedback. Evaluative feedback informs the creation of the next strategy to target the found weakness, or to take the next incremental step toward the goal. Practice continues in systematic incremental self-guided cycles, responding to meet the changing needs of the improving performer (Nielsen, 2001; Hatfield, 2016). In other words, solitary deliberate practice is self-regulated.

Theoretical Foundations of Self-Regulation

Self-regulation is the self-directive process by which learners transfer their mental abilities into skills (Zimmerman, 2002). Through self-generated thoughts, feelings, and behaviors targeted at attaining goals, self-regulated learners activate, alter, and sustain specific learning practices in social and solitary contexts (Zimmerman, 2000). Self-regulated learners set specific proximal goals, generate strategies for attaining goals, monitor performance selectively for signs of progress, restructure physical and social contexts to align with goals, manage time efficiently, self-evaluate effectiveness of strategies, attribute causation to results, and adapt future strategies in response to self-assessment (Zimmerman, 2002).

Zimmerman's model of self-regulation

In Zimmerman's Model of Self-Regulation, expert self-regulatory processes occur

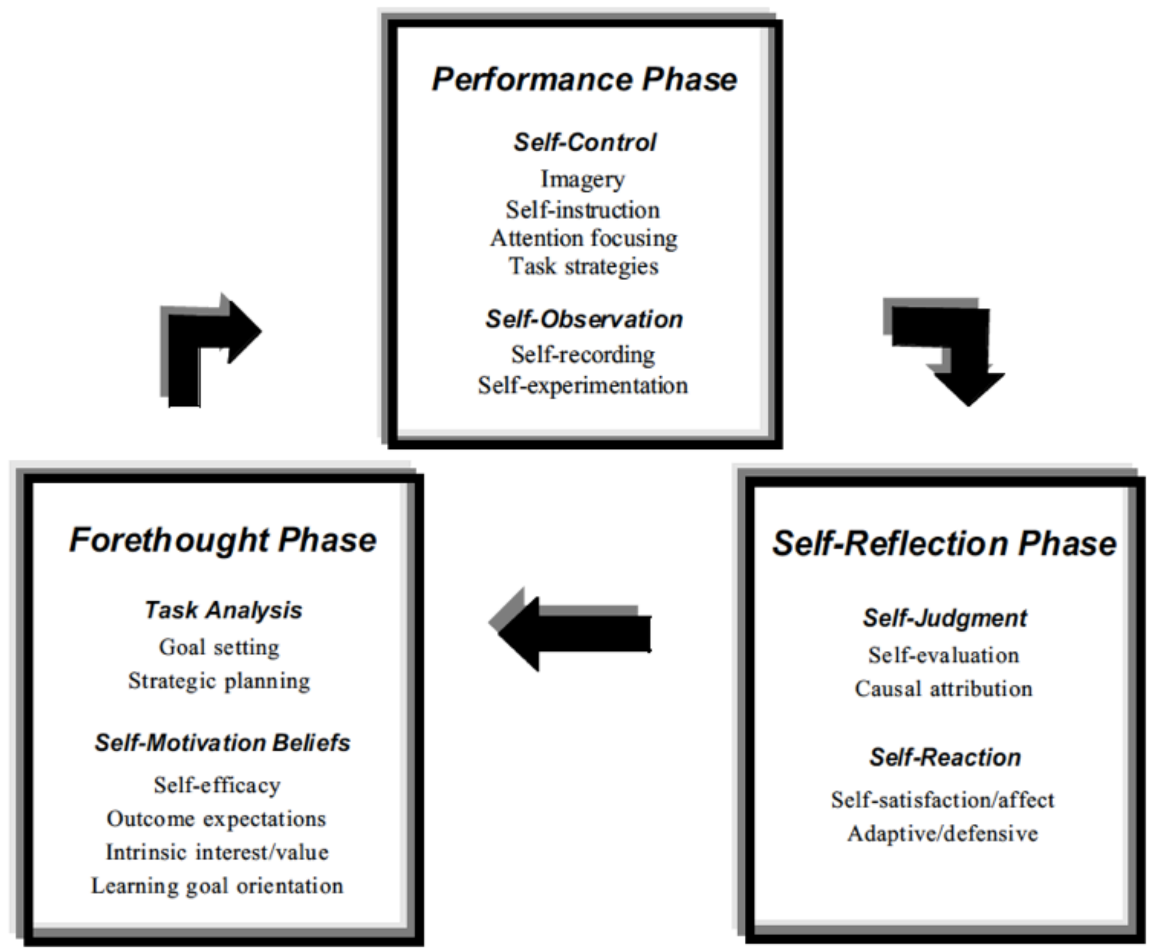

Figure 1. Phases and Subphases of Self-Regulation. (Zimmerman, 2002, p.67).

in a three-phase cycle including forethought, performance, and self-reflection (see Figure 1). During the forethought phase, self-regulated learners analyze the task in order to set goals and plan strategies while simultaneously considering motivational beliefs. During the performance phase, self-regulated learners actively control their performance through self-instruction focusing attention on task strategies while simultaneously monitoring their own performance. During the self-reflection phase, self-regulated learners self-evaluate by comparing their performance against their desired goal to determine if the goal was met and to pinpoint the cause of their triumph or failure in order to adapt future strategies according to their self-assessment (Zimmerman, 2002; Schunk & Usher, 2013).

Theoretical Foundations of Expert Practice

Experts practice. Expert performers hone their skills over years of deliberate practice, often accumulating ten years of formal practice before achieving notoriety (Ericsson et al., 1993; Hallam & Bautista, 2018). Among music students, the most successful musicians undertook more practice (Sloboda & Howe, 1991), up to four times more practice (Davidson 2002; Howe & Davidson, 2003), than less successful student musicians. In achieving a set musical standard, the quantity of practice to achieve that standard was the same whether students practiced a little over a long period of time or practiced a lot over a short period of time (Davidson, 2002; Howe & Davidson, 2003), suggesting that musical skill acquisition is a direct result of time spent practicing.

Skill is also a direct result of the quality of practice. Experts are successful in the practice room because they self-regulate their deliberate practice (Bonneville-Roussy & Bouffard, 2015). The quality of self-regulatory methods a student employs during solitary practice is a prime determinant of effectiveness (Austin & Berg, 2006; McPherson, 2005; McPherson & McCormick, 1999, 2000, 2006; McPherson & Zimmerman, 2011; Miksza, Prichard, & Sorbo, 2012; Rohwer & Polke, 2006; Schunk & Zimmerman, 1998). Experts display higher levels of self-regulatory processes during practice efforts than novices (Cleary & Zimmerman, 2000; Hallam 1997, 2001). Experts and advanced music students set specific improvement goals (Nielsen, 2001), create and prioritize strategies to reach improvement goals (Hallam et al., 2012; Maynard, 2006; McPherson et al., 2012;

Nielsen, 2001), actively image and control performance (Ericsson et al., 1993; Hatfield et al., 2017) through self-instruction (Nielsen, 2001), carefully self-monitor their performance at a detailed level (Ericsson et al., 1993; Nielsen, 2001; McPherson et al., 2012), extensively self-evaluate and adjust methods according to aural feedback (Ericsson et al., 1993; Nielsen, 2001; McPherson et al., 2012), and manage time effectively to maximize efficiency and avoid exhaustion and burnout (Ericsson, et al., 1993).

Nielsen's model of self-regulation during practicing

Based on analysis of the learning strategies of advanced collegiate organ performance majors, Nielsen's Model of Cyclic Self-Regulation of Learning During Practicing (see Figure 2) illustrates the extensive self-regulatory processes advanced musicians engage in when practicing to improve musical performance (Nielsen, 2001). She describes the model as follows:

> The core of the model consists of the student's 'problem belief,' 'strategy use,' and 'self-evaluation,' and their interrelations. The content depends on changes as the musical work is mastered. In the course of mastery, problem beliefs may be revised (e.g. technical vs. expressive problems in focus), and the student's self-evaluation relies on criteria that may be revised (e.g. rapidity vs. accuracy criteria) during learning periods…Student's problem beliefs are influenced by patterns in the musical material…that may be revised due to the students' evaluation of their performance of the music…The problem belief may influence the strategy use during practice. The students' metacognitive competence and their self-efficacy beliefs may also influence the strategy use. For example, to evaluate their progress, the students compared the present performance with the specific goal

(e.g. their idea of the final performance of the piece). Changes in their strategic activities were based on their reactions to self-evaluative judgements. The belief that they were making progress enhanced their self-efficacy for the task at hand, and they attributed their success to an effective use of strategies. However, it is

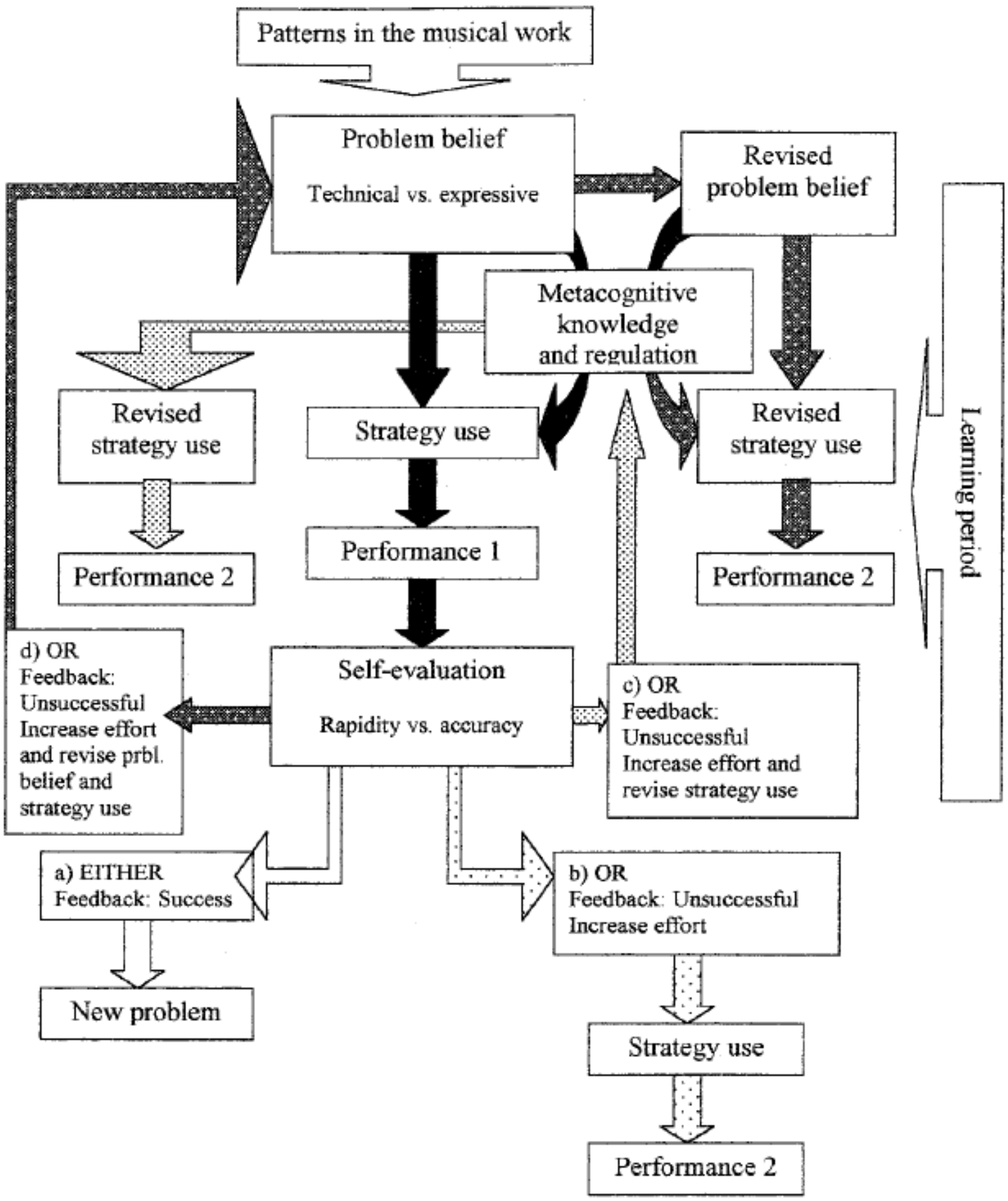

Figure 2. Cyclic self-regulation of learning strategies during practice, showing the basic first step and all four alternative problem-solving activities to follow it. (Nielsen, 2001, p.165).

> also possible to account for their changes in strategic activities based on a negative self-evaluation with an unsuccessful performance attributed to an ineffective use of strategies, but with a continued belief in the value of remaining strategic. Their use of strategies may also be independent of metacognitive control. (Nielsen, 2001, p.164)

Theoretical Foundations of Novice Practice

Novices are unsuccessful in the practice room because they do not self-regulate their practice. Novices display lower levels of self-regulatory processes during practice efforts than experts (Cleary & Zimmerman, 2000; Hallam 2001). One specific difference is that "novices fail to engage in high quality forethought and instead attempt to self-regulate their learning reactively. That is, they fail to set specific goals or to self-monitor systematically" (Zimmerman, 2002, p.69). Several analyses of novice music practicing seem to support that claim, revealing that up to 90% of novice practice time is spent playing through pieces or exercises from beginning to end without any attempt at self-correction or any strategies to improve performance (Gruson, 1988; Hallam, 1997; McPherson & Renwick, 2000, 2001; Pitts et al., 2000; McPherson et al., 2012). When novices reach the end of the piece or exercise, no matter how many mistakes they make, they simply move on to the next piece, exercise, or task (McPherson & Renwick, 2001; McPherson et al., 2012). This evidence illustrates that the goal set by these novice musicians is merely to get through the pieces on the practice assignment, rather than to improve their performance of the pieces (Oare, 2012). They showed no signs of self-monitoring their performance.

Rom’s model of beginning self-regulation of music practicing

If novice music students were able to self-regulate their practicing, they might have more success. High achieving novice music students are those who are in the beginning stages of developing their abilities to image, monitor, and control their playing (McPherson et al., 2012). Drawing from Nielsen’s model, The Rom Model of Beginning Self-Regulation of Music Practicing is an illustration of how a novice music student might practice employing basic self-regulatory methods (see Figure 3). It specifically illustrates the process a novice music student who is beginning to self-regulate would go through when practicing to master pitches and rhythms from written notation. In the forethought phase (orange), students engage in task analysis and strategic planning. Musicians first look at a short passage of musical notation (task) and plan a simple strategy to attain the aural goal image by playing the pitches and rhythms correctly. The simple strategy includes identifying the notes, translating notes to fingerings, pressing down the corresponding fingers on their instrument, and audiating an aural goal image of what the music should sound like. In the performance phase (green), students play the passage (perform) while listening to the sounds coming from their instrument (monitor). In the self-reflection phase (blue), students compare the sound of their performance (auditory feedback) to their audiated aural goal image of what the music is supposed to sound like, to evaluate their performance (self-evaluation). Based on their assessment of whether their performance matched the goal or not, the student chooses the next step. If the performance and goal aligned (match), the student would go on to the next musical passage, returning to the top of the cycle to go through it again to play the next task. If the performance and goal do not align (mismatch), the student figures out what went wrong and why (problem belief), and then uses that information to figure out how to adjust the strategy for the next attempt through the cycle.

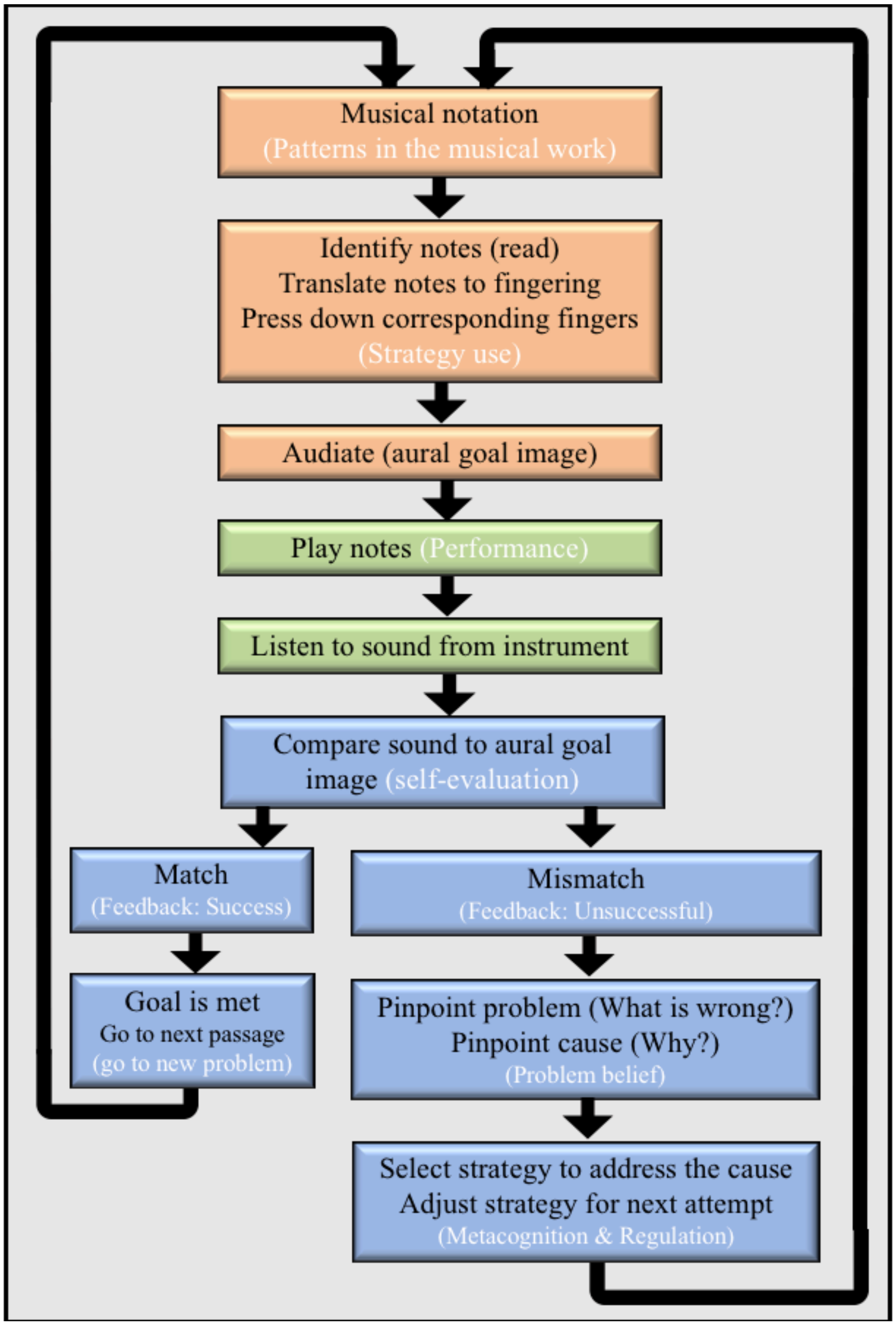

Figure 3. Rom’s Model of Beginning Self-Regulation of Music Practicing.

Novice aural skill deficiencies.

Novice music students are unable to self-regulate practice because they do not yet have the necessary aural skills to do so. Analysis of novice music student practicing illustrates that beginners ignore the auditory feedback from their playing, “rarely picking out small-scale or even global errors such as inaccurate rhythm or pitch, poor tuning, or unpleasant tone” (McPherson et al., 2012, p.35). Beginners do not seem to be aware of where they are going wrong because they have not yet developed appropriate internal aural schemata to pinpoint and correct their mistakes (Barry & Hallam, 2002). Therefore, novices are unable to self-regulate practice because they are not yet able to audiate an aural goal model from written notation, nor perceive the aural feedback from their playing, nor provide themselves with self-oriented evaluative feedback from assessment of aural evidence.

Audiation deficiency

Novice music students are unable to audiate an aural goal image from written notation, which prevents them from being able to self-regulate their practice (see Figure 4). Music students who are taught through the traditional visual orientation, that begins with notation, tend to be inefficient in their ability to audiate music from notation or aurally (McPherson, 1993), possibly because “there is insufficient opportunity to learn to associate their nascent aural schemata with the notation” (McPherson & Renwick, 2001, p.179). If students are unable to figure out what a piece is supposed to sound like, they have nothing to compare their performance to, and therefore are not able to determine if the notes they are playing are correct. The most commonly ignored error in student practicing is a failure to observe the key signature, suggesting that students believe their wrong note must be correct because they are using what they believe is the correct fingering (McPherson & Renwick, 2001). They assumed it was correct, because, in the absence an aural goal image, they had no idea what the piece was supposed to sound like. However, when students do know how the music should sound, they are more successful. In novice students, "prior familiarity with tunes such as *Old Macdonald* or the aural

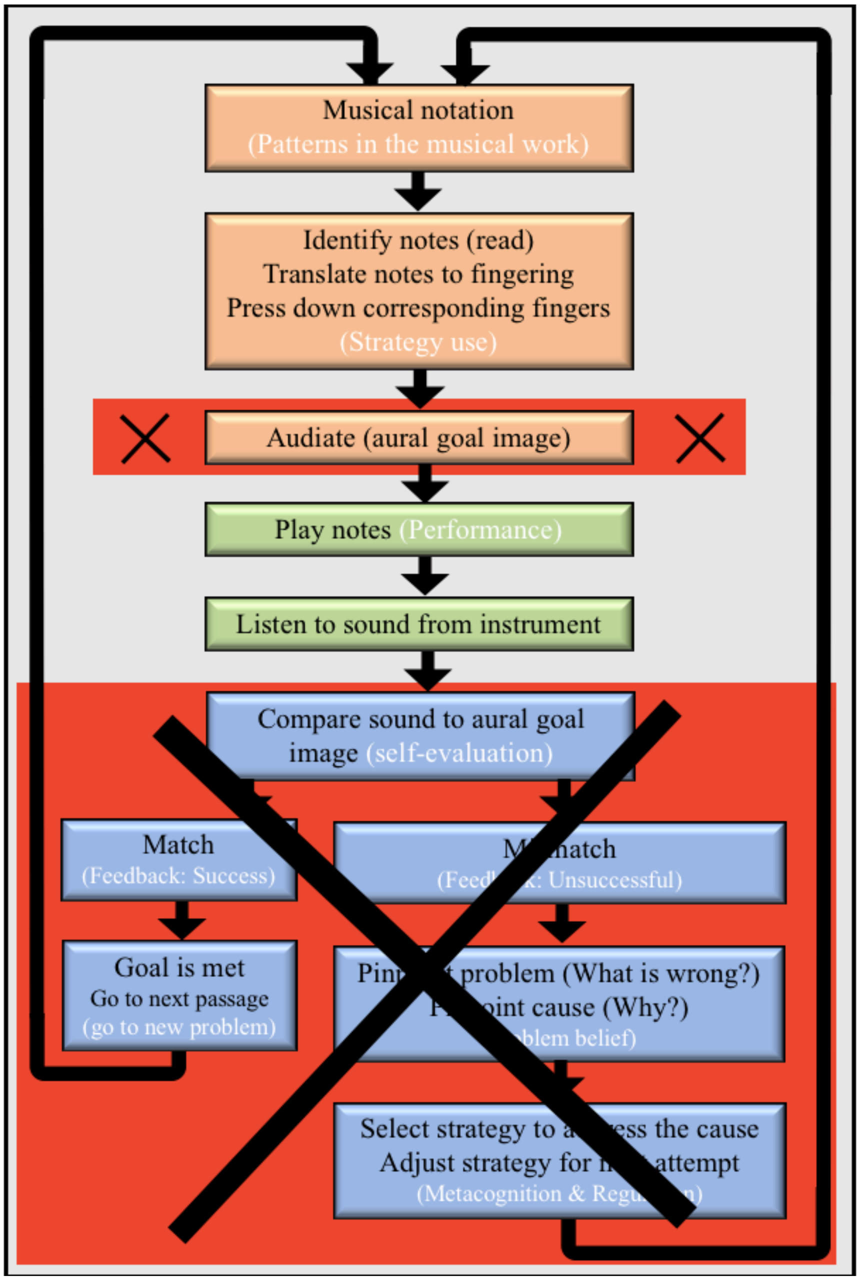

Figure 4. Novice Audiation Deficiency.

memory of their teacher's rendition guided their rhythmic accuracy" during practicing (McPherson & Renwick, 2001, p.181).

