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Content-Dependent Behavior in Musical Practice

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Content-Dependent Behavior in Musical Practice

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Dissertation

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Doctor of Philosophy

The University of Texas at Austin

December, 2016

Dedication

I dedicate this to my family: Denita, Charlotte, Mom, and Dad; but also to David, Olivia-Beth, Yvonne, Colin, and the others who have become family. But I want particularly to remember my grandfathers, John and Paul, who demonstrated the joys of supporting and making great music, and to my mother, who held my nose to the grindstone during the critical years.

Acknowledgements

It of course takes a village to raise a thirty-something doctoral candidate. Many, many people have supported me through countless small acts over the past years; they will not find their names below, but I would like to first thank them for contributing to my life and education. I want to thank my family: Denita, Mom and Dad, Charlotte; my sisters, aunts, and uncles; and more—you know who you are. Betty Gehring, Bill Ickstadt, June DeForest, Danny Morgenstern, Dan Pritchett, John Bradford, Lee Shirer, Miguel Rosario, Dennis Friesen-Carper, and (though you will not read this) grandpas Paul Diko and John Strietelmeier—without you I would neither have thought about music as a career nor considered it as a viable option for a college major. I also want to thank my Austin family, especially Dave, Olivia-Beth, Colin, Yvonne, Bryan, and my Congregationalist friends, but including all those who have helped such a distant place become a true home.

Without my participants, this project would not have been possible. To those of you who gave your time and energies, and who allowed me to watch you engaged in some at times uncomfortable practice, I give thanks. I would also like to thank the people who participated in earlier projects of mine, but whose data did not make it into this book. Everything I learned from your efforts led to this project. Thank you to the people who helped me identify and recruit musician participants: Debbie and Stephanie Price, Susan Larson, Lani Hamilton, Eva van Houten, and the violin faculty at The University of Texas at Austin. Thank you also to my reliability judge, who dedicated precious summer hours to helping me complete this project.

Without the guidance of Dr. Laurie Scott, I might never have undertaken a Ph.D. program in the first place, let alone completed it. Dr. Robert Duke's guidance and insightful criticism has challenged me to become a clearer, more analytical thinker from the moment I began the program. Together with the other members of the Music and Human Learning faculty, these two individuals have changed the way I think and work.

Content-Dependent Behavior in Musical Practice

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The University of Texas at Austin, 2016

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Individual practice is the primary context in which musicians develop their musical and technical skills and learn new repertoire. The pedagogical literature (including books, websites, articles, and treatises) has treated the subject extensively, offering advice on how musicians should practice to optimize their efficiency. A central theme in this body of literature is the need to tailor one's approach to the specific challenges presented by the music; that is, to use different strategies to practice different kinds of problems.

Prior research in musical practice seeking to explore how student musicians regulate their behaviors during practice has examined students' knowledge and, to a limited degree, their use of specific behaviors. However, existing studies often rely on self-reporting or employ a case-study methodology. Studies that have used controlled observation to examine how and when musicians employ specific behaviors typically observe individuals working on a single example. These approaches preclude a direct comparison of whether or how musicians modify their practice behaviors in response to different types of musical material, nor do they allow for an examination of how any such modifications change as musicians develop expertise in the activity of practicing.

In the present study, violinists of three experience levels (high school, collegiate music majors, and professional) practiced three excerpts characterized by distinct technical challenges (string crossings, shifts, and syncopated bowing patterns). Results show that musicians do indeed selectively employ or omit certain practice behaviors in response to the material they are learning, apparently representing the modified approaches that many pedagogues prescribe. However, the rates at which participants employed these strategic behaviors were low; whether these behaviors are potent problem-solving tools that need only be applied sparingly or whether the behaviors were under-utilized is unclear. Musicians of different experience levels choose similar locations within the music to practice, suggesting that groups do not differ in the problems within the material they identified. However, between-group differences emerged in the use of specific behaviors, suggesting that musicians' ways of working on a particular problem changes as they gain practice experience. Less experienced participants were more likely than more experienced individuals to exhibit ratcheted practice, apparent attempts at extended or event complete performance trials interrupted by small backtracks, possibly representing in-the-moment error corrections.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

> There is nothing more precious to an instrumentalist than the ability to work efficiently—to know how to accomplish the maximum in beneficial results while using the minimum of time to do so. One of the most important things that a teacher ought to teach his students is, therefore, the technique of good practice. —Ivan Galamian (1985, p. 93)

> In every difficult passage, there is one element or more which accounts for its difficulty. . . Whatever the difficulty, it is the player's duty to discover and conquer it. —Phillip Farkas (1956, p. 45)