Aural perception deficiency

Novice music students are unable to perceive the aural sounds from their playing, which prevents them from being able to self-regulate their practice (see Figure 5).

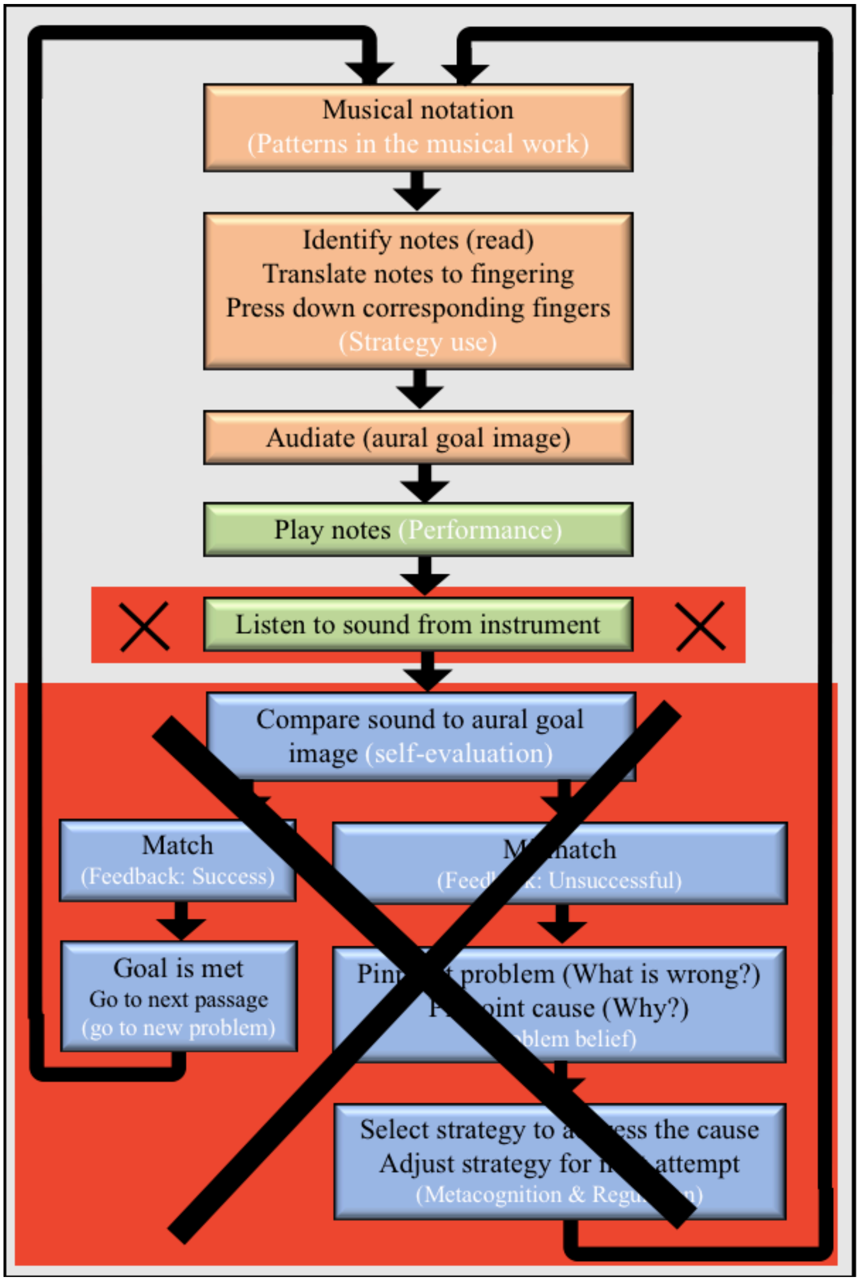

Figure 5. Novice Aural Perception Deficiency.

Perhaps the student knows what the piece is supposed to sound like, but is unable to hear his or her own performance in a way that they can compare what they heard from their own playing to the aural goal image of what the piece should sound like. Practice analysis uncovered a general inability of these young learners to correct their performances based on the feedback they received while playing (McPherson & Renwick, 2001), suggesting that they are not able to attend to their own auditory feedback while they are playing, possibly due to the large cognitive load required to read music while manipulating the instrument, before simple playing mechanics have become automatic. Without auditory feedback to compare to the aural goal image, they are unable to self-assess the performance to provide themselves with self-evaluative feedback to inform future strategies.

Evaluative feedback deficiency

Self-regulation is not possible without self-oriented evaluative feedback. “In the absence of adequate feedback, efficient learning is impossible and improvement only minimal even for highly motivated students” (Ericsson, Krampe, & Tesch-Romer, 1993, p.367). Music students need self-oriented feedback in order to choose and use appropriate strategies, decide what kind of instruction they need, and stay on track mentally and motivationally (McPherson et al., 2013). Self-regulated musicians use their performance feedback directly to modify and adapt their playing in the moment while practicing (McPherson & Renwick, 2001). Music students need feedback to practice successfully. As a result, students rely heavily on their teachers to provide evaluative feedback (McPherson et al., 2013), out of necessity. Because proper practice takes years to develop (McPherson, Davidson, & Faulkner, 2012), it is recommended that a teacher or person trained in deliberate practice should be monitoring practice of novices to provide them with feedback (Ericsson, et al., 1993). The great musical prodigies of history had in-home music teachers who monitored their daily practice (Lehmann, 1997). However, most novice music students do not have the luxury of parent musicians or the financial means for private music tutors. Only six percent of parents in close proximity to their practicing child were able to provide any evaluative feedback (McPherson et al., 2012). In some cases, the presence of parents during practicing had a negative effect on musical progress, as lack of optimism in their child's musical potential eventually rubbed off on the music student (Davidson & Borthwick, 2002; McPherson & Davidson, 2002).

Theoretical Foundations of Motivation

Relying solely on others for evaluative feedback may undermine autonomy, which decreases motivation to practice. Students who practiced at the same time every day, under a parent-controlled environment, were more likely to quit playing their instruments (Faulkner et al., 2010). Young musicians require an environment which is facilitating and encouraging but allows personal space and freedom (Hallam, 1998).

Students who practice poorly do not achieve competency, which decreases motivation to practice. Musicians' motivation to practice comes from their motivation to improve their performance (Ericsson, Krampe, & Tesch-Romer, 1993). When play-through is the only practice strategy, progress is not possible (Sloboda et al., 1996). The number of practice sessions novice music students completed decreased steadily over the course of a year (McPherson et al., 2012), suggesting a decline in motivation to engage in fruitless practice. Students who continue to engage in fruitless practice do so because they believe, as do their parents, that practicing is critically important (McPherson et al., 2012), and parents may provide extrinsic rewards (Faulkner et al., 2010). In other words, they are motivated by external factors that became unsustainable.

Theoretical Foundations of Digital Scaffolds (DS)

If students need feedback to achieve competency and need freedom and personal space to achieve autonomy, perhaps students can get feedback assistance from a non-human source which allows them to achieve competency and autonomy. In the same way calculators have provided support to math students checking their work, technology such as electronic tuners and metronomes are important tools in the practice rooms of successful musicians.

Aural Model DS (Model)

A novice music student who is not yet able to audiate an aural goal image from written notation could listen to an audio file of the music to get an aural goal image of the piece. The aural model is a digital audio file of the music used to scaffold a student's aural goal image of what the written notation is supposed to sound like.

Auditory Playback DS (Playback)

Similarly, a student struggling to hear her own performance in the moment could listen to an audio playback after the cognitive demands of reading notes and manipulating the instrument are over. This auditory playback feedback (Playback) is a digital audio recording of the musician's performance of the music played back to the student after the performance, in order to scaffold the student's aural perception of their own performance.

Visual Evaluative Feedback DS (Visual Feedback)

Technology also exists that can assess pitch and rhythmic accuracy of a student's performance of written notation. The computer program *SmartMusic* assesses pitch frequency and rhythmic durations, displaying a color-coded visual image indicating which notes the musician played correctly (highlighted in green) and which notes the musician played incorrectly (highlighted in red). This tool could be used to provide novice music students with visual evaluative feedback while practicing on their own.

Conceptual Model

Music students' ability to self-correct performance in order to improve is dependent upon their aural skill proficiency, which is influenced by prior music experience and training. Maturation, music exposure, age at which students begin lessons on their instrument, music teachers, and frequency and effectiveness of prior practice all play a role in each participant's music experience, which, in turn, influences their aural skill development and proficiency. Because students have a diverse range of aural skill proficiencies, they vary in their abilities to audiate goal images of the music, hear and monitor their own playing, and self-assess their own performance (see Figure 6). The digital scaffolds in this study are intended to target each of those three skills (see Figure 7, Figure 8, Figure 9), which are prerequisite for self-correction and subsequent improvement of pitch and rhythmic accuracy.

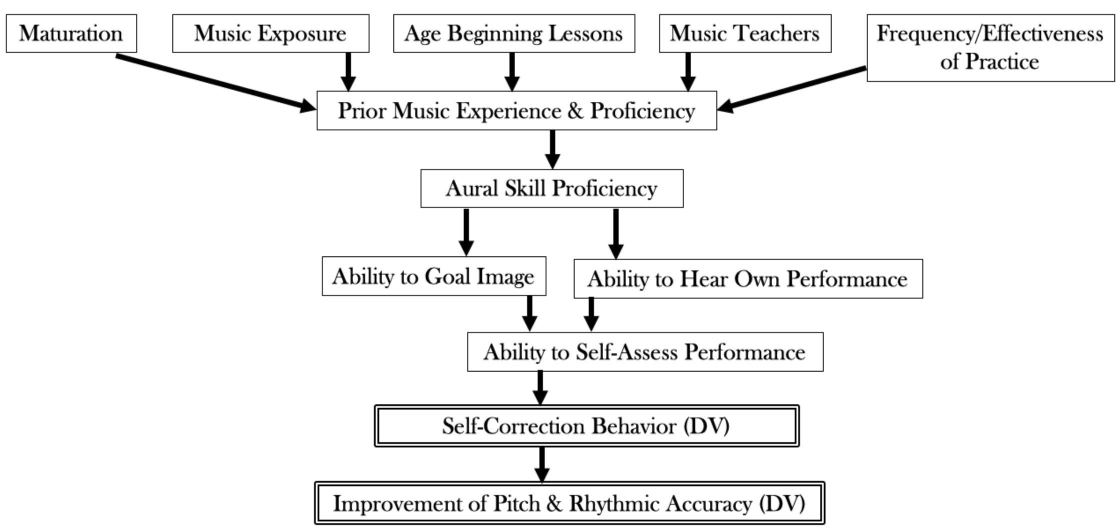

Figure 6. Conceptual model for self-correction and improvement as a function of component aural skills used during independent music practicing (control condition).

Digital Scaffolds Impact on Conceptual Model

The digital scaffolds in this study are intended to target the component aural skills necessary for self-regulating independent music practice.

Aural Model Digital Scaffold.

The Aural Model Digital Scaffold (AM) is a digital audio recording of the melody performed on piano. For students who may have difficulty audiating an aural goal image of the musical task from written notation, hearing an aural model of what the melody is supposed to sound like should enable the student to form an accurate goal image. If the aural skill audiating an aural goal image from written notation is the only deficient aural skill, the use of an aural model should impact self-correction behavior and improvement of pitch and rhythmic accuracy (see Figure 7).

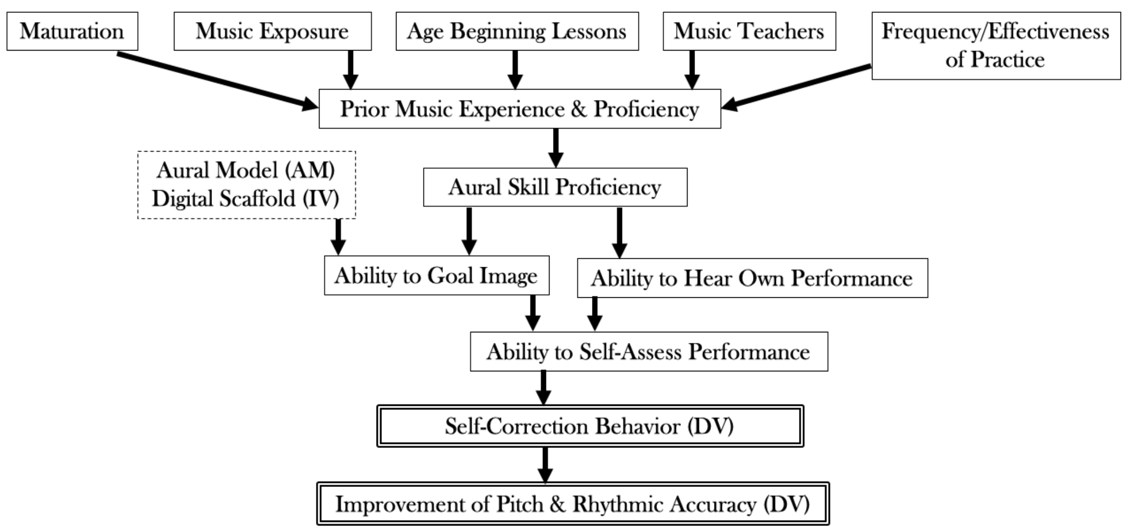

Figure 7. Conceptual model for self-correction and improvement as a function of aural model digital scaffold on component aural skills used during independent music practicing (Model condition).

Auditory Performance Playback Feedback Digital Scaffold.

The Auditory Performance Playback Feedback Digital Scaffold (Playback) is a form of self-recording. In this study, a participant's performance is recorded and played back to the participant. According to Cognitive Load Theory, if too much complex information is bombarding the student at once, the processing load required to make sense of it could be greater than the limited cognitive resources available in working memory (Bruning, Schraw, & Norby, 2011, p.13-36). Playing an instrument and reading music involve a highly complicated combination of skills. If participants are unable to hear their own performance in real time due to cognitive overload from producing the sound, then hearing their performance played back, when they are not exerting effort and cognitive energy to make the music, should enable them to attend to what they hear. The aural playback feedback digital scaffold (playback) is intended to support one's ability to hear and self-monitor his or her own performance. As a result of enabled self-monitoring, the participant may be better able to self-assess their performance, and as a result increase self-correction behavior and improve pitch and rhythmic accuracy. Because self-monitoring performance occurs after (and is dependent on) goal imaging in the cycle of self-regulation of music practice (see *Rom's Model of Beginning Self-Regulation of*

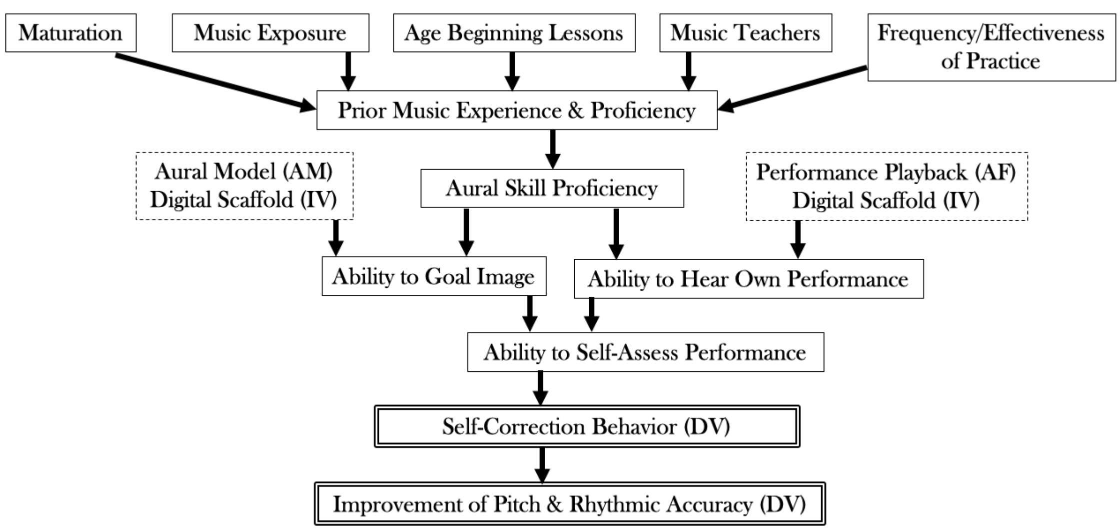

Figure 8. Conceptual model for self-correction and improvement as a function of aural model and auditory performance playback feedback digital scaffolds on component aural skills used during independent music practicing (Model+Playback condition).

Music Practicing), the aural model digital scaffold is used in combination with the auditory performance playback feedback digital scaffold in one of the experimental practice conditions in this study (see Figure 8).

Visual Performance Assessment Evaluative Feedback Digital Scaffold. The visual performance assessment evaluative feedback digital scaffold (feedback) is a color-coded display of the music highlighting notes played correctly in green, while highlighting notes played incorrectly in red, through the computer program *SmartMusic*. The program also displays a numeric percentage of notes played correctly in terms of pitch and rhythmic accuracy out of the total number of notes. This scaffold is intended to help students who have trouble identifying discrepancies between what the music should sound like and what they actually played. If this digital scaffold supports a participant's ability to assess their performance, then it should increase self-correction behavior and improve pitch and rhythmic accuracy. Because self-assessment is dependent on both goal imaging and self-monitoring in the cycle of self-regulation of music practice (see *Rom's*

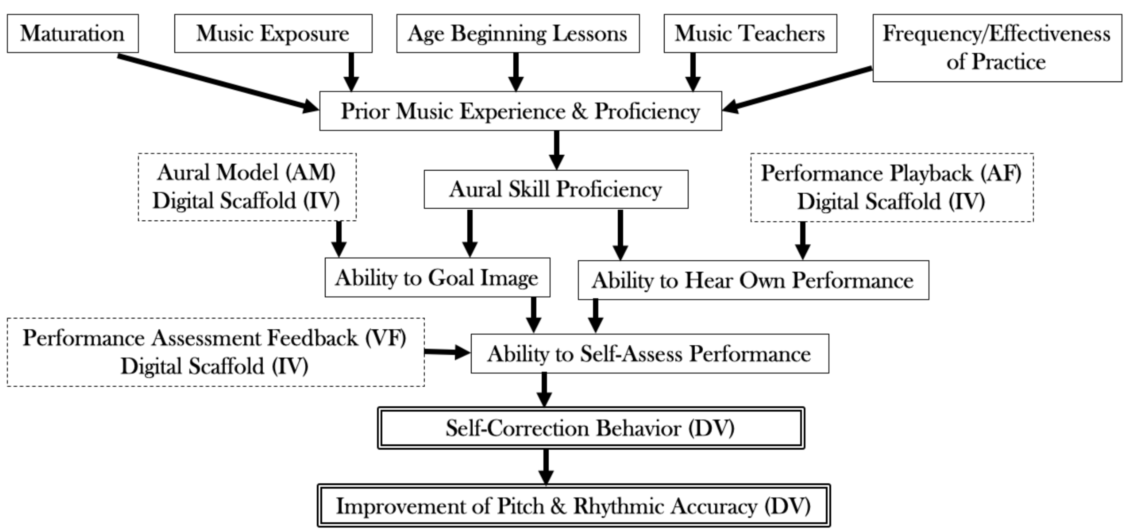

Figure 9. Conceptual model for self-correction and improvement as a function of aural model, auditory performance playback feedback, and visual evaluative feedback digital scaffolds on component aural skills used during independent music practicing (Model+Playback+Feedback condition).

Model of Beginning Self-Regulation of Music Practicing), the visual performance assessment evaluative feedback digital scaffold is used in combination with the aural model digital scaffold and the auditory performance playback feedback digital scaffold in one of the experimental practice conditions in this study (see Figure 9).

Summary of Theoretical Foundations

Skill acquisition occurs through deliberate practice (Ericsson et al., 1993). Solitary deliberate practice is possible through self-regulation (Zimmerman, 2002). Experts are successful in the practice room because they self-regulate their practice (Nielsen, 2001). Novices are unsuccessful in the practice room because they do not self-regulate their practice (Gruson, 1988; Hallam, 1997; McPherson & Renwick, 2000, 2001; Pitts et al., 2000; McPherson et al., 2012). Novices are unable to self-regulate their practice because of aural skill deficiencies (Barry & Hallam, 2002). More specifically, novice music students are unable to audiate an aural goal image from written music notation (McPherson, 1993), and cannot perceive the aural sounds from their own playing (McPherson & Renwick, 2001). Audiation and aural perception are necessary to hear the discrepancy between one's performance and what it should sound like, in order to provide self-oriented evaluative feedback based on self-assessment of this aural evidence. Self-regulation is not possible without evaluative feedback (Ericsson et al., 1993). Music students need evaluative feedback to practice successfully and achieve competency. If students need feedback to achieve competency and need freedom and personal space to achieve autonomy, perhaps students can get the feedback they need from a non-human source that allows them to achieve competency and autonomy, which could increase motivation to practice, according to self-determination theory of motivation (Deci & Ryan, 2000).

Technology exists that could potentially support these aural skill deficiencies. An aural model digital scaffold (Model), in which an audio file of the music is played for the student, could provide support to novice music students with audiation deficiency. An auditory playback feedback digital scaffold (Playback), in which an audio recording of the student's performance is played back to the student, would provide support to novice music students with aural perception deficiency. A visual evaluative feedback digital scaffold (Feedback), in which pitch and rhythmic accuracy assessment is displayed through a color-coded visual image indicating which notes the musician played correctly (highlighted in green) and which notes the musician played incorrectly (highlighted in red), would provide support to novice music students with evaluative feedback deficiency. As a result of these digital scaffolds, novice music students should be able to get past their aural deficiencies in order to engage in self-regulatory methods that were not possible without the digital scaffolds. Potentially, these digital scaffolds can patch the gaps in novice music student independent practice, enabling self-regulation leading to improved performance (see Figure 9).

Purpose

The purpose of this study was to gain insight into the deficiencies and capabilities of high school string players in the practice room, through a mixed methods within-subjects experiment exploring the impact of digital scaffolds on pitch and rhythmic accuracy growth, self-assessment, self-correction, and other self-regulatory behavior during independent music practicing.

Research Questions

Employing a convergent mixed methods design (QUAN+QUAL), I sought to understand how digital scaffolds impact high school string students' individual music practicing. More specifically, the quantitative research questions are:

- Q1(QUAN): Do digital scaffolds impact the pitch and rhythmic accuracy growth of high school string players practicing independently?
- Q2(QUAN): Do digital scaffolds impact the amount of time a high school string player persists at practicing a musical task?

The qualitative research questions are:

- Q3(QUAL): How do high school string students experience music practicing with and without digital scaffolds?
- Q4(QUAL): What self-regulatory behaviors do high school string students employ when practicing with and without digital scaffolds?

The mixed methods research questions are:

- Q5(MIXED): Do the pitch and rhythmic accuracy scores align with students' description of their own assessment of their performance with and without digital scaffolds?
- Q6(MIXED): In what ways do quantitative data and qualitative data converge and/or diverge to illuminate deficiencies and capabilities of high school violinists, violists, and cellists in the practice room?

Definition of Key Terms

For the purposes of this study, the following terms need clarification:

Digital Scaffolds (DS) are computer-centric tools that provide information which is necessary for engagement in a larger task. In this study, digital scaffolds provide support for student deficiencies so that students can engage in self-regulated practicing. Digital scaffolds in this study include aural models, aural feedback, and visual evaluative feedback.

Aural Model (Model) will refer to the sound goal image of written notation, or 'what the music is supposed to sound like.'

Aural Model DS is an audio file of the music.

Auditory Playback Feedback (Playback) will refer to the sound produced by the musician during music practicing, or 'what sounds actually come out of the instrument.'

Auditory Playback Feedback DS is a playback recording of the student's performance.

Visual Evaluative Feedback (Feedback) will refer to performance assessment information visually appearing in a color-coded display. Performed sounds that match the written notation are highlighted in green while performed sounds that mismatch the written notation are highlighted in red, assessed and displayed through the computer program *SmartMusic*. This could also be defined as 'a color-coded display indicating which notes the musician played correctly, and which notes were played incorrectly.'

Visual Evaluative Feedback DS is the color-coded display and percentage of accurate notes.

SmartMusic is computer software that can assess the pitch and rhythmic accuracy of a student's performance of uploaded written music notation.

Aural skills will refer to the abilities to recognize pitch and discern intonation, including audiation and the ability to hear and identify pitch, intervals, melody, harmony, rhythm, and other basic musical elements.

Audiation, a specific aural skill, will refer to the ability to mentally hear music from printed notation or to hold a mental aural representation of music in mind.

Take will refer to one music recording made by the musician

Delimitations

For the purpose of this study, independent music practice is examined in terms of high school string students working to perform the pitches and rhythms of written notation on their instrument for later application in orchestral ensemble rehearsal settings. It is assumed that musical interpretation and expressive elements would be decided and incorporated by the ensemble during subsequent rehearsals, in the same way that actors learn their lines on their own before rehearsing and interpreting the play with full cast. The specific type of practice that is the focus of this study is only one component of a well-balanced practice regimen, which would be inclusive of both formal and informal practice with a range of foci including pitch and rhythmic accuracy, tone production, technical fluency, expressive exploration and interpretation, memorization, improvisation, playing by ear, and more.

Anticipated Results

The ‘business-as-usual’ control condition will provide a glimpse into the way intermediate music students practice, and possibly struggle, when attempting to master pitches and rhythms from written notation. It will serve as a baseline measure of how intermediate music students typically practice on their own. If the main problem students face is not being able to come up with and use corrective strategies, practicing with digital scaffolds in this study will not impact student behavior or pitch and rhythmic accuracy differently than practicing without digital scaffolds. However, if the main problems students face are deficiencies in aural skills, the students practicing with digital scaffolds in this study will demonstrate differences in both behavior and performance accuracy, when compared to the baseline. If a student struggles only with audiation, the Model condition will illicit an increase in observed self-regulatory behavior and improvement in pitch and rhythmic accuracy (SMPRA scores), when compared to the baseline (see Figure 7). If a student struggles with both audiation and hearing their performance in the moment, the Model+Playback condition should illicit increase in observed self-regulatory behavior and SMPRA scores, when compared to the baseline (see Figure 8). If a student cannot hear that there is a discrepancy between their performance and the aural goal model or cannot pinpoint the exact pitches that are the problem, the Model+Playback+Feedback condition should increase the student's self-regulatory behavior and SMPRA scores, when compared to the baseline (see Figure 9).

Conclusions and Implications

In light of this present study, researchers, music educators, parents, and students will gain a better understanding of how novice music students experience individual practicing, and what they need to be successful in the practice room. Music researchers looking to increase student self-regulation during practicing have focused on teaching strategy use. The present study may support the need to look further into supporting aural skill development as a means to increasing self-regulated music practicing. If music educators were able to spend less time during ensemble rehearsals fixing pitches and rhythms, then more time could be spent focusing on higher level music skills such as musical expression and interpretation. Equipping teachers with tools to help their students master the pitches and rhythms on their own successfully would increase the time directors could focus on really making music during rehearsals. Parents feel responsibility to make their child practice. If parents had tools that allowed their children to feel autonomous and achieve competency during solitary practice, perhaps students would be more motivated to practice without as much nagging, pleading, and bribery from parents. This study could illuminate tools to help students practice effectively on their own. The more students who are able to practice successfully, the more students who will continue playing music.

This dissertation will also contribute to the understanding of students' experiences with technology, informing the use of scaffolding technologies that can better support students. Computer technologies, like *SmartMusic*, that can provide immediate pitch and rhythm feedback, may be helpful in scaffolding solitary practice sessions so that students can make progress and feel competent and autonomous, even while they are still developing the aural skills to do so on their own.

Musicians who make it through the novice period of aural skill development are often successful due to access to private music tutors who point out these practice errors in one-on-one settings (Lehmann, 1997). However, it has been my experience that many students learn to play an instrument in public school orchestral settings where large class size restricts the amount of individual practice feedback a teacher is able to provide. Many of my students are first generation violinists, violists, or cellists who do not have the luxury of parent musicians or the financial means for private music tutors. This reality perpetuates the elitist idea that high-level musical achievement is reserved only for the chosen few who can afford the financial cost of nurturing it. Of the 21% of high school seniors who participated in school music ensembles nationally in 2010, students in the lowest SES quartile were underrepresented in music programs (Elpus & Abril, 2011). If the present study contributes to the discovery of a solution that can help to close the gap between the students who have a privileged early start and those who are still learning, then it may be the key to opening doors for students like Emma who currently see only exits. The human experience of high-level musicianship should be available to all. With the development of research based technological scaffolds, it might become more attainable for any student like Emma who seeks it.

Chapter 2: Review of the Literature

The Role of Practice in Musical Skill Acquisition

Practice increases skills. Several researchers asked musicians to report the amount of time they spent practicing. Ericsson, Krampe, and Tesch-Romer (1993) asked 40 collegiate violinists to recall their musical development. They found that the "good" and "best" violinists pursuing performance majors had accumulated more hours of practice by the age of 18 and continued to practice more hours more regularly than their music education major counterparts (Ericsson, Krampe, & Tesch-Romer, 1993). In a similar study, Jorgensen (2002) had musicians report the amount of time they spent practicing and also had their performance evaluated as "good," "very good," or "excellent." Results indicated that the "excellent" musicians reported practicing significantly more than the "good" or "very good" musicians (Jorgensen, 2002).

An investigation of one academic year of practice (42 weeks) of 257 music students (8 to 18 years old) revealed that higher achieving music students who gained entrance into a music specialty school spent more time practicing and practiced more consistently than their lower achieving peers, and more of that practice was spent working on technique and repertoire (Sloboda, Davidson, Howe, & Moore, 1996). They also found that the amount of accumulated practice was approximately the same for achieving the next level on a national exam, whether the student practiced less frequently for a long period of time or more frequently for a short period of time (Sloboda et al., 1996). Still other studies indicate that the musicians who spend the most time practicing are the musicians who achieve the highest musical outcomes (Sloboda & Howe, 1991; O'Neill, 1997; Hamann & Frost, 2000).

In order to best predict musical achievement, Bonneville-Roussy and Bouffard (2015) found that the combination of three factors mattered most. Musicians at the highest levels of musical achievement put in the time engaging in self-regulated deliberate practice (Bonneville-Roussy & Bouffard, 2015).

Parent Regulation of Practice

In an examination of two weeks of practice diaries of instrumental musicians ages six to ten, O'Neill (1997) found that the high achieving students not only practiced more minutes, more times a week, than lower achieving students, but also had significantly more parental involvement during practicing than the lower achieving students (O'Neill, 1997). In a qualitative inquiry, Sloboda & Howe (1991) interviewed 42 British music conservatory students and their parents. They found that parents play an important role in encouraging, monitoring, and regulating the 200 to 500 hours of practicing their children do each year, as the students were not very self-motivated to practice or able to maintain concentration while practicing (Sloboda & Howe, 1991). A look at the famous musical prodigies through history illustrates a similar picture. Lehman (1997) analyzed the biographies of famous music prodigies and found that "supervised practice is a prerequisite for early exceptional achievements" (p.162). All of the prodigies had live-in music tutors, in many cases a parent, that monitored and regulated their daily practice (Lehman, 1997).

Characteristics of Expert Practice

Not only have experts spent a great deal of time practicing, but their practicing is also effective and efficient. Expert musicians engage in deliberate practice (Ericsson & Harwell, 2019; Lehmann & Jorgensen, 2018). Hallam (1995) studied the practicing of 22 professional musicians finding that professionals engaged in metacognition including self-awareness, strategy knowledge, planning, monitoring, and evaluating during practice (Hallam, 1995). In a comparative study of collegiate music faculty and undergraduate music majors, Barry (1991) found that faculty participants were more likely than undergraduate students to focus on trouble spots, use mental rehearsal, scan the music before playing, play slowly, and use a metronome when practicing (Barry, 1991). In another study, Duke, Simmons, and Cash (2009) found that the top pianist students were better able to identify, pinpoint the source, rehearse and correct errors; vary tempo of problem segments systematically; and repeat practice targets until errors were fixed (Duke, Simmons, & Cash, 2009).

Siw Nielsen (1997, 1999, 2001) analyzed the practice of organ performance majors, having them speak their thoughts out loud as they learned and practiced concert repertoire. She found that these high-level students engaged in a lot of problem recognition and self-evaluation (Nielsen, 1997). She was also able to categorize the strategies organ performance majors used as selection (e.g., visual examination/chunks), organization (e.g., systematic repetition), and integration (e.g., imagery, association) (Nielsen, 1999). A collective case study conducted by Siw Nielsen (2001) examined two conservatory organ majors during music practice sessions. While participants engaged in their naturally occurring practice sessions, they were videotaped while verbalizing their thought processes out loud as they worked through musical problems in real time on the organ in the practice room. Immediately after practicing, participants engaged in a debriefing session in which they watched the video of their practice session while they provided further explanation of the specific thought processes and strategies used during their practice session. Nielsen found both students to be highly skilled in all areas of self-regulation of their individual music practicing (Nielsen, 2001). As a result of her research, Nielsen created a model of the cyclic self-regulation of learning strategies during practice, mapping the mental and behavioral processes as they occur in real time during music practicing.

Characteristics of Novice Practice

In contrast to experts, novices are much less effective in their practicing. Researchers have discovered that novice students employ low level practicing strategies, such as playing the entire piece over and over again without correcting errors, or without stopping to practice excerpts that need improvement (Davidson, & Faulkner, 2012; Hallam, 1997; McPherson & Renwick, 2001; McPherson, Oare, 2012; Pitts et al., 2000). Hallam (1997, 2001) studied the practice of 55 novice string players through interview and observation. She found that these novices tended to play straight through the music without stopping to make corrections. However, the novices with higher performance achievement scores used more strategic practice behaviors (e.g., repetition and planning) than their lower achieving peers (Hallam, 2001). According to Hallam, effective practicing is fundamentally dependent on the student's ability to monitor and self-evaluate progress (Hallam, 1997). Similarly, a study examining the self-reported strategy use and a five-minute practice observation of eighth grade band students revealed a positive relationship between practice strategy use and achievement scores (Rohwer & Polke, 2006). In this study, analytic practicers, who broke down the music, had significantly higher performance achievements scores than holistic practicers, who played straight through the music (Rohwer & Polke, 2006). A longitudinal study of seven beginning Australian musicians age seven to nine recorded their practice over three years. The participants showed low levels of self-regulatory processes and tended to play straight through the music without noticing or acknowledging errors, but found that as students gained self-regulatory processes, their achievement increased quickly (McPherson & Renwick, 2001).

Even older novices exhibit similar trends in the practice room. A study of adult beginner instrumentalists revealed a lack of routine, lack of corrective behaviors, and lack of error detection, as participants were unable to identify trouble spots or evaluate their own progress (Rohwer, 2005). Even undergraduate music students were more likely than collegiate music faculty to report playing through entire pieces of music when practicing (Barry, 1991). All of this research suggests that novice musicians lack the component skills to be able to self-regulate their practice.

Self-Regulation of Practice

As the research of expert and novice musicians suggests, experts self-regulate practice while novices do not. Zimmerman (2000, 2002) illustrates the three-phase cycle of self-regulatory processes including forethought, performance, and self-reflection. The forethought phase includes *task analysis* such as goal setting and strategic planning, and *self-motivation beliefs* such as self-efficacy, outcome expectations, intrinsic interest/value, and learning goal orientation. The performance phase includes *self-control* such as imagery, self-instruction, attention focusing, and task strategies, and *self-observation* such as self-recording and self-experimentation. The self-reflection phase includes *self-judgement* such as self-evaluation and causal attribution, and *self-reaction* such as self-satisfaction/affect and adaptive/defensive (Zimmerman, 2002; Schunk & Usher, 2013).

These self-regulatory processes have been found in the practice rooms of successful musicians (Bonneville-Roussy & Bouffard, 2015; Hatfield, 2016; Hatfield et al, 2017; Osborne et al., 2020). McPherson and Zimmerman (2002) pinpoint the self-regulatory processes that are most prevalent in music practice. They are motive (e.g., working through distractions, parental influence, self-motivation), method (e.g., task-oriented strategies, mental strategies, self-instruction), time management (e.g., planning, management, concentrating focus on task), behavior (e.g., metacognition, self-evaluation/monitoring), environment (e.g., physical structure), and social factors (e.g., parental involvement, siblings, peers, help-seeking) (McPherson & Zimmerman, 2002).

Many studies illustrate a positive relationship between self-regulatory practice behavior and music performance achievement (Hatfield, 2016; Hatfield et al., 2017). McPherson (2005) found that as students gain musical competence, they gain the abilities to better self-regulate their practice (McPherson, 2005). McPherson and McCormick (2000) asked student musicians to self-report self-regulation and found that the amount of reported self-regulation was a significant predictor of performance achievement (McPherson & McCormick, 2000). Austin and Berg (2006) also found a positive relationship between self-regulatory practice behavior and amount of time spent practicing (Austin & Berg, 2006). Self-regulatory practice behavior is also positively related to time spent engaging in formal practicing (McPherson & McCormick, 1999, 2006; Miksza, 2006).

Some researchers suggest that self-regulatory processes may develop unevenly, resulting in ineffective practice in novices and intermediate musicians. One study found that some self-aware students who were highly motivated seemed to still lack the strategies to draw upon to help them improve their musical performance (Pitts et al., 2000). Much of the research on intermediate music students focuses on observable strategy use. Miksza, Prichard, and Sorbo (2012) observed thirty middle school band students while they practiced concert band repertoire independently for a twenty-minute period at a summer music clinic. They found that the strategies most frequently employed were varying tempo, repeating fewer than four measures, repeating more than four measures, and irrelevant playing (Miksza et al., 2012). They found that participant self-regulation scores (measured by Miksza's self-regulation scale) correlated positively with the frequency of practice strategies such as slowing and repetition, while self-regulation scores correlated negatively with frequency of irrelevant playing (Miksza et al., 2012).

In another study, Miksza (2013) investigated the effects of self-regulation training on practice behavior and performance achievement. A training video provided informational guidance on goal setting and planning, concentration, reflective activity, and practice strategies. Half of the 28 collegiate music majors participating in the study watched the self-regulation training video at the beginning of each of five days of practice, while the other half watched a training video containing practice strategies only. On the first day, participants sight read an etude, practiced the etude for twenty minutes, and then gave a final performance of the etude. On the fifth day of the study, participants did the same with a different etude, so that gain scores could be compared from the first and last days of the study and from the control to the treatment group to see if practicing with self-regulation training would impact performance achievement. They found that the treatment group had significantly greater gains in performance achievement on the last day of the study compared to the control group when controlling for gains on the first day of the study (Miksza, 2013). The treatment group also focused on more nuanced objectives beyond pitch and rhythmic accuracy than the control group (Miksza, 2013).

In a 2009 review of music practice studies, Zhukov described a consensus of researchers that, "above all, developing students' cognitive skills and self-regulation will lead to independence and self-reliance in learning [music]" (p.10). Carol Benton suggests encouraging students to reflect and self-assess more to help develop their metacognition when practicing (Benton, 2013). Similarly, McPherson, Nielsen, and Renwick (2013) emphasize the importance in getting students to reflect on what they are doing and how they are doing it, in order to encourage those metacognitive self-regulatory skills (McPherson, Nielson, & Renwick, 2013).

Feedback for Practicing Pitch Accuracy

Feedback is necessary for musicians to be able to self-assess and reflect. Whether the feedback is the sound they hear coming from their instrument, the visual feedback they get when they look at their finger and bow placement, the tactile feedback of the way the bow responds to physical movements, or evaluative feedback given by a teacher, feedback is the essential information necessary for self-regulatory practice.

Music educators and researchers have used a multitude of different methods and strategies in an attempt to help their students achieve better intonation. Many of these studies focus on types of feedback that lead to the greatest results in improved intonation. Salzberg (1980) split 50 university music majors into five groups. Each group used a different method or strategy in an attempt to improve their intonation. The first group received contingent verbal feedback. The second group was given a tape recorder so they could listen to their own playback. The third group was given a model performance. The fourth group used free practice. The fifth group was the control group, which received no treatment. Salzberg found that each method produced a different intonation outcome. The group that showed the most accurate intonation was the group that received contingent verbal feedback. The verbal feedback group was significantly more in tune than the groups that received model performances or tape recorders (Salzberg, 1980). In another study of eight students in a string methods course, Sogin (1997) looked at the use of contingent verbal feedback referring to finger numbers versus contingent verbal feedback referring to pitch names. The results showed that referring to finger numbers was significantly better in improving intonation accuracy than was referring to pitch names (Sogin, 1997).

The most common types of feedback used to develop a student's intonation skills in the school orchestra setting are visual, aural, tactile, and verbal. A commonly used visual feedback tool is the use of lines or tapes placed on the fingerboard in the early stages of string instrument instruction. This pedagogical tool lets the student know visually where the finger should be placed in order to have the pitch sound in tune. Finger tapes give the students immediate visual feedback as long as they consciously look at the fingerboard tapes. They also give the student tactile feedback as long as the student feels for the slight ridge of the tape. Aural feedback is another commonly used approach, such as providing a harmonic background for the students to play with. Students listen to their pitch and adjust to fit in the harmonic structure provided by piano accompaniment or recorded CD accompaniment. Louis Bergonzi (1997) conducted a study in which he tested both aural and visual feedback for intonation in beginning string students. He split 76 sixth grade students who were in their first year of learning a string instrument into four heterogeneous classes. The first class, the experimental group, received finger placement markers on their fingerboards, while the second class, the control group, did not receive finger placement markers. The third class, the experimental group, received harmonic accompaniment recorded tapes to practice with at home, while the fourth class, the control group, did not receive the harmonic accompaniment recorded tapes. He found that the students who had finger placement markers played significantly more in tune than those who did not have finger placement markers. He also found that students who practiced at home with the harmonic accompaniment tapes performed at an overall higher ability level. He also noted that the differences were significant even after adjusting for musical aptitude (Bergonzi, 1997). His study supports the use of both finger tapes and harmonic accompaniment in beginning string classrooms for teaching accuracy of intonation.

In a study investigating aural feedback on pitch accuracy, eight cellists performed shifts of differing distances from one pitch to another on the same string. Cellists performed the paired pitches, at a speed of one pitch per second, both with the bow and without the bow (left hand only). When the cellist played with the bow, he or she was receiving acoustic feedback, but when the cellist played without the bow, the movement was made without acoustic feedback. They found that "overall, our subjects exhibited a high degree of accuracy in executing tasks when using the bow...[and that] when acoustic feedback was absent, note distributions were shifted, multimodal, and had large variability; error-correction movements within a single note also significantly decreased, indicating that the stability and precision of the motor map depends on constant re-calibration and updating by acoustic information" (Chen, Woollacott, Pologe, & Moore, 2008, p.493).

The research illuminates the importance of many different kinds of feedback involved in playing a string instrument in tune. Still one more type of feedback may be involved in intonation execution. Vibrotactile feedback, or feeling the vibrations produced by the instrument, was examined in violin, double bass, guitar, and piano performance. Researchers measured the vibrations produced in normal playing conditions and at various dynamic levels. They found that vibration levels were high enough to be felt by the player. They write that "the vibration levels…were evaluated with regard to reported thresholds for detection of vibrotactile stimuli. The results show that the vibration levels are above threshold for most positions on the instruments in normal playing. Thus, the perceived vibrations may be of assistance with regard to intonation in ensemble playing, in particular for the bass instruments." (Askenfelt & Jansson, 1992, p.311).

Digital Scaffolds

Scaffolding is the support provided to an individual that makes achievement possible. Through this type of supportive learning, lower mental functions evolve into more complex higher mental functions (Vygotsky, 1978). Digital scaffolds are technologies that provide feedback for learning, which could include aural models, digital recording playback, tuners, metronomes, or other computer software.

Aural Model

Several researchers have investigated the effects of aural models on musical achievement outcome, and have found the presence of an aural model to be more effective than no model (Zurcher, 1975; Rosenthal, 1984; Rosenthal, Wilson, Evans, & Greenwalt, 1988; Fortney, 1992; Linklater, 1997) and to facilitate significantly greater musical gains (Henley, 2001).

Self-Recording Playback

Hewitt (2001) engaged 82 middle school wind and percussion students in sixth through ninth grades in a study investigating aural model, self-listening, and self-evaluation during practicing on music performance and attitude about practice. Participants were assigned to one of eight conditions as they attempted to master an etude over a nine-week practice period. Each condition was one of all possible combinations for the presence or absence of three factors: model (tape recording of the etude performed accurately on the instrument), self-recording (tape recording of the student playing the etude each week), and self-evaluation (training and practice in evaluating their own performance each week using the Woodwind Brass Solo Evaluation Form). Hewitt found that participants using the aural model and self-evaluation achieved higher musical performance scores (Hewitt, 2001).

Visual Evaluative Feedback

An investigation on the effects of an oscilloscope on pitch matching found that young children matched pitch the best when they saw the visual feedback from the oscilloscope and had knowledge of the results (Welch, 1985).

A few studies have examined computer programs that scaffold self-regulation in music practicing, such as goal setting, archiving music recordings, and self-reflection through ePEARL (Upitis, Abrami, Brook, Troop, & Catalano, 2010) and iSCORE (Brook & Upitis, 2015). Although researchers see promise in technology to provide support during practicing (Upitis et al., 2010; Brook & Upitis, 2015), there is a need for research focusing on computer programs that provide students with immediate pitch and rhythmic assessment feedback during music practicing.

Feedback for Motivation

The three psychological needs at the center of Self-Determination Theory are the need for autonomy, the need for competency, and the need for relatedness (Deci & Ryan, 2000). Activities through which people fulfill these needs are perceived as enjoyable. These activities become intrinsically rewarding because the need for autonomy, competency, and relatedness are being met. Therefore, people are motivated to continue engaging in the activity. The competency a person feels can be illuminated by the right kind of feedback, and as a result of feeling the need for competency fulfilled, motivation increases. Several researchers have investigated the effects of various types of feedback on motivation consistent with Self-Determination Theory (Guthrie, 1970; Clarke, 1972; Clarke, 1976; Van der Kleij et al., 2012; Burgers et al., 2015; Hagger et al., 2015; Siemens et al., 2015).