Musicians and their teachers understand that practice is essential. Practice is the primary mechanism for developing proficiency and improving abilities in musical interpretation, technical skill on the instrument or voice, or specific repertoire. As such, some pedagogues have devoted entire books to the topic (e.g., Carney, 1980; Fischer, 2004; B. Kaplan, 2004; Klickstein, 2009; Morganstern, 2002; Nardolillo, 2015; Westney, 2003; Wye, 2000). Other pedagogues have included chapters on practice in longer treatises devoted specifically to their respective instruments, or have interwoven commentary on practice throughout their works (e.g., Farkas, 1956; Galamian, 1985; Mozart, 1951). In addition to pedagogical advice, researchers in music education have investigated patterns of repetition (Maynard, 2000, 2006); self-regulation and cognitive knowledge of ways to practice, often called "practice strategies" (Barry, 1992; Cremaschi, 2012; Leon-Guerrero, 2008; Nielsen, 2001, 2004, 2008); and the relationships between practice behaviors and motor skill acquisition (Duke, Cash, & Allen, 2011; Duke, Simmons, & Cash, 2009; Duke & Davis, 2006; Simmons & Duke, 2006). Some research has also employed a case study approach to extensively analyze how an individual practices material over time, including changes in approach with improved knowledge of the repertoire (Chaffin & Imreh, 1997, 2001, 2002; Chaffin, Imreh, Lemieux, & Chen, 2003; Chaffin, Lisboa, Logan, & Begosh, 2009; Ginsborg & Chaffin, 2011).

Researchers from outside the field of music education have also developed an interest in music practice, particularly as an example of how people acquire expert-level skill. Famously, research suggests that individuals must accumulate approximately 10,000 hours of focused practice as a prerequisite to mastering a musical instrument, though other authors have stressed that sheer accumulated practice time is insufficient to explain individual achievement (Ericsson, 2008; Ericsson, Krampe, & Tesch-Römer, 1993; Hambrick & Meinz, 2011a; Hambrick, Pink, Meinz, Pettibone, & Oswald, 2008; Lehmann & Ericsson, 1997; Meinz & Hambrick, 2010). While it is clear that achieving high levels of musical skill requires a tremendous amount of experience, it is equally apparent that sheer accumulated time on its own does not explain individuals' different ability levels. On a single short-term task, practice time does not correlate significantly to performance results (Duke et al., 2009). Similarly, Madsen (2004) found that accumulated practice time also did not correlate strongly with long term career achievement, even though the participants in the study strongly believed that it did. Further complicating the relationship between practice and skill acquisition are factors beyond musicians' control, including heritable cognitive factors such as working memory capacity that could collectively be labeled "talent," that influence success and achievement levels (Hambrick & Meinz, 2011a, 2011b; Meinz & Hambrick, 2010). In their well-known hypothesis, Ericsson and colleagues specify that the approximately 10,000 hours of work needed to gain expertise in a field must be *focused* study, although they do not specify exactly what sort of work meets this description. Pedagogues themselves stress that simply logging time is insufficient. Galamian (1985) for instance repeatedly stresses the need for concentration, and suggests taking breaks or switching tasks to keep one's mind engaged. Likewise Hambrick and Meinz (2011b) explicitly state that they do not intend to deny the central role of practice in acquiring expertise and that their research demonstrates only that other factors also contribute to individuals' skill.

Researchers, musicians, and pedagogues agree that a tremendous amount of practice is needed to acquire expertise, even after including the caveat that other factors, including some stable and heritable traits that could be labeled "talent," also contribute to musicians' success. Yet studies investigating links between practice time and accomplishment on both specific tasks and long-term achievement have failed to show that practicing more leads to greater success. One can propose an explanation for this apparent contradiction using some of the principles of operant conditioning, a branch of behavioral psychology.

Musical practice is a complex series of goals, actions made in pursuit of those goals, and subsequent decisions about next steps. A hypothetical violin student who has been told to practice for 30 minutes may play various material, but make very few critical decisions. In this case, an individual may make little progress, while still feeling he has accomplished his goal of logging a set amount of time. A second student may practice for the same amount of time, but instead frame her goal in terms of learning some particularly difficult passage within the music. She chooses to pursue this goal by repeating the entire passage over and over again, and although this approach may work for some people, her performance after 30 minutes is not noticeably different from what it had been at the start. A third student spends her practice time attacking the same troublesome passage, but chooses to play well under tempo so that it is easier to execute, identifies the specific notes and transitions that cause the problems, and resolves those before returning to the whole passage, which is now easier to play correctly. A fourth student works on the same passage, but avoids playing the hard passage at all, precisely because it is frustrating. He spends a pleasant half hour sounding good on the rest of the material without achieving mastery of the entire passage because he has not made any improvements on its most difficult challenges.

Pedagogues might describe the first and last hypothetical students, the one who played mindlessly for 30 minutes and the one who avoided the material that needed the

most work, as being disengaged or not focused in their work; the middle two could be described as engaging in focused, concentrated practice. Behavioral psychology allows us to explore these hypothetical practice sessions in more detail. Operant conditioning defines rewards or reinforcements as experiences following a behavior, experiences that an individual perceives as (1) an outcome of the behavior and (2) more pleasant than the behavior itself, and therefore lead to more or more intense instances of the behavior in the future in order to obtain more reward (Domjan, 2005). Like rewards, individuals perceive punishments as resulting from the behavior, but experience these consequences as negative, resulting in fewer or less intense instances of the behavior in order to avoid further punishment.

If producing a pleasing sound and making progress are pleasant and rewarding experiences for students, while repeated failure is punishing, these four students' experiences within their practice sessions may train them to practice very differently in the future. The last student engaged in many instances of playing relatively easy material, and had a series of rewarding experiences sounding good. From this training, he will be more likely to practice in the future, but he will also be more likely to choose activities during practice that involve playing material he already knows he can play well, which might not be his teacher's idea of focused work. Students two and three have experienced the outcomes of identifying and practicing the material that causes them the most difficulties, precisely the sort of focused practice in which we want students to engage. Student three directly approached the most difficult material and experienced repeated rewards in the form of incrementally improved performances. She is likely to engage in these same strategies and behaviors again in the future. However, student two experienced a frustrating, punishing lack of progress as the outcome of her efforts, and she may perceive this punishment as a consequence of (1) her choice to just play it over and over without changing strategies, (2) her decision to play the hardest material, (3) practicing in general, or (4) playing the violin at all. Unless she happens to make the

rather sophisticated connection between her naïve approach to the difficult passage and the punishing results, she is more likely to avoid challenging material, or practicing at all, in the future. The first student, because he was only minimally engaged in making critical decisions within practice, is unlikely to associate his perceived outcomes with specific activities inside practice at all. Whether those outcomes are rewarding or punishing, and therefore whether he is more or less likely to practice in the future, depends on whether he feels rewarded by pleasing his teacher, he feels relieved to avoid getting a zero for the day's practice grade, or he feels punished by having missed half an hour of video game time.

Analyzed this way, practice is an activity composed of many discrete behaviors. Individuals may perceive reward and punishment at each step in the process, and they may perceive practicing as a whole as either rewarding or punishing. Experiencing reward on many specific behaviors may lead individuals to accumulate large amounts of practice, whether those behaviors represent "focused practice" that leads to increases in skill (breaking down the troublesome passage) or not (sticking to familiar material and avoiding the difficult music). Individual differences, possibly including personal tendencies to focus on details or individuals' working memory capacity, could influence how successful and therefore rewarding each behavior is. In particular, a different student might have experienced success using the second student's strategy of just repeating the hard material at tempo and might therefore be more likely to try that again in the future. This student might therefore practice as much and achieve similar results as student three did while using a very different approach, until one day encountering a passage too difficult even for an individual with her advantageous traits.

Viewing practice through the lens of operant conditioning suggests that individuals who are rewarded (including reward by perceived success) for specific behaviors in practice are more likely to engage in those behaviors in the future, and thus accumulate more practice time will than those who experience less reward or even

punishment. As such, they may be more likely to persist in music and gain expertise while accumulating a great amount of practice time. However, the specific practice behaviors that musicians have chosen in the past will vary among individuals; even when different individuals have tried the same practice behaviors, they may have experienced different outcomes for a variety of reasons, including stable individual traits, alertness levels on a particular day, or simply chance. Only those who persist in practicing and accumulate a significant amount of practice time can be expected to achieve expertise, but because of different past experiences, the specific behaviors that individuals engage in will vary even among individuals with comparable accumulated practice time. These learned patterns of behavior, together with individual strengths and weaknesses as well as the specific challenges of each new piece of material they learn, contribute to the amount of success that individuals have when practicing specific tasks in the future.

Exactly which practice behaviors prove beneficial to an individual may change over time. In the hypothetical example above, student three approached a challenging piece of material by playing at a slower tempo and isolating different material, while student two approached the same passage by playing it repeatedly at tempo. If hypothetical students two and three were to approach the same passage five years later, we might expect that because of their increased abilities, both would experience rewarding success by playing the entire passage several times, while isolating each detailed problem might be mildly punishing in its tedium while not producing noticeably more rewarding results. Similar effects have been seen in chess, where experts are able to perceive structures typical of the game at sight without needing to analyze them in greater detail (Chase & Simon, 1973; Chase, Simon, Collins, & Smith, 1988; Simon & Chase, 1973). This rapid, apparently automatic recognition may apply not only to the current strategic situation of the board, but also to the selection of subsequent moves. One-time world champion José Raúl Capablanca is reported to have claimed, "I see only one move ahead. . . but it is always the correct one" (Ross, 2006). His self-reported reliance on

immediate recognition may not have been entirely accurate, or his approach may have been idiosyncratic. More recent research shows that experts do think ahead, but they focus more on identifying weaknesses of their theories and strategies whereas less expert players look more for confirmation of their initial ideas (Byrne & Cowley, 2004). Either approach, however, suggests that chess players' approaches change as they gain expertise, and we might expect that as musicians become better and more experienced at practicing, their strategies and behaviors will shift as well.