An early study by Guthrie found that immediate feedback produced significantly more perseverance on a task than delayed feedback, and that there was a positive correlation between perseverance and scores on a summative comprehension test (Guthrie, 1970). Clarke did a similar study in which participants worked an insolvable problem. The group who received feedback displayed significantly more persistence (spent more time working on the problem) than the non-feedback group (Clarke, 1972). More recent studies zeroed in on the ways specific types and delivery of feedback influenced motivation (Van der Kleij et al., 2012; Burgers et al., 2015; Hagger et al., 2015).

According to cognitive research, criterion-reference evaluation and informational rewards increase intrinsic motivation (Bruning, Schraw, & Norby, 2011). Van der Kleij, Eggen, Timmers, and Veldkamp studied 152 undergraduates who completed Computer Based Assessments (2012). Participants were randomly assigned to one of three feedback conditions during a pre-test. One group received immediate correct response and elaborative feedback after each question on the assessment (immediate KCR + EF). The second group received correct responses and elaborative feedback for the questions after the completion of the entire assessment (delayed KCR + EF). The third group received only a numeric score after completing the entire assessment (delayed KR). Participants took a post-test, immediately following the pre-test, to measure student growth that could be attributed to feedback type. A questionnaire was also completed to measure student motivation, perceived test difficulty, perceived usefulness of the feedback, and whether students read the feedback. Researchers also kept track of how long each participant had a feedback screen open on their computer to measure how long students attended to the feedback (p. 267). Results indicate that students prefer immediate feedback to delayed feedback, and that the immediate feedback group spent significantly more time reading feedback than the other two groups (p.269). Students paid more attention to feedback for incorrectly answered items. A significant positive correlation between study motivation and time spent reading feedback was found (p. 270).

Burgers, Eden, van Engelenburg, and Buningh conducted a study of 157 participants who completed a brain-training game and then received descriptive, comparative, or evaluative feedback that was either positive or negative (Burgers et al., 2015). After playing the initial game and receiving the feedback, participants completed a questionnaire measuring immediate game behavior, future game behavior, perceived autonomy, perceived competence, intrinsic motivation, extrinsic motivation, attitude towards the feedback, and perceptions of the agent (virtual cartoon that delivered the feedback) (Burgers et al., 2015). Results indicated that participants appreciated positive feedback more than negative feedback, and participants who received positive feedback perceived themselves as more competent and autonomous than those who received negative feedback (p.98). Participants who received negative feedback were more likely to immediately play the game again than those who received positive feedback, possibly because they wanted to prove that they could do better (p.101). Evaluative feedback increased the likelihood that participants would play the game again in the near future, while comparative feedback decreased the likelihood to immediately play the game again (p.101). Participants who perceived low competence were likelier to play the game again immediately, while participants who perceived high autonomy were likelier to play the game again immediately and in the future (p.101). Intrinsic motivation was positively related to immediate and future game play (p.101).

Motivation to Practice (Persistence)

Other studies have examined the variables that lead to greater persistence at practicing. In young musicians, labeled as having advanced musical proficiency, a significant positive correlation was found between intrinsic interest and persistence (Martin, 2008). Varela et al. (2016) found that across research on this topic, persistence was moderately linked with intrinsic interest and self-recording among beginning music students (Varela et al., 2016). Two studies found that a musician's motivation to practice consistently and rigorously has been positively related to their level of interest in the music (Renwick & McPherson, 2002; Lehmann & Papousek, 2003).

Chapter 3: Methodology

Design

In the hands of a good musician, a trumpet can produce beautiful melodies. In the hands of a professional musician, through a lifetime of technical practice and experience, a trumpet can produce almost any musical expression imaginable, in a variety of styles, articulations, and tone colors. The best can even expand the pitch range to impressive heights. However, due to the physical construction of the trumpet, the best trumpet player in the world will never be able to play pitches below the fundamental pitch. Similarly, a trombone is incapable of producing pitches as high as the trumpet's upper register. Only when a trombone and a trumpet come together in duet, is a wider range of pitches possible. The duet not only capitalizes on the pitch range strengths of both instruments, but also makes harmony possible, which neither instrument can produce on its own.

Similarly, in the hands of a good researcher, quantitative inquiry can produce new revelations about a phenomenon. In the hands of a professional experienced researcher, through a lifetime of technical practice and experience, quantitative methodology can be used to examine almost any variable, and the best have invented ways to measure phenomena that have never before been measurable. However, due to the limitations of quantitative methods, the best researcher in the world will never be able to quantify in totality the experience of a student learning a new instrument, or the complete experience of music performance anxiety. On the other hand, qualitative methodology is able to gather the essence of human experience and context. Only when quantitative and qualitative methods are used in combination is a more complete investigation of research questions possible (Creswell & Plano Clark, 2018).

Music education research has been dominated by quantitative methodology since Carl Seashore first attempted to quantify musical talent with his musical aptitude test *Measures of Musical Talent* (Seashore, 1915). Many aspects of musical art are difficult or impossible to quantify. Like an orchestra employing only one single musician with a trumpet, quantitative research alone cannot fully illustrate the complexities of a phenomenon like musical talent. A mixed methodology is useful when either the qualitative or quantitative approach alone falls short of developing "multiple perspectives and a complete understanding about a research problem or question" (Creswell, Klassen, Plano Clark, & Clegg Smith, 2011, p.6).

The present study was a mixed methods within-subjects experiment exploring the impact of digital scaffolds on pitch and rhythmic accuracy growth, self-assessment, self-correction, and other self-regulatory behavior during independent music practicing. A mixed methods approach to this research problem was necessary in order to understand quantitative measures of pitch and rhythmic accuracy and time spent practicing in the qualitative context of how students experience practicing with and without digital scaffolds. A convergent mixed methods design was employed for this study, in which qualitative and quantitative data were collected in parallel (during a series of practice activities), analyzed separately, and then merged (see Figure 10).

Sixty high school string students individually completed a 30-minute practice session divided into four practice scenarios (1.Model, 2.Model+Playback, 3.Model+Playback+Feedback, and 4.control). During each practice scenario, performances at sight-read (pretest), during practicing (formative), and after practicing (posttest) were assessed for pitch and rhythmic accuracy by computer software *SmartMusic*. While participants practiced, they spoke their thoughts out loud, self-

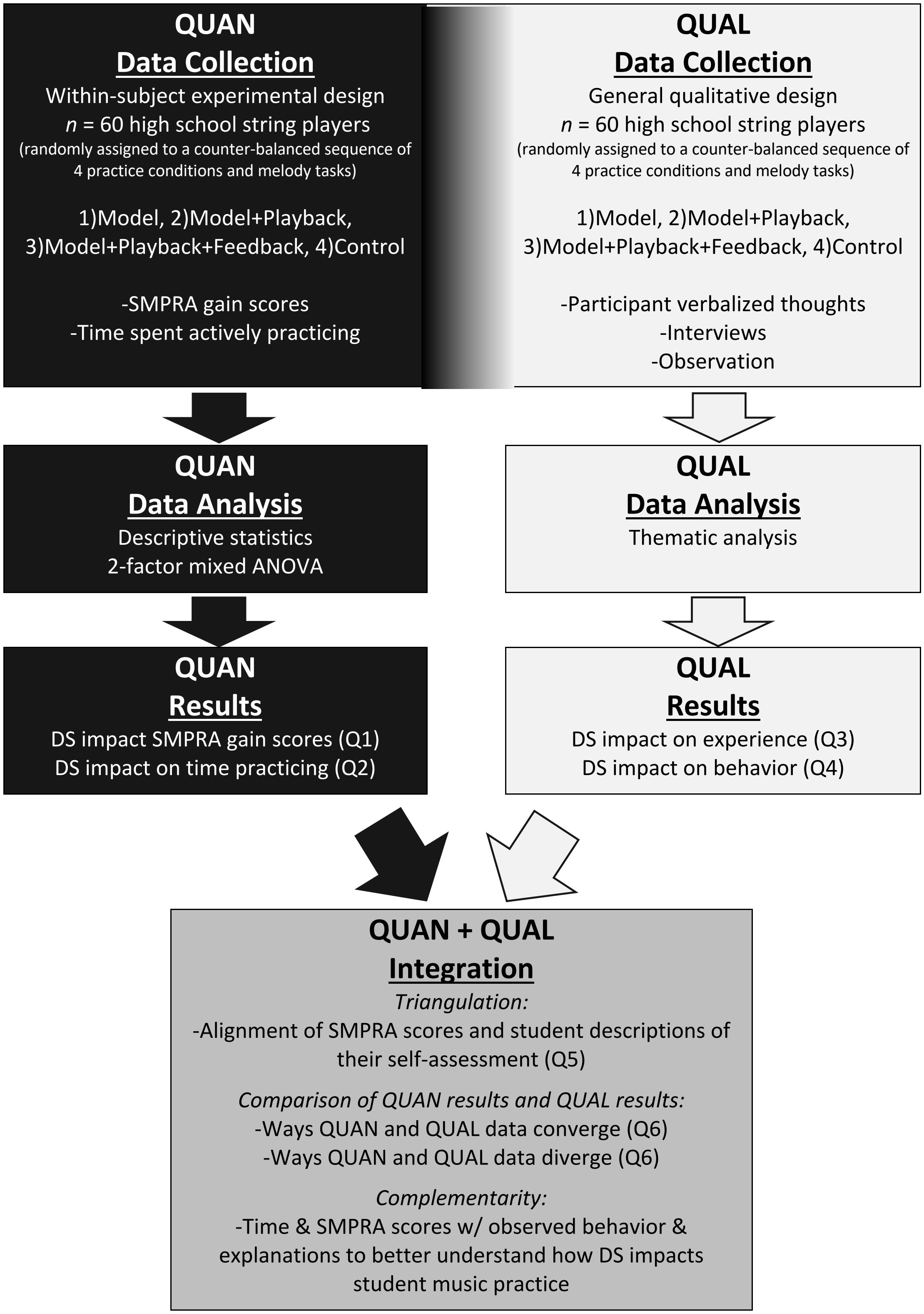

Figure 10. Mixed methods design procedural diagram.

assessed their progress, and answered questions about their experience with each digital scaffold. The quantitative strand measures performance accuracy through *SmartMusic* pitch and rhythm assessment (SMPRA) scores, and time spent practicing. The qualitative strand measures self-regulated practicing behaviors through observation of the participants verbalizing their thoughts while working through the practice scenarios, and explores participants' experience through follow-up interviews after each practice scenario. The reason for collecting both quantitative and qualitative data is to converge the two forms of data to bring greater insight into the problem than would be obtained by either type of data separately. Specifically, qualitative and quantitative strands will converge for triangulation and complementarity.

In this within-participant experiment, 60 string students from 3 large Midwestern high schools completed each practice scenario in a series of individual music practice scenarios. A within-participant design was chosen so that accuracy measures could be compared at an individual level, across practice condition scenarios for each participant, in addition to the group level comparison of group means across practice conditions.

Participants

Sixty high school string students enrolled in curricular orchestra classes in a Midwestern public school district participated in this study. Twenty participants from each of the district's three high schools volunteered to participate. Ranging in age from 14 to 18 years old, the sample included 21 freshmen (35%), 17 sophomores (28%), 19 juniors (32%), and 3 seniors (5%). Forty-two participants were female (70%), and 18 were male (30%). Most (47) of the participants began learning their instrument in fourth grade (78%), which is when string instruction begins in this school district. Eleven participants (18%) began learning their instrument earlier (pre-K through 3rd grade), and two participants (3%) began instrumental instruction later (5th and 6th grade). In this school district, students receive orchestral instruction in large group lessons and ensemble settings, which was the exclusive orchestral education of 42 participants (70%). Eighteen participants (30%) reported taking additional private lessons on their string instrument outside of school. The sample included 29 violinists (48%), 16 violists (27%), and 15 cellists (25%).

Digital Scaffolds (DS)

Aural Model DS (Model). The aural model scaffold is a digital audio recording of the melody performed on piano.

Auditory Playback Feedback DS (Playback). The auditory performance playback feedback digital scaffold is self-recording. In this study, the participant's performance take was recorded and played back for the participant to hear.

Visual Evaluative Feedback DS (Feedback). The visual feedback digital scaffold is a color-coded display on a computer screen of the music highlighting notes played correctly in green, while highlighting notes played incorrectly in red, through the computer program *SmartMusic*. The program also displays a numeric percentage of notes played correctly in terms of pitch and rhythmic accuracy out of the total number of notes.

Practice Conditions.

The digital scaffolds were used in combination in four different practice conditions (1.Model, 2.Model+Playback, 3.Model+Playback+Feedback, and 4. Control) (see Figure 11). Each participant practiced through all four practice conditions.

Under the Model practice condition, participants were presented with scenario 1 and practiced with the Aural Model Digital Scaffold only. Scenario 1 is: "Imagine that your teacher gave you this music and told you to make a recording to turn in for a graded playing test. You have never seen or heard this music before, but your teacher uploaded a recording of the melody to the orchestra class website, so that you could listen to it and use it any way you'd like while practicing." During the Model practice session, participants heard the model after each performance take and could request to hear the aural model as many times as they wished while practicing.

Practice Conditions

Label	**Model**	**Model+Playback**	**Model+Playback+Feedback**	**Control**
Pretest	First take	First take	First take	First take
Scenario	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Treatment of digital scaffolds	**Model** Hear aural model after each take and at will during practice.	**Model** Hear aural model after each take and at will during practice. + **Playback** Hear immediate playback of each practice take.	**Model** Hear aural model after each take and at will during practice. + **Playback** Hear immediate playback of each practice take. + **Visual Feedback** See accuracy % score and highlighting of notes for each practice take. green=accurate red=inaccurate	**Control** Practice without assistance.
	Unlimited practice takes	Unlimited practice takes	Unlimited practice takes	Unlimited practice takes
Posttest	Final take	Final take	Final take	Final take
Growth measure	Gain score	Gain score	Gain score	Gain score

Figure 11. Practice conditions.

Under the Model+Playback practice condition, participants were presented with scenario 2 and practiced with both the Aural Model and the Auditory Playback Feedback Digital Scaffolds (Model+Playback condition). Scenario 2 is: "Imagine that your teacher gave you this music and told you to make a recording to turn in for a graded playing test. You have never seen or heard this music before, but your teacher uploaded a recording of the melody to the orchestra class website, so that you could listen to it and use it any way you'd like while practicing. Your teacher also has told you to record yourself playing and listen back to it while you're practicing." During the Model+Playback practice session, participants heard a recording of their own performance immediately after each take, in addition to hearing the aural model after each take, and at will.

Under the Model+Playback+Feedback practice condition, participants were presented with scenario 3 and practiced with all the Aural Model, Auditory Playback, and Visual Evaluative Feedback Digital Scaffolds (Model+Playback+Feedback condition). Scenario 3 is: "Imagine that your teacher gave you this music and told you to make a recording to turn in for a graded playing test. You have never seen or heard this music before, but your teacher uploaded a recording of the melody to the orchestra class website, so that you could listen to it and use it any way you'd like while practicing. Your teacher also has told you to record yourself playing and listen back to it while you're practicing. In addition, your teacher has given you access to a computer program that will listen to your pitch and rhythm and show you a color-coded display of the notes you played in tune and in time colored green, and notes you played out of tune or out of time colored red." During the Model+Playback+Feedback practice session, participants saw a visual representation of the melody task with notes highlighted in green or red (green notes indicate accuracy; red notes indicate inaccuracy) as well as a numeric accuracy percentage after each take, in addition to hearing a recording of their performance after each take, and hearing the aural model after each take, and at will.

Under the Control practice condition, participants were presented with scenario 4 and practiced without any digital scaffolds (Control condition). Scenario 4 is: "Imagine that your teacher gave you this music and told you to make a recording to turn in for a graded playing test. You have never seen or heard this music before. It is a new composition so there are no recordings of it anywhere to listen to."

Melody Tasks

In order to create short melodies that would be both attainable (to avoid floor effects) and challenging (to avoid ceiling effects) for a wide range of high school student proficiencies, and equivalent to each other in difficulty, I drew from the Farnum String Scale (Farnum, 1969) to compose four novel melodies for this study. Each melody was 5 measures in length and contained 24 notes. The first two measures were inspired by level 4 of the Farnum String Scale, written in a key signature containing one sharp, within G major tonality, using eighth notes, quarter notes, and a half note. Measures 3 and 4 were inspired by level 12 of the Farnum String Scale and were written in a key signature containing one flat, with modulating tonality, accidentals, syncopation, sixteenth notes, and string crossings. The final measure of each melody was a whole note resolution. The melodies were written in standard notation for violin (see Figures 12-15), viola (see Figures 16-19), and cello (see Figures 20-23), all within first position range, so that each melody could be played entirely in first position.

In order to check the equivalency of the melody tasks, I asked participants about the difficulty of the melody tasks after they had completed all practice scenarios, and I ran a one-way repeated measures ANOVA on the pre-test scores.

Figure 12. Melody task Alpha for violin.

Figure 13. Melody task Beta for violin.

Figure 14. Melody task Charlie for violin.

Figure 15. Melody task Delta for violin.

Figure 16. Melody task Alpha for viola.

Figure 17. Melody task Beta for viola.

Figure 18. Melody task Charlie for viola.

Figure 19. Melody task Delta for viola.

Figure 20. Melody task Alpha for cello.

Figure 21. Melody task Beta for cello.

Figure 22. Melody task Charlie for cello.

Figure 23. Melody task Delta for cello.

Assignment to Sequence of Practice Conditions and Melody Tasks

In this within-subject experimental design, each participant practiced under four scaffold conditions with a different melody for each condition. Order effects were counterbalanced using a Greco-Latin square design (Mandl, 1985) in which each condition and melody occurred exactly once in each column and row, and each combination of melody and scaffold condition occurred exactly once. Each scaffold condition preceded and followed each other scaffold condition exactly twice, and each melody preceded and followed each other melody exactly twice, forming a digram-balanced design (Lewis, 1993). Participants were randomly assigned (drawn from a hat) to one of four sequences (rows), resulting in a balanced within-subjects design in which 15 participants completed each sequence (see Figure 24).

	First	Second	Third	Fourth
Seq. 1	Control with Melody A	Model with Melody C	Model+Playback with Melody D	Model+Playback+Feedback with Melody B
Seq. 2	Model with Melody B	Control with Melody D	Model+Playback+Feedback with Melody C	Model+Playback with Melody A
Seq. 3	Model+Playback with Melody C	Model+Playback+Feedback with Melody A	Control with Melody B	Model with Melody D
Seq. 4	Model+Playback+Feedback with Melody D	Model+Playback with Melody B	Model with Melody A	Control with Melody C

Figure 24. Greco-Latin square assignment of treatment and melody task sequence.

Quantitative Measures

The quantitative measures in this study included pitch and rhythmic accuracy percentages calculated by computer software, as well as persistence of active practicing in each practice condition scenario.

Pitch and Rhythmic Accuracy

Pitch and rhythmic accuracy, the dependent variable, was quantified using the computer program *SmartMusic* to obtain composite *SmartMusic* Pitch and Rhythmic Accuracy Scores (SMPRA scores). *SmartMusic* detects sounds entering the microphone in terms of frequencies and temporal durations. Pitches played by a musician that match the intonation of the program's goal frequencies are calculated as accurate in terms of pitch. Sounds that begin at a time that matches the program's temporal durations are calculated as accurate in terms of rhythm. *SmartMusic* calculates an accuracy percentage based on the number of musical notes that are accurate in terms of both pitch and rhythm, out of the total number of musical notes in the programmed melody. During each practice scenario, performances at sight-read (pretest), during practicing (formative), and after practicing (posttest) were assessed for pitch and rhythmic accuracy by computer software *SmartMusic*. In this study, the improvement of pitch and rhythmic accuracy was measured using gain scores, calculated by the difference between the accuracy percentage at sightread and the accuracy percentage of the final performance for each practice scenario. Gain scores were compared across treatments. Accuracy percentages of formative performances were also examined sequentially within each practice scenario to look for incremental progress during practicing on an individual basis.

Persistence

Participants' persistence in working at the task was measured in minutes of time spent actively engaging in practicing during each experimental practice session.

Qualitative Measures

Self-regulatory behavior and thought processes were measured through participant verbalizations and researcher observation as they worked through practice scenarios, and interviews following their experiences.

Thought Processes

Participants spoke their thoughts out loud as they practiced. I reminded them at the beginning of each practice scenario to narrate their practicing and verbalize their inner thoughts.

Self-Assessment

Participants self-assessed each pretest, formative, and posttest performance in terms of pitch and rhythmic accuracy by assigning a numeric score between zero (no pitches or rhythms performed accurately) and 100 (all pitches and rhythms performed accurately) for each performance. Some participants also included rationale for the score they gave their performances.

Observation

I observed participants as they worked through the series of practice sessions, noting non-verbal behaviors (e.g., humming, clapping, fingering, plucking). The practice sessions were video recorded for later reference and review.

Interviews

Post-session Interview. After the posttest was completed, I asked the participant to briefly reflect on their experience practicing under that practice condition, with the prompt, "Is there anything else you want to say about that practice experience?"

Post-experiment Interview. After the participant had completed all four practice sessions, I asked them to reflect on their experience across the four practice sessions. I asked, "Considering all of the practice scenarios you just did, tell me which practice aids you found most/least helpful, and which you liked/disliked, and why?" and, "In what ways did these practice aids impact your practicing?" I also asked each participant to identify which (if any) of the practice aids they would choose to use in future practice. Finally, I asked them which of the melody tasks they found to be the most difficult, and which they found to be the easiest.

Data Collection Procedure

Sixty high school string students individually completed a 30-minute practice session divided into four practice scenarios. During each practice scenario, the participant was asked to sight-read a unique melody and then practice that melody under a designated digital scaffold condition in attempts to perform the music as accurately as possible. While participants practiced, they spoke their thoughts out loud, self-assessed their progress, and answered questions about their experience with each digital scaffold.

Set-Up

Participants entered a technologically equipped practice room to see a chair and two music stands. One music stand held an iPad that video recorded the practice session. The other music stand, which was used to hold the melody task sheet music, had a small microphone clipped to it. Just below that stand, a small audio speaker sat on the ground (see Figure 25). Cords from the speaker and microphone ran under a temporary dividing

Figure 25. Set up (participant view).

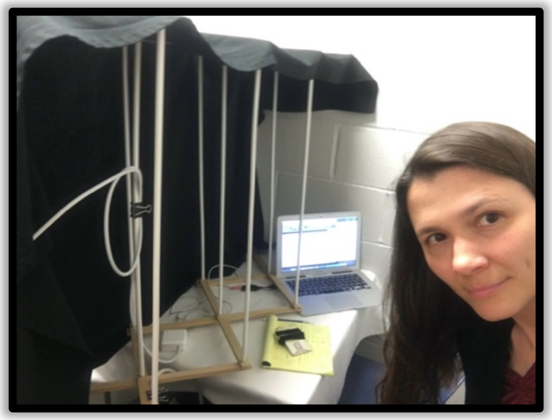

Figure 26. Set up behind dividing wall.

wall, behind which was the computer equipment and me, the researcher (see Figure 26). Even though the participant could not see me, the iPad was set in a position that allowed me to see the participant on the iPad screen. While walking the participant into this practice room, I explained, "I'm basically trying to get inside the heads of high school strings players to find out what you're thinking about when you're practicing. So, I'm going to give you four different practice scenarios and I want you to speak your thoughts out loud as you practice through them." Before beginning with the first melody task, I made them aware of the iPad that would video record the experiment, asked them background questions (i.e., age/year in school, grade beginning string instrument study, and private lessons), and calibrated their instrument to the computer software by tuning their open strings (A 440, equal temperament).