When applied to practice, these ideas from behavioral psychology suggest that the specific behaviors or strategies that individuals employ during a given practice session not only contribute to the effectiveness of that session but also train the practice habits they will employ in the future. Individuals' experiences will train them to exhibit behaviors that lead to rewarding practice more frequently in the future, and to exhibit those behaviors that lead punishing practice experiences less frequently. However, the behaviors that a student perceives as rewarding may not be those that lead to effective, efficient learning, such as avoiding the difficult spots. At the same time, students who try practice strategies that might please a teacher, yet for one reason or another result in a negative experience (such as homing in on the difficult passage, yet being unable to master it) are likely to avoid those behaviors in the future. Moreover, the same approach may yield a different reward or punishment to different students or to the same student in different situations, such as different musical material or states of mental alertness. Over time, some students will have been trained by their practice experiences to practice rigorously for long periods, accumulating hours of experience, whereas others' negative experiences may have led them to avoid practicing or to quit their musical studies entirely. Of those students whose experiences have led them to engage in practice, some will have been reinforced in behavior patterns that allow them to rapidly and accurately learn new material, whereas others will have learned habits that do not allow them to accomplish as much in the same amount of time. Simply put, this analysis of practice

suggests that the relationship between practice time and accomplishment—in a single task, during a college semester, or over a career—is mediated by what musicians actually do with that practice time, and by how they perceive the outcomes of each individual action, and that these results are influenced in turn by circumstance and individual differences.

The pedagogical literature is laden with suggestions for how musicians should practice. Pedagogues assert that musicians should determine what types of challenges exist within the material they are trying to learn, and should tailor their approaches to these specific challenges (Farkas, 1956). Some teachers have even written entire volumes of practice ideas formulated as, "If your music presents challenge X, practice it using technique Y" (e.g., Fischer, 2004). If the relationship between practice and achievement is indeed similar to that described above, such an approach would make sense. The pedagogical literature, however, presents little evidence to support the idea that teachers actually observe students in the act of practicing to verify that (1) those students actually follow these suggestions, or that (2) those times when they make musical progress correspond with the times when they behave as suggested. Arguments from authority, even the suggestions of eminent pedagogues, should be examined with systematic research. Although vast, these experts' advice is rooted in anecdotal observation, and could be subject to confirmation bias. Expert pedagogues have been demonstrably inaccurate at times, even when their assertions represent the consensus in the field, as was the case with violinists' and violists' use of vibrato (Geringer & Allen, 2004; Geringer, Allen, & MacLeod, 2005; Geringer, MacLeod, & Allen, 2010; Geringer & MacLeod, 2009). And while experts may suggest certain ways of practicing, research suggests that far less lesson time is spent directly addressing the skill of practicing (as opposed to working with the outcomes of that practice) than either teachers or their students believe (Koopman, Smit, de Vugt, Deneer, & den Ouden, 2007). If teachers are not training their students to practice, students' accomplishments may have more to do with ways of

working that students have independently discovered than with their teachers' suggested approaches.

Unfortunately, the research literature contains surprisingly few analyses of what people actually do when they practice. Chaffin and colleagues have published several case studies of individual artists preparing pieces for performance (Chaffin & Imreh, 1997, 2001, 2002, Chaffin et al., 2003, 2009; Ginsborg & Chaffin, 2011). However, as case studies, these results are of limited use in assessing the validity either of pedagogues' specific assertions or of the broader picture of musical success moderated by accumulated individual practice experiences. Studies have used students' cognitive knowledge of, and self-reports of using various practice strategies as proxy measures for the connection between practice skill and achievement (Leon-Guerrero, 2008; Nielsen, 2001, 2004, 2008). Besides using the term "strategies" in slightly different senses (some authors use the term to mean specific behaviors to deploy like tools in response to the challenge at hand, others to describe broader traits such as focusing on the process versus the product), few of these studies actually observe practice, and instead often rely on surveys and self-report. Some studies have employed an experimental design, having participants practice the same material using different approaches (Barry, 1992; Cassidy, 1993; Killian & Henry, 2005). Observing different individuals practicing the same material, however, cannot address the fundamental assertion that musicians do or should vary their approach depending on the material they are trying to learn.

A few studies have indeed examined in detail the relationship between the specific behaviors musicians exhibit during practice and their subsequent performances. While finding no relationship between total practice time and performance outcomes, the highest-performing participants in Duke et al. (2009) shared a suite of practice behaviors; while other participants employed some of the individual behaviors, only those whose posttests ranked the highest displayed the entire set of behaviors in combination. Watching the instrumentalists' practice behaviors while memorizing an excerpt, Mishra

(2002) compared the behaviors of participants who accomplished the task in the least time with those who took the longest; again, a set of behaviors emerged that distinguished the work of the fastest learners from that of the slowest. Duke et al. (2011) employed an experimental design, cueing participants to practice while focusing on different aspects of their physical approach rather than examining the relationship between participants' freely chosen approaches and performance outcomes. Focusing on the performance outcome rather than the physical action required to effect that outcome led to better and more generalizable achievement, and the size of the effect increased as the focus of attention became more distant (fingers vs. keys vs. sound). These studies collectively support the idea that the specific behaviors people employ while practicing influence their performance outcomes. However, none of them examine whether individuals employ different approaches when working on different types of material, and none of them look at how those approaches change as participants become better and more experienced at practicing.

The pedagogical literature assumes that the nature of the musical material to be learned must influence the behaviors that one should use when learning that material, but the research literature provides little information on this assumption's validity. The lack of understanding of the mechanisms inside the blanket activity of practice leads to conflicting research results regarding the influence of accumulated hours of work on skill acquisition; when treated as a "little black box," practice's effects seem mysterious. The poorly understood relationships among engaged practice, individual differences or talent, and musical achievement sometimes lead to reports to the general public that portray the field as an oversimplified conflict, the classic "nature versus nurture" dichotomy (Hambrick & Meinz, 2011b).

Because of the relative paucity of research regarding the detailed relationship between practice behaviors and outcomes, I looked at theories of general human goal pursuit to seek support for the picture suggested by the operant conditioning model.

Action Identification Theory in particular suggested a structure of goals, actions, and proximal outcomes that might be used to inspect how musicians select next behaviors. This theory suggests that, although any action can be understood in several different ways (e.g., running a road race, keeping in shape, or avoiding *that* pothole), people actually perceive themselves to be doing only one of these things at any given time. People tend to settle on the broadest, most general view of their actions possible, which facilitates automated behavior (e.g., putting one foot in front of the other without conscious control) and provides meaning and context for their actions. At the same time, "the broadest view of their actions possible" is practically defined by problems that arise (e.g., tripping on a pothole directs a runner to focus on placing their next step). Because many actions can be understood as elements of two different broader actions (e.g., running a race could contribute both to staying in shape and to damaging one's knees), an episode leading an individual to focus on the details of one's actions can eventually lead to a new, different broad understanding.

Action Identification Theory seems to place great importance on structural moments, on the times when a person decides to change (or else seems to find himself changing) from one activity to another. I first attempted to see whether I could find evidence of the activity patterns this theory describes by engaging undergraduate and graduate musicians in an interview in which we examined their practice decisions in detail. They practiced their current repertoire on camera, then engaged in a two-part interview while we watched the practice session together. In the first part, they freely narrated what they recalled thinking during practice; in the second part, we re-watched a portion of the video while I asked them about their recollections in detail, probing every time I saw a change in behavior in the video that seemed to suggest they had made a decision.

Together with a broad research question (What are musicians thinking during practice?), this protocol proved too unfocused to yield demonstrable, convincing results.

Each participant worked on different pieces containing many different challenges, each brought with them different practice approaches and levels of prior learning on that piece, and it was unclear how accurately participants recalled their thoughts from many minutes earlier. Each practice session was simply too individualized to draw many conclusions about patterns across participants. In response, I designed a protocol that would examine an anecdotal observation I had made in the first study, that participants often engaged in behaviors that to me, as a teacher, seemed like poor retention strategies. In particular, after making a mistake (sometimes repeatedly) participants often performed a passage only once correctly before moving on; in interviews, participants frequently commented on the mistakes and problems, but corrections often elicited no comment. The participants seemed to be satisfied by achieving a correct performance, instead of treating individual correct trials as steps in building habits. In my next project, I attempted to directly compare participants' work when they focused explicitly on retention with their work in the absence of that goal. College level violinists practiced two excerpts; before their practice session on one excerpt, I told them they would perform it the next morning, but before the other practice session, I told them it was only for control, and they would only need to play it for me at the end of practice. Each excerpt was fairly difficult, because I wanted participants to feel sufficiently challenged to engage in the type of serious, concentrated practice typical of college music majors.