Pre-Test: Pitch and Rhythmic Accuracy at Sight-Read.

I reached around the wall to place the melody task on the music stand. I instructed the participant, “First, I’ll have you sight-read this melody. You’ll hear four clicks, and then you play. The metronome will continue to click as you play the melody. Ready? Here it comes.” Participants had only the time it took me to speak the instruction to look at the melody before the sight-read take began. As the participant played the take with the metronome, computer software (*SmartMusic*) assessed their pitch and rhythmic accuracy as a percentage of correct notes out of total notes, a numeric score out of a possible 100 (which I documented, but did not share with the participant). Immediately following the sight-read take, I asked the participant to score the take they had just performed out of 100 possible points.

Practice Scenarios.

After the participant self-assessed their sight-read take, I explained the scenario for the practice condition, reminded them to speak their thoughts out loud while they practiced, and told them to let me know when they were ready to try another take.

Aural Model (Model). For the aural model digital scaffold condition (Model), I presented participants with the following scenario (scenario 1): “Let’s imagine that your teacher gave you this music and told you to make a recording to turn in for a graded playing test. You have never seen or heard this music before, but your teacher uploaded a recording of the melody to the orchestra class website, so that you could listen to it and use it any way you’d like while practicing. Here is what it sounds like (I played the recording of the melody sounded on piano w/o metronome). Go ahead and practice, and any time you want to hear this again, just tell me to play the melody. You can ask to hear the melody as many times as you want." Then participants practiced using the aural model scaffold (hearing the recording of the melody). When participants felt ready to record another take, they performed the melody with the metronome while the computer assessed their performance. After each take, participants scored their own take out of 100 possible points. In the Model condition, after scoring each take, participants heard the recording of the melody.

Aural Model with Auditory Playback (Model+Playback). For the aural model with auditory playback digital scaffold condition (Model+Playback), I presented participants with the following scenario (scenario 2): "Let's imagine that your teacher gave you this music and told you to make a recording to turn in for a graded playing test. You have never seen or heard this music before, but your teacher uploaded a recording of the melody to the orchestra class website, so that you could listen to it and use it any way you'd like while practicing. Here is what it sounds like (I played the recording of the melody sounded on piano w/o metronome). Your teacher also has told you to record yourself playing and listen back to it while you're practicing. Here is what your sight-read take sounded like (I played back the recording of their take). Go ahead and practice. You can ask to hear the melody as many times as you want." Then participants practiced using the aural model scaffold (hearing the recording of the melody). When participants felt ready to record another take, they performed the melody with the metronome while the computer assessed their performance. After each take, participants scored their own take out of 100 possible points. In the Model+Playback condition, after scoring each take, participants heard the recording of the melody and listened to the recording of what they had just played. I said, “Here is what the melody sounds like (I played the recording of the melody) and here is what you just played (I played back the recording of their take).”

Aural Model with Auditory Playback and Visual Evaluative Feedback (Model+Playback+Feedback). For the aural model with auditory playback and visual evaluative feedback digital scaffold condition (Model+Playback+Feedback), I presented participants with the following scenario (scenario 3): “Let’s imagine that your teacher gave you this music and told you to make a recording to turn in for a graded playing test. You have never seen or heard this music before, but your teacher uploaded a recording of the melody to the orchestra class website, so that you could listen to it and use it any way you’d like while practicing. Here is what it sounds like (I played the recording of the melody sounded on piano w/o metronome). Your teacher also has told you to record yourself playing and listen back to it while you’re practicing. Here is what your sight-read take sounded like (I played back the recording of their take). In addition, your teacher has given you access to a computer program that will listen to your pitch and rhythm and show you a color-coded display of the notes you played in tune and in time colored green, and notes you played out of tune or out of time colored red. Here is how the computer assessed your sight-read take (I held up the computer above the wall to show them the computer screen for about 20 seconds). Go ahead and practice. You can ask to hear the melody as many times as you want.” Then participants practiced using the aural model scaffold (hearing the recording of the melody). When participants felt ready to record another take, they performed the melody with the metronome while the computer assessed their performance. After each take, participants scored their own take out of 100 possible points. In the Model+Playback+Feedback condition, after scoring each take, participants heard the recording of the melody and listened to the recording of what they had just played, and then I lifted my computer over the wall so they could look at the color-coded visual display of their assessment on the screen of the computer for about 20 seconds. I said, "Here is what the melody sounds like (I played the recording of the melody), here is what you just played (I played back the recording of their take), and here is how the computer assessed your pitch and rhythm (I showed them the computer screen for about 20 seconds)."

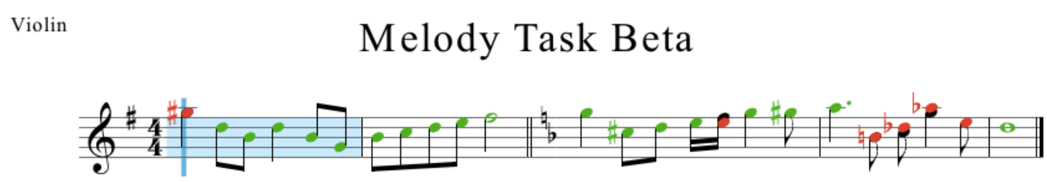

Figure 27. Visual feedback display example.

Control. For the control practice condition, I presented participants with the following scenario (scenario 4): "Let's imagine that your teacher gave you this music and told you to make a recording to turn in for a graded playing test. You have never seen or heard this music before. It is a new composition so there are no recordings of it anywhere to listen to." Then participants practiced with no digital scaffolds. When participants felt ready to record another take, they performed the melody with the metronome while the computer assessed their performance. After each take, participants scored their own take out of 100 possible points. In the control condition, after scoring each take, participants were given no digital feedback scaffolds.

Number of Takes.

Participants performed two to five takes of a melody in each practice condition. After a participant completed a second take, I asked them if they'd like to practice more, or if they felt they had mastered the melody. In some cases, when participants had been on a melody for an extended period of time, I encouraged them to move on to the next practice condition in order to get the entire experiment completed within the allotted time. I documented the exact time each take was recorded to see how much time passed between takes, and how much time was spent on each practice condition.

Posttest: Pitch and Rhythmic Accuracy After Practicing.

The last take served as the posttest. In some cases, the final take was not the best take performed by the participant. However, in all cases, I believe the final take was an accurate representation of how the participant was performing the melody during practicing. In the rare occasion that a participant performed a catastrophic error during their final take that was uncharacteristic of how they were performing the melody during practicing, I asked them to perform another take immediately. For example, one participant started a beat early on their last take. After the take I said, “Let’s do that one again; my equipment didn’t capture it right.” That way, without pointing out their error, I could see if their error was a fluke. In this case, the participant did not make the error again.

Qualitative Post-Session Interview.

After the posttest was completed, I asked the participant to briefly reflect on their experience practicing in that practice condition, with prompts such as, “Is there anything else you want to say about that practice experience?”

Qualitative Post-Experiment Interview.

After the participant had completed all four practice sessions, I asked them to reflect on their experience across the four practice sessions. I asked, “Considering all of the practice scenarios you just did, tell me which practice aids you found most/least helpful, and which you liked/disliked, and why?” and, “In what ways did these practice aids impact your practicing?” I also asked each participant to identify which (if any) of the practice aids they would choose to use in future practice. Finally, I asked them which of the melody tasks they found to be the most difficult, and which they found to be the easiest. At the end of this interview, I stopped the video recording, thanked the participant, and invited him or her to take a candy from the candy bowl on their way out of the room.

Data Analysis

Quantitative and qualitative data were analyzed separately and then merged for a more complete interpretation of results.

Quantitative Analysis.

SMPRA gain scores from each practice session were analyzed using a two-factor mixed ANOVA. The factor digital scaffold was within-subjects, and the factor order/melody sequence was between-subjects. Gain scores from each practice scenario was examined across scenarios for each participant. Measures of time spent actively practicing were compared across practice scenarios for each participant, as well as mean time measures across scenarios. Main effects were probed through follow-up contrasts.

Qualitative Analysis.

Research observations were coded and analyzed to examine the ways in which participants engaged in practicing in each scenario, specifically for instances of self-regulatory behavior including task analysis (e.g., scanning music, humming written notation), strategic planning (e.g., changing finger positioning, playing a chunk in slow motion, clapping/tapping rhythms), self-observation/self-evaluation (e.g., verbalizations such as “that was pretty rough” or “nice!”), problem diagnosis (e.g., re-checking key signature, talking pitches out loud).

Participant verbalizations and interviews were coded for thematic analysis. Previous research coded interview evidence into four categories of self-correction (McPherson et al., 2012), including ‘hopelessness’ (e.g., ‘I usually give up and keep going.’; ‘I don’t try to fix it, I go through everything once.’), ‘superficial attention to mistakes’ (e.g., ‘If I get it right I move on, otherwise I’ll play the mistake over once or twice.’), ‘effort to correct the problem’ (e.g., ‘I go through the section and find trouble spots, and I go over them really slow and then speed them up.’), and ‘self-regulated correction’ (e.g., ‘I try to think about how my teacher played it, then go back over it slowly and then speed it up.’; ‘I play slowly, play the section with different rhythms and think about it before I play it again.’) (McPherson et al., 2012, p.47).

Power and Sensitivity

Power analysis done through G*Power set to ANOVA repeated measures, within factors, and set to a medium effect size (0.25), indicated the necessity for 36 participants in order to find a significant effect. A sensitivity analysis indicated that a repeated-measures ANOVA of a sample of 60 participants should be able to detect an effect of 0.19 or larger.

Expected Results

The ‘business-as-usual’ control condition will provide a glimpse into the way novice music students practice, and possibly struggle, when attempting to master pitches and rhythms from written notation. It will serve as a baseline measure of how music studnts typically practice on their own. If the main problem students face is not being able to use corrective strategies, accuracy growth and behavior during the treatment practice sessions will not be different than accuracy growth and behavior during the control. However, if the main problems students face are deficiencies in aural skills, the treatment conditions in this study will show differences in both behavior and performance accuracy, when compared to the baseline control. If a student struggles only with audiation, the Model condition will produce an increase in observed self-regulatory behavior and improvement in pitch and rhythmic accuracy (SMPRA scores), when compared to the baseline. If a student struggles with both audiation and hearing their performance in the moment, the Model+Playback condition should illicit more observed self-regulatory behavior and SMPRA scores, when compared to the baseline. If a student cannot hear that there is a discrepancy between their performance and the aural goal model or cannot pinpoint the exact pitches that are the problem, the Model+Playback+Feedback condition should increase the student's self-regulatory behavior and SMPRA scores, when compared to the baseline.

Confidence & Limitations

Potential Threats to Validity

There was a potential threat of ceiling and floor effects, threats to both internal and construct validity. If the melody tasks were too difficult for participants, there would be floor effects in the event that a participant's work during the practice condition cannot change performance accuracy scores because the music was way beyond what the participant could do. If this was the case, participants might have obtained a score of zero at both beginning and end measures of a practice scenario. Similarly, if the melody tasks were too easy, participants would have been able to achieve a perfect performance accuracy score at first site of the music, and therefore would have had no room to measure improvement from the practice condition, resulting in ceiling effects. Floor and ceiling effects could have produced results that falsely indicated no effect (increase in type II error). In this case, because the melody task prevented the true effect from being captured accurately, due to poor operationalizing (construct validity threat), results could have indicated that the relationship between digital scaffolds and performance accuracy was not causal (internal validity threat), when in fact it was (type II error). In order to attempt to prevent floor and ceiling effects in this study, each melody task was composed in a way that began simple and ended more difficult. This provided a slight range of difficulty within each task to accommodate the diversity of participant proficiency levels. Additionally, if melody tasks varied in their difficulty from one to another, mean pretest scores compared across melody tasks should have indicated that. Since the statistical analysis of the experiment relied on a balanced sample, it was not possible to ignore or throw out any perfect pretest scores.

There was a potential threat that fatigue could have influenced performance in late sequence data collection. Since all four practice scenarios occurred sequentially in one day, there was potential for participants to get tired physically, mentally, or both as they completed the scenarios. If that occurred, participants may not have worked at the final scenario as long or with as much focus as they would have if that scenario had been completed first when they were fresh and energized. If this occurred, the measure of time spent working at task in each scenario would have reflected it. In order to minimize the chance that fatigue could impact one condition more than the others, the sequence of conditions was randomized so that fatigue effects were evenly distributed across conditions, using a Greco-Latin square design.

Another potential threat to construct validity that also impacts internal validity is the measurement tool for pitch and rhythmic accuracy. Although *SmartMusic* pitch and rhythm assessment has been used in a few dissertation studies and has a reputation as a consistent accurate measure of pitch and rhythmic accuracy, reliability and validity of this tool has not been published. If *SmartMusic* is not consistent in measuring pitch and rhythm produced on violin, viola, and cello (unreliable), then that would be a threat to construct validity that would impact internal validity of this study. In order to check reliability and validity of the *SmartMusic* assessments, each recorded take could also be assessed by electronic tuner (for pitch) and electronic metronome (for rhythm) and then compared to the *SmartMusic* assessments of pitch and rhythm. Differences would illuminate a potential problem with the reliability and/or validity of the *SmartMusic* measure. In the present study, I listened critically to the performances as participants completed performance takes throughout the experiment, and I compared my own assessment of their performance to the assessment the computer program gave. Throughout the experiment, I agreed with the computer's assessment of the participants' pitch and rhythmic accuracy. In my opinion, as a musician, I believed the computer's assessments were valid and reliable.

Practicality

In order to minimize attrition, each participant completed all four practice scenarios in a one-time sequence. Although this eliminated attrition, it created the potential problem of fatigue (addressed above). Also, due to no funding to purchase unlimited *SmartMusic* subscriptions, or to pay additional researchers to help collect the data, the 60 participants were not able to complete the study on the same day. This opened up potential for historic events to influence participants unequally. However, over the three weeks it took to complete this study, no historic events occurred that gave me any reason to believe the sample had been unevenly impacted by the date they completed the study.

Chapter 4: Presentation and Analysis of Data

The purpose of this study was to gain insight into the deficiencies and capabilities of high school string players in the practice room, through a mixed methods within-subjects experiment exploring the impact of digital scaffolds on pitch and rhythmic accuracy growth, self-assessment, self-correction, and other self-regulatory behavior during independent music practicing. Sixty high school string students individually completed a 30-minute practice session divided into four practice conditions with the order randomly assigned using a Greco-Latin square design (1.Model, 2.Model+Playback, 3.Model+Playback+Feedback, and 4.Control). During each practice condition, performances at sight-read (pretest), during practicing (formative), and after practicing (posttest) were assessed for pitch and rhythmic accuracy by computer software *SmartMusic*. Analysis of variance was completed on quantitative data. While participants practiced, they spoke their thoughts out loud, self-assessed their progress, and answered questions about their experience with each digital scaffold.

In each condition, the participant made an immediate attempt to play the musical task (first take), which served as a pre-test. After practicing in the condition, a final recording was made of the participant playing the musical task (final take), which served as a post-test. The difference between the test scores (measured by music assessment software *SmartMusic*) served as gain scores for each individual within each of the four practice conditions, with a positive score representing improvement and negative score indicating deterioration. Gain scores were analyzed through a two-factor mixed ANOVA and follow up contrasts. The number of takes made during each practice condition was noted, and the amount of time each participant spent working in each condition was recorded. Time data were analyzed through a one-way repeated-measures ANOVA.

Participants spoke their thoughts out loud while working through each practice condition. After each condition, I asked the participant short follow-up questions to illuminate their process and mental representations. All practice sequences were observed and video recorded for later transcription. All qualitative data were transcribed, coded, and analyzed for emergent themes.

Sample Descriptive Statistics

Sixty high school string students enrolled in curricular orchestra classes in a Midwestern public school district participated in this study. Twenty participants from each of the district's three high schools volunteered to participate. Ranging in age from 14 to 18 years old, the sample included 21 freshmen (35%), 17 sophomores (28%), 19 juniors (32%), and 3 seniors (5%). Forty-two participants were female (70%), and 18 were male (30%). Most (47) of the participants began learning their instrument in fourth grade (78%), which is when string instruction begins in this school district. Eleven participants (18%) began learning their instrument earlier (pre-K through 3rd grade), and two participants (3%) began instrumental instruction later (5th and 6th grade). In this school district, students receive orchestral instruction in large group lessons and ensemble settings, which was the exclusive orchestral education of 42 participants (70%). Eighteen participants (30%) reported taking additional private lessons on their string instrument outside of school. The sample included 29 violinists (48%), 16 violists (27%), and 15 cellists (25%). Of the sixty participants, 4 participants (7%) reported practicing their instrument every day outside of orchestra class, 26 participants (43%) reported practicing two to five times per week outside of class, 20 participants (33%) reported practicing outside of class one to four times per month, and 10 participants (17%) reported never practicing outside of orchestra class.

Table 1. *Sample Demographics.*

	n	% of sample
Total participants	60	100%
School		
High School A	20	33%
High School B	20	33%
High School C	20	33%
Year in School		
Freshman	21	35%
Sophomore	17	28%
Junior	19	32%
Senior	3	5%
Gender		
Female	42	70%
Male	18	30%
Instrument		
Violin	29	48%
Viola	16	27%
Cello	15	25%
Grade began learning instrument		
PreK – 3rd grade	11	18%
4th grade	47	78%
5th – 6th grade	2	3%
Private Lessons		
No	42	70%
Yes	18	30%
Self-reported practice frequency		
Every day	4	7%
2-5 times per week	26	43%
1-4 times per month	20	33%
Never	10	17%

Assumption Statistics

Four different melody tasks were composed in order to avoid practice effects. In order to counterbalance fatigue effects, I used a Greco Latin square design to assign participants randomly to an order of levels of practice conditions and an order of melody tasks. I subjected the sample data to Mauchly's test for sphericity which was not significant (W = 0.8573237, $p = 0.1344$), indicating that the assumption of sphericity was met.

A Priori Analysis of Power

Power analysis done through G*Power set to ANOVA repeated measures, within factors, and set to a medium effect size (0.25), indicated the necessity for 36 participants in order to find a significant effect. A sensitivity analysis indicated that a repeated-measures ANOVA of a sample of 60 participants should be able to detect an effect of 0.19 or larger.

Quantitative Results

Quantitative data included pitch and rhythmic accuracy and time spent practicing. Pitch and rhythmic accuracy was measured before practicing (pretest), during practicing (formative), and after practicing (posttest). Mean accuracy growth (gain scores) was compared across practice conditions through a two-factor mixed ANOVA and follow-up contrasts. The average amount of time participants spent practicing in each practice session was compared using an one-way repeated-measures ANOVA.

Pitch and Rhythmic Accuracy at Sight Read (SMPRA Pretest Scores)

Pretest accuracy scores represent the pitch and rhythmic accuracy of participants sight reading the melody before practicing. Overall, of 240 pretests across conditions, participants in 11 cases (5%) achieved what would be considered a grade of A (92-100%

Table 2. *Frequency distribution of pretest scores above and below 90% accuracy by treatment practice condition.*

Practice Condition	*Perfect Scores (n) (%)*	*Above 90% (n) (%)*	*Below 90% (n) (%)*	*Total (n)*
Control	0 (0%)	2 (3%)	58 (97%)	60
Model	0 (0%)	3 (5%)	57 (95%)	60
Model+Playback	2 (3%)	4 (7%)	56 (93%)	60
Model+Playback+Feedback	1 (2%)	2 (3%)	58 (97%)	60
Total	**3 (1%)**	**11 (5%)**	**229 (95%)**	**240**

Note. (Perfect scores are included in the above 90% column.)

accuracy), including 3 (1%) perfect scores. However, 229 (95%) achieved less than 90% at sight read and therefore had potential to improve through practicing. Table 2 breaks down the frequencies according to practice condition.

Pitch and Rhythmic Accuracy Achievement (SMPRA Posttest Scores)

Posttest accuracy scores represent the final product that participants would have turned in to their teacher as their best work. Overall, out of 240 posttests across conditions, 107 (45%) would have received a grade of A from their teacher (92-100% accuracy), including 43 perfect scores, while the majority 133 (55%) were not able to achieve a grade of A (0-88% accuracy). A comparison of posttests across practice conditions begins to illustrate the impact digital scaffolds had on final accuracy achievement. Of the 60 participants in the control condition, 14 (23%) were able to achieve a final accuracy score of 92 or higher (including 5 perfect scores), leaving 46 participants (77%) with final accuracy scores of 88 or below. Of the 60 participants in the Model condition, 30 (50%) were able to achieve a final accuracy score of 92 or higher (including 13 perfect scores), leaving the other half of participants (50%) with final accuracy scores of 88 or below. Of the 60 participants in the Model+Playback condition, 29 (48%) were able to achieve a final accuracy score of 92 or higher (including 12 perfect scores), leaving the other 31 participants (52%) with final accuracy scores of 88 or below.

Table 3. *Frequency distribution of posttest scores above and below 90% accuracy by treatment practice condition.*

Practice Condition	***Perfect Scores (n) (%)***	***Above 90% (n) (%)***	***Below 90% (n) (%)***	***Total (n)***
Control	5 (8%)	14 (23%)	46 (77%)	60
Model	13 (22%)	30 (50%)	30 (50%)	60
Model+Playback	12 (20%)	29 (48%)	31 (52%)	60
Model+Playback+Feedback	13 (22%)	34 (57%)	26 (43%)	60
Total	**43 (18%)**	**107 (45%)**	**133 (55%)**	**240**

Note. (Perfect scores are included in the above 90% column.)

Of the 60 participants in the Model+Playback+Feedback condition, 34 (57%) were able to achieve a final accuracy score of 92 or higher (including 13 perfect scores), leaving the other 26 participants (43%) with final accuracy scores of 88 or below. (See Table 3)

Although posttest scores begin to illustrate pitch and rhythmic accuracy achievement, they do not tell the whole story. In order to measure accuracy improvement during each practice condition, SMPRA scores at sight read need to considered. Therefore, gain scores accounting for the difference in each participant's score from pretest to posttest serve as a much better measure of accuracy growth.

Pitch and Rhythmic Accuracy Growth (SMPRA Gain Scores)

According to the 240 computer-assessed accuracy gain scores, most of the participants were able to improve their pitch and rhythmic accuracy during practicing, resulting in 207 positive gain scores (86%). However, some participants' performances actually deteriorated during practicing, resulting in 21 negative gain scores (9%). Out of 240 pre-tests over the entire experiment, three scored 100, leaving no room for improvement (2 during the Model+Playback condition, and 1 during the Model+playback+Feedback condition). Ignoring those three cases (1%), participants who

Table 4. *Frequency distribution of positive, flat, and negative gain scores by practice condition.*

Practice Condition	Positive (n) (%)	Flat (n) (%)	Negative (n) (%)	Total (n)
Control	43 (72%)	6 (10%)	11 (18%)	60
Model	55 (92%)	0 (0%)	5 (8%)	60
Model+Playback	51 (85%)	4 (7%)^^	5 (8%)	60
Model+Playback+Feedback	58 (97%)	2 (3%)^	0 (0%)	60
Total	207 (86%)	12 (5%)	21 (9%)	240

^*Note*. (1 of these flat scores was due to perfect pre-test scores.)
^^*Note*. (2 of these flat scores were due to a perfect pre-test score.)

had room for improvement but did not improve resulted in 9 gain scores of zero (4%). Table 4 breaks down the positive, flat, and negative gain scores by practice condition (see Table 4).

Computer-assessed pitch and rhythmic accuracy gain scores were 14.27 for participants during the Control condition, 25.90 in the Model condition, 21.10 in the Model+Playback condition, and 31.77 in the Model+Playback+Feeedback condition. (See Table 5).

Table 5. *Accuracy gain score means and standard deviations for each of practice condition.*

	n	M	SD
Control	60	14.27	22.00
Model	60	25.90	20.36
Model+Playback	60	21.10	20.64
Model+Playback+Feedback	60	31.77	18.67

Note. (60 participants completed each practice condition once in a within-subjects design.)

In this study, order sequence was a between-subjects factor due to the Greco-Latin square design used to randomize participants to melody tasks and order of practice condition. The means table reflecting mean SMPRA gain scores by condition according to sequence/melody order is shown in Table 6.

Table 6. *SMPRA gain scores means table.*

	Control	Model	Model+Playback	Model+Playback+Feedback	
Seq. 1	14.8	26.4	28.6	21.9	22.93
Seq. 2	13.5	22.8	12.0	29.9	19.55
Seq. 3	12.5	36.1	26.4	27.7	25.68
Seq. 4	16.3	17.7	17.4	47.6	24.75
	14.28	25.75	21.1	31.78	

A two-factor mixed ANOVA revealed a statistically significant main effect for the within-subjects factor of scaffold condition, $F(3,168) = 9.21$, $p < .0001$, but not for the between-subjects factor of sequence, $F(3,56) = 0.87$, $p = 0.46$ at an alpha level of .05. (see Table 7)

Table 7. *Mixed ANOVA table for pitch and rhythmic accuracy gain scores.*

Source	df	SS	MS	F	p
Between Subjects	59				
Sequence	3	1394.51	464.84	0.87	0.4617
Error	56	29890.30	533.76		
Within Subjects	180				
Scaffold	3	10228.25	3409.42	9.21	< .0001*
Scaffold X Sequence	9	10409.20	1156.58	3.13	0.0017*
Error	168	114099.56			
Total	239	114099.56			

*$p < 0.05$

Compared to the Control condition, average pitch and rhythmic accuracy growth was significantly greater during the Model condition ($F(1,56) = 12.81$, $p = .0007$, partial

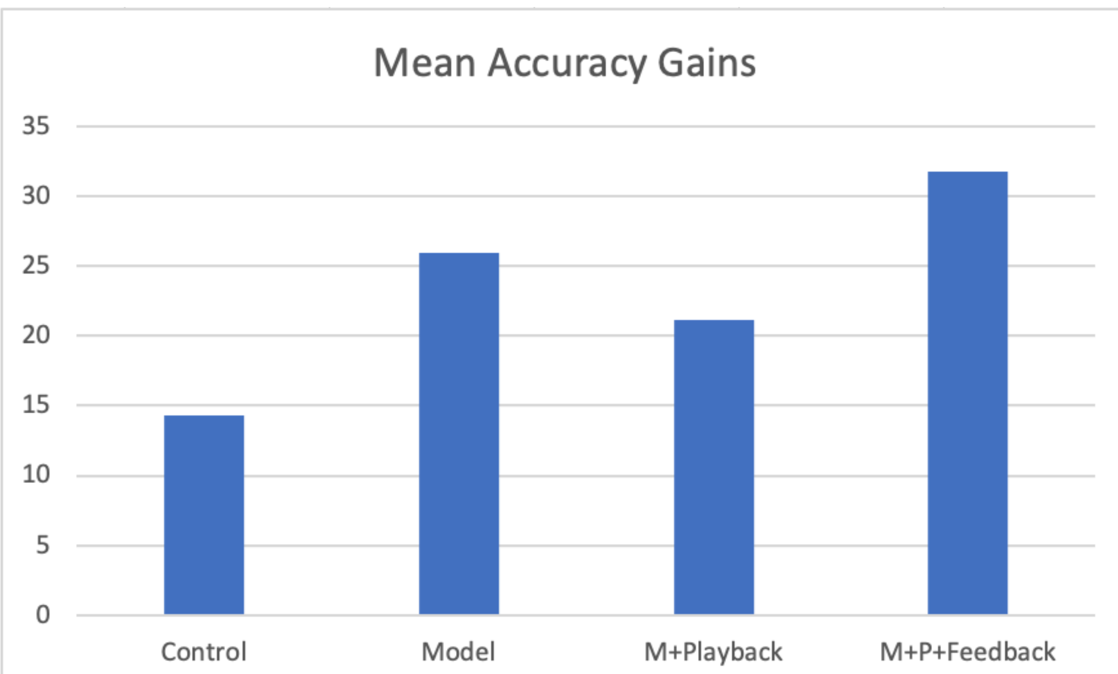

Figure 28. Gain scores by scaffold condition.

η^2 = .11) and during the Model+Playback+Feedback condition ($F(1,56) = 19.84$, $p <$ .0001, partial η^2 = .30), but not during the Model+Playback condition ($F(1,56) = 3.07$, p = .0855). Compared to the Model+Playback condition, average accuracy growth was significantly greater during the Model+Playback+Feedback condition ($F(1, 56) = 11.91$, p = .0011). Figure 28 shows a visual representation of the mean SMPRA gain scores by condition, collapsed across sequence.

Persistence (Time Spent Practicing)

Participants spent approximately equal time practicing in each treatment

Table 8. *Mean time spent practicing (minutes) in each practice condition.*

	n	M	SD
Control	60	5.65	2.86
Model	60	4.55	2.26
Model+Playback	60	4.62	2.33
Model+Playback+Feedback	60	4.45	2.89

Note. (Time spent listening to playback or viewing computer displays was not included.)

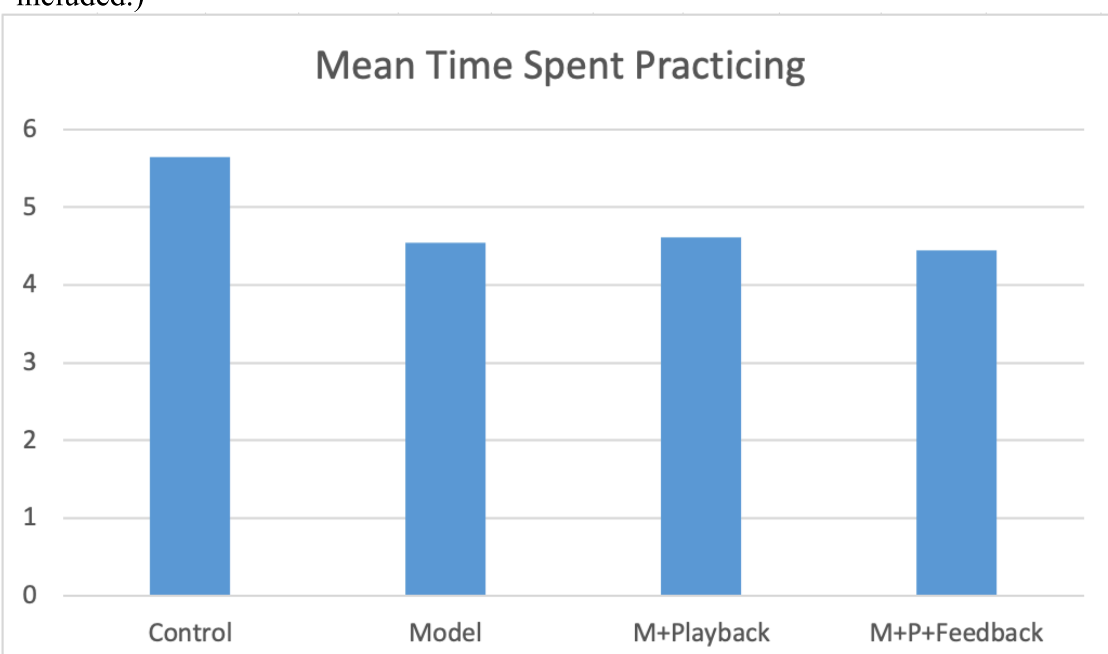

Figure 29. Mean time spent practicing in each condition.

condition. Mean times were 5.65 minutes in the Control condition, 4.55 minutes in the Model condition, 4.62 minutes in the Model+Playback condition, and 4.45 minutes in the Model+Playback+Feedback condition (see Table 8). A visual representation of mean time (in minutes) spent practicing in each condition, collapsed across sequence is illustrated in Figure 29.

Qualitative Findings (Experience and Behavior)

Participants spoke their thoughts out loud while they practiced and answered open-ended questions after completing all four practice scenarios. I asked, “Considering all of the practice scenarios you just did, tell me which practice aids you found most/least helpful, and which you liked/disliked, and why?” and, “In what ways did these practice aids impact your practicing?” I also asked each participant to identify which (if any) of the practice aids they would choose to use in future practice. Of 60 participants, 51 (85%) expressed that the aural model was helpful, 30 (50%) expressed that the visual evaluative feedback was helpful, and 16 (27%) said that the auditory playback feedback was helpful. Although participants were asked about their experiences in each practice scenario where they experienced digital scaffolds in combination, they spoke about the scaffolds individually. Descriptions of their experiences differed by scaffold as follows.

Control – Practicing without Digital Scaffolds

Participants expressed the most difficulty when they had to practice without digital scaffolds. Most participants said, “I didn’t know how it was supposed to sound,” and “the accidentals; I knew what they were, but I didn’t know what they sounded like.” Participants also expressed lack of confidence that they were playing the melody correctly, such as, “It sounds awful, but I don’t know if it’s supposed to be that way.” One confessed, “The last measures, I guessed. It’s all just kind of a guess,” and another said, “I’m going in blindly. I don’t know where I went wrong.” In comparison to the other conditions, there was a strong consensus that the control condition “was definitely way harder than the other scenarios,” and “my confidence was very low on this.” Participants commented that, “It was harder than the other scenarios, without having a reference, without the reassurance of hearing the melody.” And, “It’s a lot harder to know what it’s supposed to sound like.” And, “It was a lot harder because I didn’t have an expectation of what to play. I had to figure out the rhythm and fingering myself.” Because, as participants said, “you’re on your own to figure out how it goes,” they spent more time counting and clapping rhythms and checking intonation with open strings and double stops, than they did in the other conditions. One said, “I have to count in my head and go a little slower.”

Aural Model Digital Scaffold

Participants interacted with the Model in scenario 1 (Model condition), scenario 2 (Model+Playback condition), and scenario 3 (Model+Playback+Feeedback condition). Qualitative data suggest that the aural model enabled participants to imagine a more accurate and complete aural goal image, and therefore, they were better able to achieve the goal. As one participant expressed, “When I heard the recording of the melody, it solidified what it was supposed to sound like, because when I first played it, I didn’t know how it was supposed to go.” Another participant said, “I feel like these melodies didn’t make sense musically in the last measures; they sounded weird, so listening to the melody really helped.” Additionally, the aural model illuminated mistakes for some participants who said, “Once I heard the actual correct rhythm being played, I knew the rhythm I thought was right [during sight-read] was actually wrong.” There was a consensus that, “hearing the melody helped the most,” and the aural model, “made it easier to hear how the rhythm and intonation sounds." Almost every participant said something along the lines of, "Hearing the melody helped me get it into my head," or "I know how to read music, but it helps to hear it too," or "It's helpful to hear the melody so you're not just guessing." The exception were a few participants who said, "I got the rhythm the first time through, so hearing the melody didn't really help, but it confirmed that I had it correct." And, "I wouldn't have even thought about the F-natural in measure three, but other than that, hearing the melody wasn't too helpful." Many participants used the model to check their answers. While the model played, 40 of the 60 participants either fingered, plucked, or played along with it.

Auditory Playback Feedback Digital Scaffold

Participants interacted with the Playback in scenario 2 (Model+Playback condition) and scenario 3 (Model+Playback+Feedback condition). The presence of the playback seemed to have contaminated some participants' aural goal images. One participant said, "My own recording kind of messed me up because it was wrong, so I heard it wrong." Another said, "By the time I listened to the recording of myself playing, I had forgotten what the melody [aural model] sounded like." Hearing their errors played back seemed to reinforce the false aural goal image of some participants, or at least blurred their memory of the correct aural model. Many participants commented that the auditory playback feedback was the least helpful of the digital scaffolds. Some participants were visibly uncomfortable listening to their own playback recording, and commented that they did not enjoy listening to it. Hearing their own performance playback made some participants deflated, stating, "I don't think hearing the recording of myself was helpful. It brought my confidence down," and "Ew, I don't like listening to myself [on a recording] because it sounds terrible. I don't even listen to my playing tests before turning them in." A few participants had the opposite reaction, stating, "Hearing the recording of myself motivated me because I heard how bad it was and I wanted to make it better, and it helped me see what I needed to fix," and "My recording was not as bad as I thought I played it, and it helps me hear where I made mistakes." Participants reported that the playback allowed them to hear their performance with full attention. One participant said, "I feel like you sound a little different in the moment. You're thinking about the notes that are coming up, not necessarily focusing on what you sound like." Another said, "I like listening to my own playback because it's a lot easier to hear mistakes, rather than hearing it while I'm playing." Some identified concrete errors that the playback allowed them to hear. For example, one said, "When I compared my recording [playback] to the real recording [model] I heard I didn't play the B-flat. Yikes!" Other participants felt that the playback didn't provide much useful information. One said, "The playback was helpful the first time, but not the second time. It just sounded the same to me every single time I played it." Another said, "I don't think the playback was very helpful because I heard myself play the wrong pitch when I was playing it." Others stated, "I didn't hear any mistakes I wasn't already aware of." That is not to say that participants actually heard all of their mistakes, as the less-than-perfect accuracy scores indicated.

Visual Evaluative Feedback Digital Scaffold

Participants interacted with the Visual Feedback in scenario 3 (Model+Playback+Feedback condition). The visual feedback enabled participants to detect errors beyond what they perceived audibly. Participants said, "The computer shows me the spots where I made mistakes that I was not aware of," and "I trust the machine more than I trust myself with intonation." Comparing the playback to the visual feedback, participants said, “Seeing the notes I got wrong was more helpful than hearing my own playback.” And, “The recording [of my own performance] shows me what I have to work on, but the computer tells me exactly. It’s particular.” The visual feedback illuminated the details, providing more information for correcting the problems. According to participants, “The computer showed me what to focus on. It was helpful to see not just that the intonation or rhythm was wrong, but to see exactly how wrong the intonation or rhythm was.” And, “I could tell the second half was my problem area, but it was really nice to see exactly which notes were the problem.” And, “Seeing the red and green helped me see exactly where and what to fix.” And, “The red and green showed me that the end was not as good, and *why* it was not as good.” Some participants thought the visual feedback was particularly helpful for rhythmic specifics saying, “I knew there were sixteenth notes I was getting wrong, but there was one eighth note I didn’t know was wrong until I saw the red on the computer.” Or, “Seeing the reds and greens, I realized the eighth notes at the end of the measures aren’t right next to each other; I could see where my rhythm was off. It showed you what you did wrong and what it should be.” Other participants commented that the visual feedback was particularly helpful for pitch and intonation, saying, “The second time I saw the red and green, it was more useful because it showed me which notes were out of tune. It’s good for fine tuning.” And, “[The visual feedback shows you that] you may have hit the note, but you played it sharp or you played it flat.” Specific intonation issues were mentioned by participants who said, “I knew I missed the B-flats, but I didn’t know there were some other pitches out of tune until I saw it.” And, “I liked the computer because it helped me figure out which notes I needed to shift my finger a little for, because there were some accidentals I wasn’t playing high enough.” Even the participants who were unable to hear the clashing dissonance of their incorrect pitches while they played along with the aural model said, "It [visual feedback] helped me realize there was a G-sharp instead of a G-natural, and helped me adjust my fingerings and rhythms." As a result, even these participants improved their intonation.

When participants had the visual feedback, they made many comments pinpointing specific musical errors. After seeing the red and green display they said, "Okay, so those quarter notes go a lot slower than I thought they would." Or, "Oh, that's a natural not a sharp. That's why it sounded weird." Most participants were able to decode the visual message to pinpoint the errors in their thinking that had led to the wrong notes saying, "Okay, I'm going a little too fast there." "I missed the flat coming down." "Oh, that's a B-flat at the end!" "I saw where I was playing low two where it should have been high two." "Oh, I missed all the B-flats."

Participants believed the visual feedback allowed them to be more efficient in their practicing saying, "When I saw the red, it helped me focus on my problems, so I worked on those spots right away." Or, "It confirmed that I was right about which spots I needed to work on more. The green allowed me to see that I don't need to work on that section, so I could focus on the red spots." And, "I like seeing the notes. It saved time because I knew where to work."

Alignment of SMPRA Scores and Self-Assessment

After performing each take, participants rated their performance from zero to one hundred, self-assessing their pitch and rhythmic accuracy. If a participant's self-assessment increased from one take to the next, then the participant self-assessed improvement. A decrease in score from one self-assessment to the next was viewed as a self-assessment of performance deterioration. According to participant self-assessment scores, participants whose performance deteriorated (SMPRA scores got worse) during practicing actually thought they were improving. In 20 of the 21 cases of overall deterioration experiment-wide, participants had self-assessed their performances as improving. For example, one participant during the control condition self-assessed their three takes at 70, 75, and 85 while the computer assessed their takes at 63, 29, and 13. Another participant self-assessed their four takes at 25, 35, 60, and 65 while the computer assessed their takes at 88, 79, 46, and 46. Table 9 illustrates these occurrences broken down by practice condition. Even some participants who ended up with positive overall gain scores had setbacks along the way (formative deterioration) that went unnoticed. On the opposite side, no participants mistakenly assessed a positive gain score as a deterioration, and only a few self-assessed formative improvement as deterioration (see Table 9). Overall, participants self-assessed improvement in all but one of the 240 practice sessions.

Table 9. *Mismatch of self-assessment and SmartMusic accuracy scores by practice condition.*

Practice Condition	Negative gain scores self-assessed as improvement (n) (%)	Formative deterioration self-assessed as improvement (n) (%)	Positive gain scores self-assessed as deterioration (n) (%)	Formative improvement self-assessed as deterioration (n) (%)
Control	11 (18%)	22 (37%)	0 (0%)	8 (13%)
AM	4 (7%)	14 (23%)	0 (0%)	3 (5%)
AM+AF	5 (8%)	23 (38%)	0 (0%)	4 (7%)
AM+AF+VF	0 (0%)	11 (18%)	0 (0%)	1 (2%)
Total	20 (8%)	70 (29%)	0 (0%)	16 (7%)

Internal Validity

It was necessary to check for factors that may have influenced participants in the practice sessions unequally. To check the equivalency of the four melody tasks, a one-way repeated-measures ANOVA was conducted on pretest scores according to melody task. In addition, a two-factor mixed ANOVA was conducted to see if there were main effects of scaffolds, order/melody, or interactions between the two factors.

Melody Tasks

In order to check the equivalency of the melody tasks, I asked participants about the difficulty of the melodies after they completed all four practice scenarios and ran a one-way repeated measures ANOVA on pre-test scores.

Melody Task Pre-Test Scores

The four melody tasks were titled Alpha, Beta, Charlie, and Delta. Mean pre-test accuracy scores were 63.97% for Melody Alpha, 59.12% for Melody Beta, 54.07% for Melody Charlie, and 50.25% for Melody Delta (see Table 10). A one-way repeated measures ANOVA revealed a statistically significant difference between the mean pre-test scores ($F_{(3, 177)} = 5.52$, $p = .0012$), indicating that the melody tasks were not of equal difficulty (see Table 11).

Table 10. *Pretest means and standard deviations for each of four melody tasks.*

	n	M	SD
Melody Task Alpha	60	63.97	22.63
Melody Task Beta	60	59.12	19.87
Melody Task Charlie	60	54.07	20.64
Melody Task Delta	60	50.25	26.26

Note. (60 participants interacted with each melody task once in a within-subjects design.)

Table 11. *One-way repeated measures ANOVA of pre-test scores by melody task.*

Source	*df*	*SS*	*MS*	*F*	*p*
Melody Task	3	7084.50	2361.50	5.52	0.0012*
Error	177	75690.50	427.63		

*$p < 0.05$

Probing the main effect revealed statistically significant differences between Alpha and Charlie pre-test scores, $F(1,59) = 4.16$, $p = .0459$, between Alpha and Delta pre-test scores, $F(1,59) = 14.72$, $p = .0003$, and between Delta and Beta pre-test scores, $F(1,59) = 12.19$, $p = .0009$ (see Figure 30). Although there appeared to be differences in difficulty, the melody tasks were evenly distributed across practice conditions using a Greco-Latin square design that controlled for these differences. Therefore, internal validity was not compromised by this difference in melody difficulty.

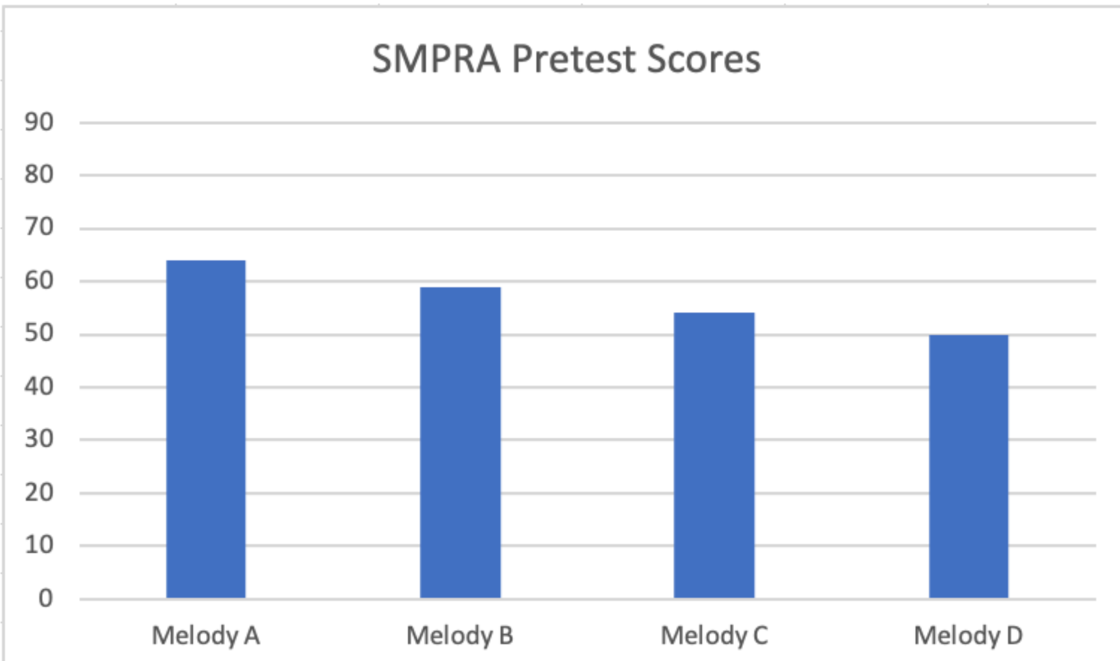

Figure 30. SMPRA pretest scores by melody task.

Melody Task Participant Perception of Difficulty

At the end of the experiment, I asked each participant to identify which melody task was easiest, and which was the most difficult, taking only the music into consideration. Most commented that the melodies were all similar. A few participants said they were unable to choose any one that was harder or easier than the others, while a few chose two or more that were the hardest or easiest. Most participants were able to select one as the easiest and one as the hardest. Considering the easiest melody task, participants pointed to Melody Alpha 27 times, Melody Delta 14 times, Melody Charlie 12 times, and Melody Beta 11 times. Considering the most difficult melody task, participants identified Melody Charlie 23 times, Melody Beta 21 times, Melody Delta 14 times, and Melody Alpha 3 times. As a sample, it appeared the participants found Melody Alpha and Delta to be the easiest while they found Melody Beta and Charlie to be the most difficult (see Table 12).