This experiment also failed to produce measureable results, primarily because of my attempt to present participants with sufficiently challenging material. It may or may not be the case that participants' beliefs about the need to retain their learning for delayed performances affected their work, but the effects of this cognitive cue were dwarfed by the problems inherent to the material itself. What observable differences in behavior did arise seemed to be functions not of the variable I was attempting to manipulate, but instead reflected the particular excerpt presented in each condition, as well as individual habits. In addition to the practical effect of thwarting my ability to determine if

participants practiced differently than in the control situation when they anticipated the need to replicate their results later, the failure of this experiment pointed back to the assumption behind pedagogues' practice advice: the nature of the material itself should dictate the approaches musicians choose when practicing. Even if the experiment had produced significant results, it would not have addressed this fundamental premise, nor would it have addressed whether practice behaviors change as musicians gain expertise. My focus in choosing excerpts for the second, experimental project had been to present two difficult pieces of material dissimilar enough to avoid crossover learning, not to present examples that clearly differed in their content. As such, I could not simply reanalyze the data I had collected.

Instead, I designed a new protocol designed to directly answer these fundamental questions. Participants in this study were violinists in three groups: high school students, professional musicians, and college students (including graduate and undergraduate students). Each participant engaged in three practice sessions, and learned a different excerpt in each session. Within a session, the participant practiced one excerpt for 10 minutes, then performed it three times. I composed the excerpts for the present study, and each excerpt featured a distinct primary musical challenge typical of violin repertoire. One focused on string crossings, repeatedly moving the bow and, when necessary, the fingers of the left hand, among the instrument's strings. Another focused on shifting, repositioning the left hand and arm along the fingerboard. The third excerpt featured patterns of slurred notes (notes that are executed with a single bow stroke) that did not line up with the beat. Because any piece of music necessarily includes many potential variables in execution and interpretation, the excerpts were not precisely matched in difficulty, but they were all comparable to the challenges found in standard etude books (Dont, 1968; Gaviniès, 1963; Rode, 1962). Similarly, technical challenges overlap in musical material; for instance, any passage that features slurs must either also include string crossings or shifts, or else limit itself to a maximum range of a fifth, in which case

it may feel musically artificial or prove too easy to warrant serious practice. Slurs often become difficult only when present in combination with other factors. The excerpts in this study thus also include several musical and technical factors, but each is characterized by a different signature technical challenge. Armed with recordings of participants at different experience levels practicing three qualitatively different types of music, I analyzed their practice behaviors to answer two questions essential to understanding how musical practice builds expertise:

1. Do musicians use different behaviors to practice material presenting qualitatively different challenges?
2. If so, do musicians' approaches to the same type of challenge vary as a function of their experience level?

Chapter 2: Review of Literature

Acquiring mastery of a skill as broad and complex as playing a musical instrument depends on a range of factors. Great teachers guide and shape their students' efforts and careers, serving as models of excellent musicianship as well as incisive, persistent, and supportive critics (Duke & Simmons, 2006; Sand, 2000). Individuals' "talents" or cognitive profiles, including abilities such as working memory capacity, clearly contribute to their successes (Hambrick & Meinz, 2011a, 2011b; Meinz & Hambrick, 2010). But even individuals with advantageous traits must develop their specific knowledge of music and of performing on their instrument. Music is one of the skill sets supporting the famous theory that individuals require 10,000 hours of focused practice to develop expertise in their field (Ericsson et al., 1993; Lehmann & Ericsson, 1997). Individual practice is commonly considered the most important factor contributing to musicians' development and success, because it is the setting in which individuals focus on the development of their domain-specific musical and technical skills, using any talent, individual cognitive traits, or prior experiences at their disposal.

Music students, their teachers, and the professional community have access to several sources of information regarding this central activity in their lives. A body of pedagogical literature from eminent performers and teachers extends back centuries. Some of these experts have written chapters or segments about practice within broader treatises focused specifically on their instruments (Auer, 1980; Farkas, 1956, 1976; Galamian, 1985; Mozart, 1951). Others have written books devoted specifically to practice; some even take the form of a troubleshooting manual, matching specific problems to proposed solutions (Carney, 1980; Fischer, 2004; Klickstein, 2009; Morganstern, 2002; Nardolillo, 2015; Westney, 2003; Wye, 2000). State and national professional organizations publish journals frequently containing articles that include practice ideas, as do unaffiliated magazines such as *The Strad*. Many of these traditional

print media now frequently publish similar pieces online (Editors of The Strad, 2014; Hahn, 2004; Owen, 2015; Rosand, 2014; Ševčík, 2014). The past few decades have also seen the emergence of blogs and online videos in which teachers and performers distribute ideas about practice and other musical topics, as well as forums and discussion boards where users exchange ideas among themselves (Blackerby, n.d.; Deverich, n.d.; Niles, 2011; O'Connor, n.d.; Thomsen, 2011).