Table 12. *Frequency of melody task being identified by participants as the easiest or hardest.*

	Easiest	Hardest
Melody Task Alpha	27	3
Melody Task Beta	11	21
Melody Task Charlie	12	23
Melody Task Delta	14	14

Melody Task Difficulty Integration

Participants expressed the perception that melodies Alpha and Delta were the easiest, while melodies Beta and Charlie were the most difficult. However, quantitative data suggests that melody Alpha was the easiest, while Delta was the most difficult.

Scaffold X Sequence/Melody Interaction

A two-way mixed ANOVA revealed a significant interaction for Scaffold X Sequence/Melody $F(9,168) = 3.13$, $p = 0.0017$ at an alpha level of .05 (see Table 7). The significant interaction indicates that the effect of scaffold condition on SMPRA gain scores was different according to sequence/melody. Because of the Greco-Latin square design used to assign both order and melody task, melody task is confounded with order, making it impossible to statistically separate the two. However, I believe the significant interaction is due to the melody task Delta being more difficult than the other melodies. With lower pretest scores on melody Delta, melody Delta, a situation was created where there was more potential for scores to improve during practice. A look at the means table overlaid with melody task labels illustrates that melody Delta received the highest gain scores in each of the conditions with scaffolds, but not in the control condition (see Table13 and Figure 31).

Table 13. *Means table overlaid with melody task labels.*

	Control	Model	M+Playback	M+P+Feedback	
Sequence 1	Alpha 14.8	Charlie 26.4	Delta 28.6	Beta 21.9	22.93
Sequence 2	Delta 13.5	Beta 22.8	Alpha 12.0	Charlie 29.9	19.55
Sequence 3	Beta 12.5	Delta 36.1	Charlie 26.4	Alpha 27.7	25.68
Sequence 4	Charlie 16.3	Alpha 17.7	Beta 17.4	Delta 47.6	24.75
	14.28	25.75	21.1	31.78	

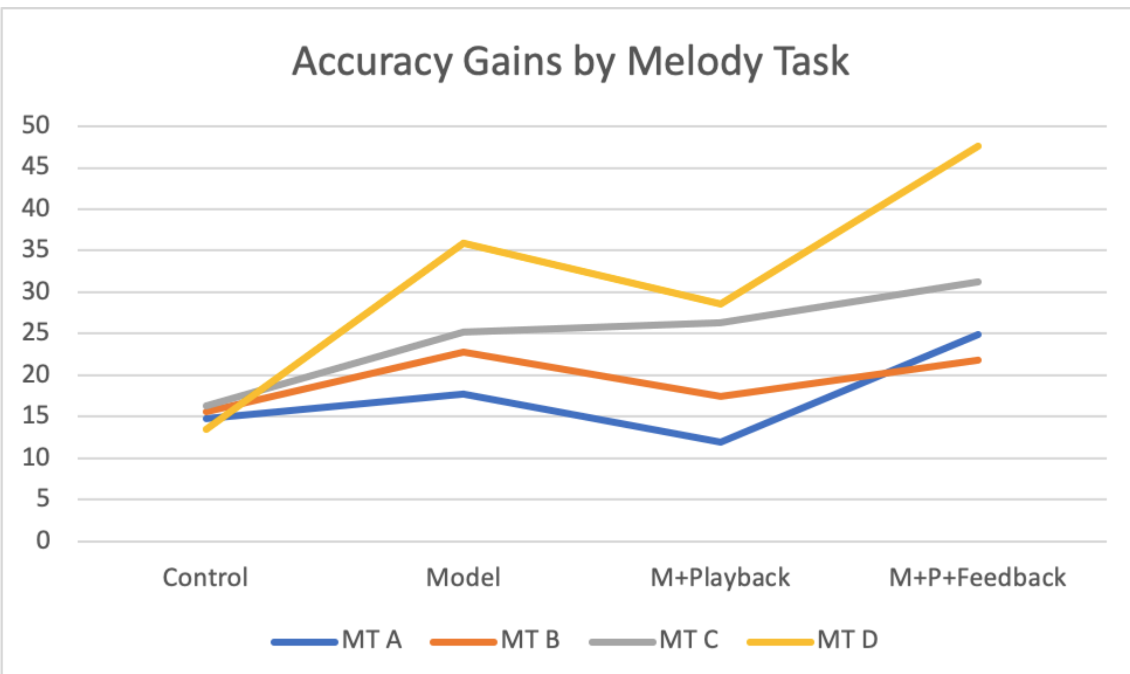

Figure 31. Accuracy gains by melody task.

In an attempt to examine order effects separately from melody task effects, an examination of the means table overlaid with order sequence labels helps to illuminate clues (see Table 14) Looking at the order of each cell in the means table reveals no apparent patterns that would suggest order effects (see Figure 32).

Table 14. *Means table overlaid with order labels.*

	Control		Model		M+Playback		M+P+Feedback		
Sequence 1	1st	14.8	2nd	26.4	3rd	28.6	4th	21.9	22.93
Sequence 2	2nd	13.5	1st	22.8	4th	12.0	3rd	29.9	19.55
Sequence 3	3rd	12.5	4th	36.1	1st	26.4	2nd	27.7	25.68
Sequence 4	4th	16.3	3rd	17.7	2nd	17.4	1st	47.6	24.75
		14.28		25.75		21.1		31.78	

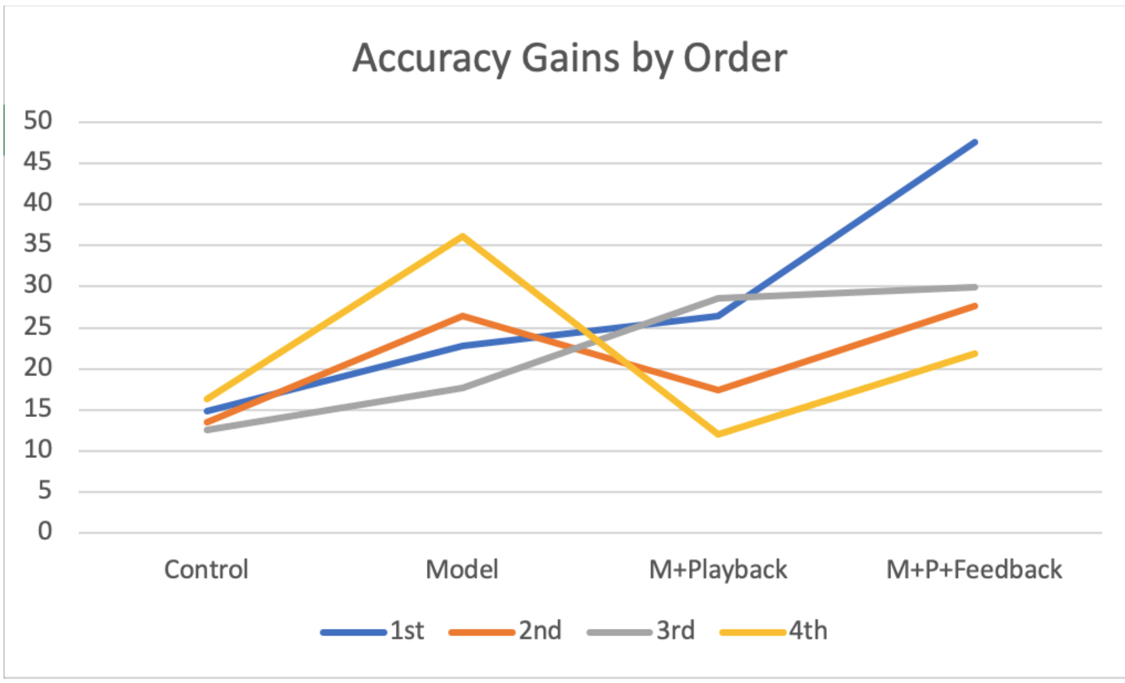

Figure 32. Accuracy gains by order.

Therefore, it seems plausible that the significant interaction for Scaffold X Sequence/Melody is likely due to the differences in the difficulty of the melody tasks. Specifically, the melody task Delta seems to have elicited greater gains than the other melody tasks in the conditions with scaffolds, exaggerating the effects of the digital scaffolds.

Chapter 5: Discussion

Skill acquisition occurs through deliberate practice (Ericsson et al., 1993). Solitary deliberate practice is possible through self-regulation (Zimmerman, 2002). Experts are successful in the practice room because they self-regulate their practice (Nielsen, 2001). Novices are unsuccessful in the practice room because they do not self-regulate their practice (Gruson, 1988; Hallam, 1997; McPherson et al., 2012; McPherson & Renwick, 2000, 2001; Pitts et al., 2000). They often play through entire pieces without stopping to make corrections (Barry & Hallam, 2002; Hallam, 1997, 2001; McPherson et al., 2012; McPherson & Renwick, 2001). Novices are unable to self-regulate their practice because of aural skill deficiencies (Barry & Hallam, 2002). More specifically, novice music students are unable to audiate an aural goal image from written music notation (McPherson, 1993) and cannot perceive the aural sounds from their own playing (McPherson & Renwick, 2001). Audiation and aural perception are necessary to hear the discrepancy between their performance and what it should sound like. It is self-assessment of this aural evidence that enables musicians to provide themselves with evaluative feedback. Self-regulation is not possible without evaluative feedback (Ericsson et al., 1993).

Consider this true story of high school violinist, Emma. Emma held back tears when she read the grading report of her latest playing test. She spent a week practicing the excerpt and felt confident about her performance of the music, but her grade turned out to be much worse than expected. Since she couldn't ace the test after really practicing, Emma decided not to waste her time practicing anymore. The problem with Emma's practicing was not her effort, but rather her inability to accurately evaluate her performance and give herself proper feedback in the moment. If Emma lacks the skill to audiate an accurate aural goal or hear her own mistake, then she would not be able to apply an appropriate strategy to target it. Perhaps if she was aware of her mistake, she could respond differently. Practicing with a model has been shown to increase student achievement (Fortney, 1992; Linklater, 1997; Rosenthal, 1984; Rosenthal, Wilson, Evans, & Greenwalt, 1988; Zurcher, 1975). In the present study, three types of digital scaffold (i.e., Aural Model, Auditory Feedback, and Visual Feedback) were explored to see which kind best enable students like Emma to practice like experts, and to provide insight to the removal of the obstacles in their practice rooms.

The purpose of this study was to gain insight into the deficiencies and capabilities of high school string players in the practice room, through a mixed methods within-subjects experiment exploring the impact of digital scaffolds on pitch and rhythmic accuracy growth, self-assessment, self-correction, and other self-regulatory behavior during independent music practicing. More specifically, the quantitative research questions were:

- Do digital scaffolds impact the pitch and rhythmic accuracy growth of high school string players practicing independently?
- Do digital scaffolds impact the amount of time a high school string player persists at practicing a musical task?

The qualitative research questions were:

- How do high school string students experience music practicing with and without digital scaffolds?
- What self-regulatory behaviors do high school string students employ when practicing with and without digital scaffolds?

The mixed methods research questions were:

- Do the pitch and rhythmic accuracy scores align with students' description of their own assessment of their performance with and without digital scaffolds?
- In what ways do quantitative data and qualitative data converge and/or diverge to illuminate deficiencies and capabilities of high school violinists, violists, and cellists in the practice room?

These research questions were addressed in the present study through a mixed methods within-subject experiment. Sixty high school string students individually completed a 30-minute practice session divided into four practice conditions (1.Model, 2.Model+Playback, 3.Model+Playback+Feedback, and 4.No scaffolds). The Model was audio of the melody. The Playback was self-recording playback. The Visual Feedback was a color-coded evaluation of performance displayed on a computer screen highlighting correctly performed notes green and incorrectly performed notes red. During each practice condition, performances at sight-read (pretest), during practicing (formative), and after practicing (posttest) were assessed for pitch and rhythmic accuracy by computer software *SmartMusic*. While participants practiced a novel melody, they spoke their thoughts out loud, self-assessed their progress, and answered questions about their experience with each digital scaffold. The quantitative strand concerns performance accuracy through *SmartMusic* pitch and rhythm assessment (SMPRA) gain scores, and time spent practicing. The qualitative strand concerns self-regulated practicing behaviors through observation of the participants verbalizing their thoughts while practicing and explores participants' experience through follow-up interviews at the end of the experiment.

Do digital scaffolds impact the pitch and rhythmic accuracy growth of high school string players practicing independently?

Model

When compared to the control, participants showed significantly greater accuracy gains practicing with the Aural Model. This aligns with other research on aural models for increasing musical achievement (Fortney, 1992; Linklater, 1997; Rosenthal, 1984; Rosenthal, Wilson, Evans, & Greenwalt, 1988; Zurcher, 1975). Adding to that body of research, the qualitative data from this present study help to illuminate why, suggesting that the aural model enabled participants to imagine a more accurate and complete aural goal image. Therefore, participants were better able to work toward and achieve the real goal. The data also painted a picture of the difficulty these music students had attaining an accurate aural goal image without the model, highlighting an inability among this sample of high school string players to audiate an aural goal image from music notation alone.

Playback

Surprisingly, when Playback was used in combination with the Model, accuracy gains in the Model+Playback condition were not statistically different from the control. This finding aligns with other studies finding no effect of self-recording during practice on music achievement (Hewitt, 2001). Qualitative data from this present study provide insight into why the addition of the playback may have resulted in less accuracy growth than the Model condition. Participants reported that “My own recording [playback] kind of messed me up because it was wrong, so I heard it wrong,” and, “By the time I listened to the recording of myself playing, I had forgotten what the melody [aural model] sounded like.” Hearing their errors played back seemed to reinforce a false aural goal image, or at least blurred their memory of the correct aural model. Therefore, participants were not able to achieve greater accuracy gains in the Model+Playback condition. Participant descriptions lead me to believe that the comparison of one's performance with the aural goal image has to happen while the participant is playing the performance, because it may be too much information to hold in short term memory to try to compare the two after the sounds have vanished from the air. It seems probable that the way musicians self-assess their performance is one or two notes at a time, in real time. It probably would have been more beneficial to play back the participant's performance and the aural model simultaneously, so participants could listen for discrepancies in a way that is more authentic to how expert musicians self-assess practice (Nielsen, 2001). However, the way that participants interacted with the playback in this present study, did not appear to help them improve pitch and rhythmic accuracy.

Visual Feedback

Accuracy gains in the Model+Playback+Feedback condition were significantly greater than the Control condition, and also significantly greater than the Model+Playback condition. In the Model+Playback+Feedback condition, even though the playback was present to potentially contaminate participants' aural goal images, the information from the visual feedback seemed to override that providing clarity and eliminating any confusion about how the music should go. The visual feedback provided a more detailed evaluation of their performance than participants were able to provide for themselves relying on their aural skills alone. As the accuracy growth scores indicate, once the feedback helped them pinpoint their errors, they applied the correct strategies to fix the problem (i.e. changing fingering or adjusting rhythm). In the other practice conditions (Control, Model, Model+Playback), participants relied on their aural skills to detect errors, and they could only apply correction strategies to the errors they could hear. However, in the Model+Playback+Feedback condition, the visual feedback allowed them to bypass their aural skills and get straight to the report of errors. The visual feedback served as a bridge that enabled participants to apply correction strategies to the errors they didn't hear and increase their pitch and rhythmic accuracy. Participants demonstrated that they have the strategies and technical flexibility to fix the errors they make when practicing, but they lack the ability to detect errors by ear. Other studies suggest intermediate students lack the strategies to improve their performance during practicing (Pitts et al., 2000; Miksza et al., 2012). This present study illustrates that some music students actually have the strategies to fix errors to improve performance, but are not able to demonstrate them when they have to identify errors by ear. This is in accordance with Hallam's claim that effective practicing is fundamentally dependent on the student's ability to monitor and self-evaluate progress (Hallam, 1997).

Do digital scaffolds impact the amount of time a high school string player persists at practicing a musical task?

Participants spent approximately equal time practicing in each treatment condition. However, the mean time for practicing in the Control condition was slightly longer than the others, which paints a clear picture that the lower gain scores in the control condition could not be attributed to participants giving up sooner than in other conditions. In fact, as observation revealed, participants spent more time practicing in the control condition because they had to clap out rhythms and check pitches against open strings, two strategic behaviors that were not employed as much when students had access to the aural model.

How do high school string students experience music practicing with and without digital scaffolds?

In light of working with the digital scaffolds, participants were able to give excellent insight into the difficulties they face practicing without scaffolds. Participant work with the aural model provided insight into the difficulties students have imagining an accurate aural goal image confidently without the model, saying, “When I heard the recording of the melody, it solidified what it was supposed to sound like, because when I first played it, I didn’t know how it was supposed to go.” Without scaffolds, participants described uncertain aural goal images, despite confidence in their ability to understand the music notation saying, “the accidentals; I knew what they were, but I didn’t know what they sounded like.” It appeared that participants were decoding the musical symbols into actions (i.e. put this finger down), rather than audiations (i.e. hearing the music in their mind). Without an model, participant statements like, “It sounds awful, but I don’t know if it’s supposed to be that way,” seemed to indicate that participants were skipping audiating an aural goal image from notation before playing. Instead, they seemed to be using the notation to figure out which fingers to press down, and then discovering the sound those fingers made as they played them, piecing together an aural goal image from the sounds they were creating. They admit, “It’s all just kind of a guess,” and, “I’m going in blindly.” This is opposite from the way expert musicians practice knowing exactly what they want the music to sound like before playing a note (Nielsen, 2001).

The model was the favorite digital scaffold. With the model, participants were able to imagine an accurate aural goal image because “hearing the melody helped me get it into my head.” It was comforting to participants to have the model to solidify the goal. Thirty-six of the participants claimed to use a recording of the music as they practiced at home. For this sample of high school string players, over half of them had already discovered the benefits of practicing with an aural model and felt comfortable working with one during this experiment. Even with access to the model, participants still relied on their aural skills to compare their own performances to the ideal for error detection, and not all were confident in their ability to do so. Exactly what participants were and were not able to hear was not revealed until they had the visual feedback to compare it to. Without the visual feedback, participants were able to hear some intonation issues like, "I knew I missed the B-flats," but didn't fully trust their ability to hear fine tuning, saying "I trust the machine more than I trust myself with intonation." Similarly, participants were able to hear some rhythmic discrepancies, stating, "I knew there were sixteenth notes I was getting wrong." Participants sometimes had a vague sense that something sounded wrong, "it sounded weird," or "I could tell the second half was my problem area," but were unable to pinpoint exactly what was wrong. We know this because when they had the visual feedback, they could articulate what they had not been able to detect saying, "I could tell the second half was my problem area, but it was really nice to see exactly which notes were the problem," and "Oh, that's a natural not a sharp; that's why it sounded weird." The visual feedback allowed them to identify specific errors that they were unable to hear. They said, "I knew there were sixteenth notes I was getting wrong, but there was one eighth note I didn't know was wrong until I saw the red on the computer," and, "I knew I missed the B-flats, but I didn't know there were some other pitches out of tune until I saw it." Once participants were aware of specific errors, they were quickly able to identify the source of the problem (i.e., second finger was too high), identify a strategy to correct the problem (i.e., try a couple of repetitions with a lower finger), and adjust their technique to execute the correct performance (i.e., perform the passage with a lower finger on that note). Even the participants who employed simple play through during the control condition that looked much like the descriptions of novice practice behavior (Hallam, 1997, 2001; McPherson et al., 2012; McPherson & Renwick, 2001; Barry & Hallam, 2002), were able to employ more sophisticated practice strategies when they had access to the aural model and visual feedback.

What self-regulatory behaviors do high school string students employ when practicing with and without digital scaffolds?

A few participants spoke little as they worked through the practice conditions, but most easily explained what they were hearing, what they were doing, and why they were doing it. The participants engaged in many self-regulatory processes including goal setting, self-monitoring, metacognition, and strategy selection, use, and adjustment. In other words, they employed many more strategies than novice musicians who have been found to use little or no strategies (Hallam, 1997, 2001; McPherson et al., 2012; McPherson & Renwick, 2001; Barry & Hallam, 2002). Typically, participants had a go-to sequence of strategies that they used when learning a new piece of music. They talked through first figuring out the rhythm; many clapped and counted. After a run, they verbalized how they thought that went for them, zeroing in on tricky spots. After they felt good about their grasp of the rhythm, they moved on to focus on pitches. Sometimes they played pitches out of rhythm in isolation checking them against double stops or open strings (especially in the control condition). Sometimes they just added a focus on pitch to the rhythm they had just figured out. In most cases, after playing a spot, participants would say, "oops, that's a B-flat" and go back to that spot and practice hitting the B-flat. They were quickly zeroing in on the mistakes they noticed and working on them with appropriate strategies. Most participants worked the last three measures of the melodies as those were more difficult than the first two measures. However, there were some participants who started at the beginning every single run through. These participants did not make as much improvement as those that zeroed in on the last measures, which is in accordance with the research on the positive relationship between strategy use and music achievement (Rohwer & Polke, 2006). In the Control condition, there was more playing through the entire melody than there was in the other conditions. The more information participants were able to get from the digital scaffolds, the more they targeted error spots. Because the melodies were short, students fairly quickly got to a point where they felt like they were playing the whole melody to the best of their knowledge. Then they did a bit of repeating the melody in its entirety without making any more changes. When students had access to the visual feedback, they saw errors they had not noticed and most participants quickly figured out the source of the error, applied a targeted strategy, and fixed it. Overall, students had effective strategies and applied them appropriately to errors they detected. However, students were less proficient at detecting their errors by ear. Some students who played through the melody repeatedly without any changes during the control condition appeared to have no strategies, because they didn't use any. However, when those same individuals had digital scaffolds to help them find their errors, they appropriately applied effective strategies to fix the errors.

In the absence of scaffolds, because, "you're on your own to figure out how it goes," participants spent more time counting and clapping rhythms away from the instrument, and spent more time checking intonation with open strings and double stops, than they did in the other practice conditions. A few participants said, "I have to count in my head and go a little slower." Participants employed some of the same strategies in the other practice conditions, but much less frequently. For the most part, these strategies were used in attempt to figure out how the music was supposed to sound (to create an aural goal image). In the other conditions with an model, participants used their memory of what the model sounded like as their aural goal image.

The ways in which participants interacted with the aural model was interesting. In the conditions with the model digital scaffold, participants could request to hear the model as many times as they wanted during practicing. On average, participants asked for two or three additional hearings of the model. Because the model automatically played after each take, not everyone asked for additional hearings of the melody between takes. Some participants were quite successful without additional hearings saying, "I just listen to it once, and then when I play it, I keep it in mind." In those cases, it seemed that the participants were able to pay attention to tempo, rhythm, pitch, and intonation all at the same time. Most participants, however, requested to hear the model a couple more times so they could focus on individual components of the melody. For example, a participant would often focus on rhythm during the first hearing of the model and then listen again focusing on pitch. Or, a participant would focus on the first measures during the first hearing, and then request a second hearing to focus on the last measures of the melody. The most model hearings requested by anyone was 9 additional hearings (12 total) by a participant who requested that I "put it on repeat, please." The number of model requests did not seem to be directly linked to accuracy growth. However, four of the five participants whose accuracy deteriorated while practicing with the model, did not ask to hear the melody at all between takes. In these four cases, I got the sense that the participant was ignoring the model, or at least did not seem to be getting any information from it that they could use.

The number of times participants heard the model seemed to matter less than the ways in which participants engaged with the model while practicing. Typically, during the first sounding of the model, participants quietly listened. On subsequent soundings, only a few participants continued to simply listen to them. Most participants fingered along, plucked along, or even bowed along with the model as it sounded. In each of the three practice conditions with the aural model, 40 of 60 participants played along with it. This enabled participants to self-monitor their own playing while comparing it to the sounding model to hear discrepancies in real time. It appeared that the participants who played along with the model were more efficient in making progress. I believe they were able to use their cognitive energy more efficiently by listening for classing pitches or misplaced rhythms in real time. When participants played along with the model, they were able to quickly hear obvious errors, accurately self-evaluate, identify the error source, and apply an appropriate strategy to correct it. Most of these participants were able to hear when their rhythm or pitch did not line up with the aural model. Therefore, they more quickly pinpointed their errors than participants who did not play along with the model. However, a few participants who played many repetitions with the model appeared unable to hear the clashing dissonances between their own wrong pitches and the correct model pitches, including one of the five participants whose performances deteriorated during the Model condition. In these cases, the participant either paid no attention to the key signatures or misinterpreted them. In those cases, playing with the model did not illuminate their mistake. Whether successful or not, it was clear that participants were playing with the model as an attempt to check their performance, to test if the rhythms and pitches they had decoded matched the ideal. Some participants also reported using the model as an attempt to simulate playing in an ensemble with a stand partner, saying, “I usually follow the person next to me; that’s why I wanted to hear the melody a lot and play along.”

Participants used the model in the forethought phase of self-regulation to set their aural goal image. Participants who played along with the model, were better able to self-monitor in the performance phase of self-regulation, and self-evaluate in the self-reflection phase of self-regulation. The model seemed to bridge the gap that enabled participants to complete a full self-regulatory cycle. They spent more time in the performance phase and self-reflection phase. In contrast, without the model, participants spent much more time in the forethought phase trying to work out an aural goal image.

In contrast, when visual feedback was part of the equation, participants were getting to the self-reflection phase quicker, because they had the evaluation information right away (at the end of their sight read pretest). With more evaluation information that was more detailed than what they were able to give themselves, they were able to apply more targeted strategies, and improve more efficiently.

Do the pitch and rhythmic accuracy scores align with students’ description of their own assessment of their performance with and without digital scaffolds?

Of 240 gain scores over this experiment, 21 were negative, meaning participant performance actually got worse from practicing. In 20 of those 21 cases, participants actually thought they were improving and self-assessed their takes with increasing scores. For example, while Bonnie practiced during the Control practice session, she self-assessed her three takes at 70, 75, and 85 while the computer assessed her takes at 63, 29, and 13. Ralph self-assessed his four takes at 25, 35, 60, and 65 while the computer assessed his takes at 88, 79, 46, and 46. Eleven cases of mismatched assessment occurred during the Control condition, four cases occurred during the Model condition, and five cases occurred during the Model+Playback condition. However, when students practiced in the Model+Playback+Feedback condition, there was no mismatch between self-assessment and computer assessment (see Table 20). I believe participants who thought they were improving when they were really getting worse had encoded an aural goal image that did not match the notation (a false aural goal image). They believed their performances were getting closer to what they thought the music should sound like, but what they thought the music should sound like was actually not what the music notation indicated. This mismatch illuminated student inability to accurately self-assess while practicing alone. These results align with Hallam's findings (1997, 2001). However, students' inability to accurately self-assess may be caused by their inability to audiate an accurate aural goal image from notation.

In what ways do quantitative data and qualitative data converge and/or diverge to illuminate deficiencies and capabilities of high school violinists, violists, and cellists in the practice room?

The data collected in this study illustrate the difficulty participants had hearing their own mistakes. They also provide clues about possible causes of that difficulty, including aural goal imaging, aural discrimination proficiencies, and attentional resources.

Aural goal imaging

Many of the mistakes and inaccurate performances were due to students getting the wrong aural goal image. What they thought the music was supposed to sound like was actually not what the music notation indicated. As shown by mismatched SMPRA gain scores and self-assessments, students built a false performance goal. As participants worked through figuring out the melody during the Control practice session, they constructed their aural goal image out of the sounds they were making rather than through audiation. They looked at the notation to find out where to put their fingers and then discovered the sound as they played the instrument. Most of them passed their construction through a rough filter asking themselves if it sounded plausible according to standard major tonalities. This came up in their verbalizations because the end of the melodies changed keys and had modulating tonalities. They said, “It sounds awful, but I don’t know if it’s supposed to be that way.” This made them even more uncertain about whether or not they were playing the music accurately. When the aural goal image is created in this way, there is no way for musicians to check differences between the ideal aural goal image and what they are playing, because what they are playing is their aural goal image. Therefore, it is no wonder that they do not stop to fix any errors, because their performance matches perfectly what they think the music is supposed to sound like. Despite their lack of confidence about their performance, they have no evidence of any errors, and therefore, nothing to fix. As they said, “It’s all just kind of a guess,” and, “I’m going in blindly.” They did not have enough information to be able to check their answers, until they had access to the model and the visual feedback.

Aural discrimination differences

Overall, participants were able to catch and fix large scale errors (e.g., pitch off by a half-step or more, a group of notes misplaced rhythmically), but often missed small scale errors (e.g., pitches out of tune by less than a half-step, a single note misplaced rhythmically). Although novices miss even large scale errors (Hallam, 1997; McPherson & Renwick, 2001; McPherson, Davidson, & Faulkner, 2012; Pitts et al., 200), and professionals catch even small scale errors (Nielsen, 2001), the high school students in this study provide an intermediate glimpse between novice and expert practice experience. It seems likely that aural skills develop from large scale to small scale. The participants in the study illustrate a rough midpoint on the spectrum of aural discrimination skill development, with some able to hear more detailed nuances than others.

One participant, let's call her Julie, is a good example at the lower end of the aural discrimination spectrum. Julie requested additional hearings of the model in all of the conditions with digital scaffolds. She played along each time the model sounded. Most other participants who played along with the model quickly heard when they played a pitch a half-step off. However, Julie consistently played G-sharps against sounding G-naturals, and played B-naturals against sounding B-flats. She clearly did not hear or notice the clashing dissonance as she played her wrong pitches against the model, because she did not mention them or try to fix them. She even said, "I think my pitches are pretty good," as she spoke her thoughts out loud. Apparently, she was trying to listen to her pitch but wasn't noticing the discrepancy which makes me suspect that her issue was with pitch discrimination rather than overloaded cognitive attention. However, when she practiced during the Model+Playback+Feedback practice session and saw the computer screen with the red highlights on her wrong pitches, she quickly was able to fix them. She said, "I liked the computer because it helped me figure out which notes I needed to shift my finger a little for."

There were a few other participants who seemed to not notice their clashing dissonance when playing with the model, but like Julie, the visual feedback made them aware of their error, and most were able to fix the problem. It seems that just because students are unable to hear pitches that are up to a half-step out of tune, does not prevent them from playing in tune. The visual feedback helped participants realize they needed to move their finger. Once they got their finger to the place that resulted in a green highlight, they could do it. Perhaps many students at this intermediate stage of instrumental music rely more on physical cues (is my finger hitting the right place on the fingerboard?) more than aural cues (did that pitch sound in tune?) to play in tune. Perhaps this is out of necessity. If students cannot hear the difference between two close pitches, they need to use other senses to compensate (If I can't hear the difference to tell which is accurate, I better look to see (or feel) if the finger is in the right spot to make sure it is accurate). If the finger is in the correct spot it will be in tune, so they associate the spot with intonation rather than the sound with intonation. So, just because a student is playing in tune, it doesn't necessarily mean that they can hear that they are playing in tune. Many participants expressed uncertainty about whether or not what they were playing was correct. When they had the visual feedback to show them the green notes, they expressed an appreciation for the assurance that what they played was indeed correct.

Attentional cognitive resources

Many participants compartmentalized the music as they practiced. Instead of working on pitch and rhythm simultaneously, they worked on each in isolation. They often first worked on rhythm only, either clapping and counting or shadow bowing without pitches, or playing the rhythm on the pitches, without concern about whether or not the pitches were accurate yet. When they believed they had mastered the rhythm, they would then focus on the pitches, either playing one pitch at a time out of rhythm or attempting to keep the rhythm going while they put all of their attention on playing the correct notes in tune. They spent a great amount of time working out the rhythm and pitches separately when they had no scaffolds to assist them. However, even with the aural model, students requested multiple hearings so they could listen just to the rhythm in one hearing and then listen to pitch in the next hearing. Perhaps at this stage of their musical development, their capacity to attend to the multi-dimensions of music is more limited than that of a professional musician. Perhaps when students are focusing on rhythm, they effectively turn off their attention to pitch and don't hear it with enough attention that they are able to notice discrepancies. Vice versa, if they are placing their attention on pitch, perhaps they more easily miss rhythmic discrepancies. This could be a reason some students are unable to catch all of their errors.

One participant, we will call her Bonnie, stood out. Bonnie described her beginning musical instruction as aural based. Beginning in the Suzuki method, she was taught to sing everything before playing it, and preferred to hear the music first rather than read notation. In the control condition, Bonnie ended up with a negative SMPRA gain score, but self-assessed her progress as improving, working toward an aural goal image that did not reflect the music notation. However, when Bonnie had access to the aural model, her behavior was unlike any other participant. Bonnie listened to the model and then sang the melody accurately after each hearing. After singing the melody accurately, she played the melody on her instrument missing all the B-flats. Then she would sing the melody again, singing all the B-flats accurately, and then play the melody on her instrument playing B-naturals instead of B-flats. She was completely unable to hear the difference between her singing and her playing and thought they sounded the same. She did this same thing in the Model+Playback condition as well, not noticing even when hearing her playback that she played B-naturals instead of B-flats. When she got to the Model+Playback+Feedback condition and saw the computer screen highlighting all of the B-flats in red, she said, "I don't know why it counted all of my Bs wrong." She never figured out that she was playing B-naturals instead of B-flats.

Bonnie's case is interesting because she clearly had an accurate aural goal image in the conditions with digital scaffolds, because she was able to sing the melodies accurately and in tune. However, there was a disconnect when she played her instrument or heard her playback that prevented her from hearing the half-step differences in pitch. I was on the edge of my seat waiting to see which scaffold would provide her with enough information for her to catch her mistake, but none of the scaffolds provided what she needed to realize her error in playing. If she was unable to discern a pitch difference of a half step, would she be able to sing the melody in tune like she did? Perhaps when she was playing her instrument, her attention was on processes other than pitch discrimination, leaving her unable to catch her pitch errors. If that was the case, one would think she would hear the pitch errors when she listened to the playback of her performance, but since she only got one hearing of the playback, perhaps she was listening for rhythm instead of pitch. Bonnie's story illustrates that even when students have an accurate aural goal image they may still lack the ability to hear discrepancies in their own performance of the music.

Implications for Teachers and Students

The present study brought light to obstacles high school musicians face practicing independently. Specifically, they have difficulty audiating a goal image from written notation and detecting performance errors by ear. When I step into my own public-school orchestra classroom with this information, I have two objectives. First, I want to provide support to students so they can practice effectively at home while their aural skills are still developing. Second, I want to target the development of the specific aural skills needed for effective practice.

To provide support to students practicing at home, teachers can give students tools to check their answers. Teachers can post practice tracks on class websites, and students would be wise to use them when practicing at home to check that they are playing the music correctly. Hearing their part and being able to play along with it will likely eliminate some of the guesswork for students and help them practice more effectively, while their aural skills are still developing. Teachers can also assign home playing quizzes to be completed using computer programs like *SmartMusic* so students can practice with visual feedback when their teacher is not there to give them live feedback.

Perhaps an even more important objective for teachers is targeting aural skill development. Teachers can add opportunities in class for students to practice translating music notation into aural goal images when the teacher is there to give students live feedback. Students should start asking themselves, "Before I play this pitch, do I know what it should sound like?" And teachers can provide opportunity for students to practice singing notation first before playing it. For example, with flash cards students can sing the note name first then play the pitch. With sight reading exercises students can hum the pitch or phrase first before playing it. Teachers should continue to advocate for an aural skill development component to instrumental music curricula so students continue to develop their abilities of audiation and pitch discrimination necessary for fruitful practice.

Limitations and Recommendations for Future Research

The present study illustrated how aural models and visual feedback helped high school string students bridge the gaps in their aural skills to engage in fruitful practice. However, whether or not the use of aural models and visual feedback help students to improve their aural skills is beyond the scope of this study. In other words, the present study was an investigation of the short-term impact of practice aids on pitch and rhythmic accuracy growth, but this study was unable to tell us if using practice aids would actually help students improve their aural skills. Therefore, it would be interesting to see future research investigating the long-term effects of practicing with digital scaffolds (e.g., aural models, digital tuners) on aural skill development.

In light of the participants' descriptions of working with the playback in the present study, it seems that hearing their performance played back separately from hearing the aural model was not helpful. It would have been interesting to have played back the performance and the aural model simultaneously to see if that enabled the students to detect more errors by ear than they were able to detect in real time while they played along with the aural model. I would be interested to see a duplication of the present study that paired playback with the model simultaneously.

The measure of time spent working on a practice task was intended to measure practice persistence, with the idea that participants would spend as much time as they wanted working in each of the practice sessions. However, with limited time to get participants through the study, I had to set time limits and, on a few occasions, had to move participants on to the next practice session. Therefore, I was unable to use time data as anticipated leaving me unable to determine if digital scaffolds had any impact on the amount of time high school string players persist at a musical task. Future research examining the motivational effects of digital scaffolds may entail measuring the amount of time students practice at home with and without digital scaffolds.

The present study brought to light the use of visual feedback as a tool to enable musicians to articulate exactly what performance errors they were not able to hear. I believe this could be a tool in future research investigating musicians' error detection.

Participants could play something and then articulate all of the errors they heard in their performance. Then participants could look at the visual feedback to identify any additional errors they did not detect by ear. It would be interesting to gather data along those lines with beginning, intermediate, and professional musicians. This line of research may paint a clearer picture of the progression of aural skill development from novice to expert.

Conclusion

The present study began to unwrap the intricacies of the practice experiences of high school string players, providing a glimpse of the obstacles in their practice rooms as well as tools to help overcome those obstacles. Although aural skills are still developing, students struggle to audiate a goal image from written notation and detect performance errors by ear when practicing independently. Many musicians who make it through this period of aural skill development are often successful due to access to private music tutors who point out performance errors in one-on-one settings (Lehman, 1997). However, it has been my experience that many students learn to play an instrument in public school orchestral settings where large class size restricts the amount of individual practice feedback a teacher is able to provide. Many of my students are first generation violinists, violists, or cellists who do not have the luxury of parent musicians or the financial means for private music tutors. Aural models and visual feedback can help close the gap for students whose aural skills are still developing, unlocking the doors to fruitful practice for students like Emma who seek it.

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Appendix A: Institutional Review Board Approval Letter

Nebraska Lincoln

Official Approval Letter for IRB project #19121 - New Project Form

April 4, 2019

Brittany Rom
Glenn Korff School of Music
WMB 113 UNL NE 685880100

Brian Moore
Glenn Korff School of Music
WMB 358 UNL NE 685880100

IRB Number: 20190419121EP
Project ID: 19121
Project Title: Scaffolding Autonomy in the Practice Room: Exploring the Impact of Digital Scaffolds on High School String Musician's Self-Correction and Improvement of Pitch and Rhythmic Accuracy During Independent Music Practicing

Dear Brittany:

This letter is to officially notify you of the approval of your project by the Institutional Review Board (IRB) for the Protection of Human Subjects. It is the Board's opinion that you have provided adequate safeguards for the rights and welfare of the participants in this study based on the information provided. Your proposal is in compliance with this institution's Federal Wide Assurance 00002258 and the DHHS Regulations for the Protection of Human Subjects under the 2018 Requirements at 45 CFR 46.

o Review conducted using expedited review categories 6 & 7 at 45 CFR 46.110
o Date of Approval: 04/04/2019
o Date of Expedited review: 03/29/2019
o Date of Acceptance of Revisions: 04/04/2019
o Funding (Grant congruency, OSP Project/Form ID and Funding Sponsor Award Number, if applicable): N/A
o Review of specific regulatory criteria (contingent on funding source): 45 CFR 46
o Subpart B, C or D review: Subpart D, Research involving children, not greater than minimal risk approved under 45 CFR 46.404

You are authorized to implement this study as of the Date of Final Approval: 04/04/2019.

We wish to remind you that the principal investigator is responsible for reporting to this Board any of the following events within 48 hours of the event:
* Any serious event (including on-site and off-site adverse events, injuries, side effects, deaths, or other problems) which in the opinion of the local investigator was unanticipated, involved risk to subjects or others, and was possibly related to the research procedures;
* Any serious accidental or unintentional change to the IRB-approved protocol that involves risk or has the potential to recur;
* Any protocol violation or protocol deviation
* An incarceration of a research participant in a protocol that was not approved to include prisoners
* Any knowledge of adverse audits or enforcement actions required by Sponsors
* Any publication in the literature, safety monitoring report, interim result or other finding that indicates an unexpected change to the risk/benefit ratio of the research;
* Any breach in confidentiality or compromise in data privacy related to the subject or others; or
* Any complaint of a subject that indicates an unanticipated risk or that cannot be resolved by the research staff.

Any changes to the project, including reduction of procedures, must be submitted and approved prior to implementation. A change request form must be submitted to initiate the review of a modification.

For projects which continue beyond one year from the starting date, an annual update of the project will be required by informing the IRB of the status of the study. The investigator must also advise the Board when this study is finished or discontinued by completing the Final Report form via NUgrant.

If you have any questions, please contact the IRB office at 402-472-6965.

Sincerely,

Rachel Wenzl, CIP
for the IRB

Full Accreditation

Appendix B: MPS Request to Conduct Research Approval Letter

Millard
PUBLIC SCHOOLS

Don Stroh Administration Center · 5606 So. 147th Street · Omaha, NE 68137-2647 · (402) 715-8200 · (Fax) (402) 715-8409

To: Brittany Rom

From: Patricia Crum, Ed.D.
Department of Assessment, Research, and Evaluation

CC: Dr. Heather Phipps, Dr. Tony Weers, Andy DeFreece, Dr. Terry Houlton, and Dr. Darin Kelberlau

Date: February 22, 2019

Re: Request to conduct research in Millard Public Schools

In accordance with MPS Rule 6900.1, this notification qualifies as our approval for you to conduct research in Millard Public Schools **under the following provisions**:

- ❑ The principal agrees to your study.
- ❑ Students, parents, teachers, and principals are notified of their right to opt out of the study, any instrument(s) included in the study, or any item on the instrument(s).
- ❑ Your study follows the structure outlined in your request.
- ❑ Ensure data security (locked files and/or password protection) and to destroy all personally identifiable information from education records when the information is no longer needed for the purposes of this project.
- ❑ Please note conducting research does not override existing district or building rules and policies.
- ❑ Upon completion of the study, you will provide the principal and MPS Coordinator of Research Projects for Assessment, Research, and Evaluation with a summary of findings and, if applicable, a complete report of procedures and findings.

Thank you for completing the application process. We look forward to reading your results.

Patricia A Crum
Coordinator Research Proposals - Department of Assessment, Research, and Evaluation
Millard Public Schools

Appendix C: Parent Informed Consent Form

IRB# 20190419121EP
Date Approved: 04/04/2019

UNIVERSITY OF Nebraska Lincoln

PARENT INFORMED CONSENT FORM – Music Practice Study

IRB #: 19121

Formal Study Title: Scaffolding Autonomy in the Practice Room: Exploring the Impact of Digital Scaffolds on High School String Musician's Self-Correction and Improvement of Pitch and Rhythmic Accuracy During Independent Music Practicing

Authorized Study Personnel

Principal Investigator: Brittany A. Rom, MA Cell: (402) 679-7074

Secondary Investigator: Brian Moore, Ph.D. Office (402) 472-2537

Key Information: If you agree that your child may participate in this study, the project will involve:

- Males and females between the ages of 14-19
- Procedures will include practicing short melody tasks on violin, viola, or cello under 4 practice conditions (1-without technology, 2-with audio recording of the music, 3-with playback of participant's own performance, and 4-with color-coded assessment from a computer program)
- This study requires 1 visit that will take 1 hour total.
- There are no risks associated with this study
- Your child will NOT be paid for your participation
- You and your child will be provided a copy of the consent/assent form

Invitation: Your child is invited to take part in this research study. The information in this form is meant to help you decide whether or not they may participate. If you have any questions, please ask.

Why are is your child being asked to be in this research study?

Your child is being asked to be in this study because they are enrolled in a high school orchestra class. They must be 14 years of age or older to participate.

What is the reason for doing this research study?

This project investigates how high school string players experience practicing their instrument on their own, and whether or not technology can impact their experience practicing alone.

What will be done during this research study?

Your child will be asked to complete a practice session in a technologically-equipped practice room at school. The entire session will take approximately 40-60 minutes. Your child will be given a short line of music notation and asked to practice it for a few minutes on their string instrument (violin, viola, or cello). Your child will be asked to "think out loud" as they work through the music, while a video recording will capture their comments in real time as they practice. The practice session will be divided into 4 parts, each part consisting of practicing the music with a different technology (1-no technology, 2-with audio recording of the music, 3-with audio playback of the participant's own performance of the music, and 4-with color-coded assessment of the performance from a computer program). Your child will answer a few questions about their practice experience immediately after using each technology.

Appendix D: Youth Assent Form

IRB# 20190419121EP
Date Approved: 04/04/2019

University of Nebraska Lincoln

YOUTH ASSENT FORM – Music Practice Study

IRB #: 19121

Formal Study Title: Scaffolding Autonomy in the Practice Room: Exploring the Impact of Digital Scaffolds on High School String Musician's Self-Correction and Improvement of Pitch and Rhythmic Accuracy During Independent Music Practicing

Authorized Study Personnel

Principal Investigator: Brittany A. Rom, MA Cell: (402) 679-7074
Secondary Investigator: Brian Moore, Ph.D. Office (402) 472-2537

Key Information: If you agree to participate in this study, the project will involve:

- Males and females between the ages of 14-19
- Procedures will include practicing short melody tasks on violin, viola, or cello under 4 practice conditions (1-without technology, 2-with audio recording of the music, 3-with playback of participant's own performance, and 4-with color-coded assessment from a computer program)
- This study requires 1 visit that will take 1 hour total.
- There are no risks associated with this study
- You will NOT be paid for your participation

Invitation: You are invited to take part in this research study. The information in this form is meant to help you decide whether or not to participate. If you have any questions, please ask.

Why are you being asked to be in this research study?
We are inviting you to be in this study because you are enrolled in a high school orchestra class, and play the violin, viola, or cello.

What is the reason for doing this research study?
This project investigates how high school string players experience practicing their instrument on their own, and whether or not technology can impact their experience practicing alone.

What will be done during this research study?
You will complete a practice session in a technologically-equipped practice room at school. The entire session will take approximately 40-60 minutes. You will be given a short line of music notation and asked to practice it for a few minutes on your string instrument (violin, viola, or cello). You will be asked to "think out loud" as you work through the music, while a video recording will capture your comments in real time as you practice. The practice session will be divided into 4 parts, each part consisting of practicing the music with a different technology (1-no technology, 2-with audio recording of the music, 3-with audio playback of your own performance of the music, and 4-with color-coded assessment of your performance from a computer program). You will answer a few questions about your practice experience immediately after using each technology.