In addition to pedagogical advice and practice ideas in print and online (including both expert-driven and "crowd-sourced" resources), researchers in music education have examined practice from a variety of perspectives, as have investigators in other fields for whom music practice provides one example of a more general topic. Researchers have examined the relationships among various aspects of music learning and performance, sheer aggregated practice over a variety of time scales, the environments that foster young and developing musicians, and the impact of apparently stable traits that may represent what is colloquially called "talent" (Coyle, 2009; Duke et al., 2009; Ericsson et al., 1993; Gromko, 2004; Hambrick & Meinz, 2011b; Lehmann & Ericsson, 1997; Madsen, 2004; Meinz & Hambrick, 2010). With the understanding that music practice involves decision making, researchers have explored the relationship between self-regulation and practice behaviors (Miksza, 2006, 2011, 2012; Oare, 2012; StGeorge, Holbrook, & Cantwell, 2012). A growing number of studies have examined the behaviors that musicians of different levels and across a variety of instruments employ while practicing (Bartolome, 2009; Clark, 2013; Dakon, 2013; Duke et al., 2009; Maynard, 2006; Miksza, 2007; Rohwer & Polk, 2006). Other studies have investigated aspects of music learning as they relate to current topics in the psychology of learning, including motor control, offline memory consolidation, and focus of attention (Cash, 2009; Cash, Allen, Simmons, & Duke, 2014; Duke et al., 2011; Schoonderwaldt & Altenmüller, 2014; Simmons, 2012; Simmons & Duke, 2006; Stambaugh, 2011; Stambaugh & Demorest, 2010).

A wealth of more general information about how people learn, gain domain-specific expertise, and engage in goal-directed activities is available to inform our understanding of how musicians practice and learn. Besides music, studies in fields such as chess have examined the differences between how experts approach problems in their field, how these approaches differ from novices' responses, and situations that show limits to experts' application of their knowledge (Byrne & Cowley, 2004; Chase & Simon, 1973; Chase et al., 1988). Music learning researchers have already begun to explore the relevance to musical practice of phenomena related to motor skill learning that were first identified in the development of sporting expertise, such as the impact of distal versus proximal targets and the role of variable practice (Duke et al., 2011; Greenhall, Domingues, & Cavazos, 1994; Simmons, 2007, p. 200; Wulf, 2007a, 2007b). In the broader area of decision making in goal-directed activities, a considerable body of research has grown describing how external and internal feedback from the environment (i.e., perceptions of success, failure, progress, or the lack thereof) affects individuals' subsequent behaviors in pursuit of a goal (Aarts, Custers, & Marien, 2009; Aarts, Custers, & Veltkamp, 2008; Dijksterhuis & Aarts, 2010; Vallacher & Nowak, 1997; Vallacher & Wegner, 1987; Wegner, Vallacher, & Dizadji, 1989; Wegner, Vallacher, Macomber, Wood, & Arps, 1984).

Efficient practice—practice that accomplishes maximal change in subsequent performances in minimal time—is a goal for performing musicians, pedagogues, and their students. By exploring self-regulation and the specific behaviors that musicians engage in, the studies referred to above acknowledge that deciding what to do next is a central aspect of learning how to practice. Noted horn pedagogue Philip Farkas explicitly stated that every difficult musical passage has a defining feature, a specific aspect of the music that accounts for or creates the difficulty, and the musician's task is to identify and then master that challenge (Farkas, 1956). The entire field of goal-directed activity concerns itself with the structure of perceptions and related actions that individuals

engage in while pursuing goals. This structural aspect of goal-directed behavior is central in both the pedagogical music literature and Action Identification Theory, a subset of the literature on goal-directed behavior (Farkas, 1956; Fischer, 2004; Nardolillo, 2015; Vallacher & Wegner, 1987). That is, both the advice of musical pedagogues and the literature on goal-directed behavior agree that individuals must modulate their actions and behaviors in response to the challenges they face; a behavior or way of practicing that accomplishes a great deal in one setting may be ineffective in, or inappropriate to, another context. An effective way to practice phrasing in a slow, lyrical passage may not help at all in mastering a faster technical passage, and two technical passages with very different inherent challenges may require equally distinct approaches.

To date, however, the music education research literature has not addressed this issue. While many studies have examined the behaviors in which musicians engage, few have engaged participants in multiple kinds of learning situations to explore the contrasts between how they work on qualitatively different kinds of material. Of those that have, the primary research mode has been the case study, which is difficult to generalize to other individuals (Chaffin & Imreh, 1997, 2001, Chaffin et al., 2003, 2009; dos Santos & Hentschke, 2010; Miklaszewski, 1989; Nielsen, 2001), whereas others have focused on only one type of behavior (Maynard, 2000, 2006). Moreover, just as experts in chess perceive and respond to meaningful structures in their domain differently than do less-skilled players, one would expect that as musicians' practice skills increase, their ways of dealing with different kinds of problems would change as well.

The present study asks these two questions: Do musicians' indeed modulate their practice behaviors in response to challenges inherent to the material they are learning, and if so, do these response patterns vary between musicians of different expertise levels? All three types of background literature described above—pedagogical recommendations, findings from research in music education and psychology, and more general

psychological topics that relate to musical practice—help inform our current understanding of the questions.

THE PEDAGOGICAL LITERATURE

One of the most famous violin teachers in the world in his era, Leopold Mozart (father to composer Wolfgang Amadeus) addressed practice in his work *A Treatise on the Fundamental Principals of Violin Playing* which was "for long the only Method for the violin" (Grove, 1880, p. 379; Mozart, 1951). Using such phrases as, "Here are the pieces for practice," "Diligent practice. . . will be useful," and "I will here set [this exercise] down for practice," he presents etudes exemplifying the types of technical skills professional violinists must be ready to execute (Mozart, 1951, pp. 88, 131, 155). That is, he couples achievement or mastery targets with representative music examples; he does not, however, devote much attention to the matter of how to approach those examples. If a student were to practice the examples in Mozart's book but experienced difficulty in mastering them, the author provides little guidance with regard to subsequent steps or methods to improve execution.

Mozart's treatment of practice is similar to many subsequent pedagogical works in that he primarily discusses what kind of materials to practice and what skills are expected of an accomplished player, but fewer details about how to master them. Like the exercises the elder Mozart presents, the body of etude books available to teachers and students of any instrument instantiate the challenges to be mastered. Few of them, however, spell out exactly which of the many kinds of challenges present in each example are intended as that etude's focus, or how to work on them, perhaps relying on a teacher's explanation, the student's analytical skills, or the material's self-evident nature. (A notable counterexample is the footnote to the first exercise in Schradieck (1986), which reads, "The pupil should be careful in all the exercises to keep the hand perfectly

quiet, letting the fingers fall strongly, and raising them with elasticity. The tempo must be lessened or accelerated, according to the ability of the pupil, but is generally moderate.") Many pedagogues recommend a practice routine, a schedule of the sorts of activities to be practiced each day, including warm-up activities, scales and technical etudes, performance repertoire, and sometimes instrument-specific activities (Farkas, 1956; Lewis, 2003; Mozart, 1951; Wye, 2000). Some even include detailed descriptions or actual transcriptions of a warm-up routine (Farkas, 1956; Morganstern, 2002).

Other pedagogues organize their division of practice time differently, discussing different modes of activity that should occur within a practice day rather than the specific order of materials to be practiced. Galamian (1985) suggested organizing one's work into three different sections that he called "Building Time" (focusing on technical growth and specific challenges, often accomplished through scales and etudes), "Interpreting Time" (planning and practice of musical ideas), and "Performing Time" (integrating work done on technical details and musical intent into context). Kaplan (2004) likewise recommends organizing one's thinking around the mode of activity rather than the material and goes into greater detail, specifying several types of work in the place of Galamian's "Building Time" (e.g., new repertoire, new skills, refinement and revival of old skills). However, whereas Galamian advocates organizing one's practice time into these categories, Kaplan treats them as a method of organizing one's thinking and suggests that all practice should be saturated by these different modes of activity. In fact, Kaplan only advocates strict adherence to a particular practice schedule when engaging in a procedure intended to diagnose one's own ability to manage one's practice time.

The flexibility that Kaplan and Galamian recommend seems to contradict the more rigid regimens prescribed by Farkas, Wye, and others. Other pedagogues offer yet more variations. For instance, while abstaining from specifying an overall order for a cellist's practice session, Morganstern (2002) suggests beginning work on each particular passage or excerpt with not one, but several in-context performances, preferably with

recorded accompaniment. He suggests that these multiple, preemptive in-context performances can help musicians recognize problems in advance and resolve them without isolation.

These multiple, sometimes conflicting analyses of how musicians should organize their practice may reflect professional disagreements or may represent instrument-specific considerations. However, each author also highlights why they recommend one routine over another, or alternatively prefer to analyze one's general approach without prescribing an order. Some authors emphasize the importance of routine or of ensuring reliable practice of particular skills, whereas others believe that musicians need to think about their own strengths and customize their schedule accordingly. For each activity in which one engages, there must be a purpose, and pedagogues' choices about whether to prescribe a particular sequence or not reflect their judgments intended to ensure that students' activities address all of the important purposes of practice.

I describe all of these pedagogues' suggestions for organizing and thinking about one's practice routine as different ways of ensuring that the musician always practices to highlight a point in which the pedagogical literature is in explicit agreement: practice must always be focused. Mozart (1951) not only presents etudes for study, he also specifies that the pupil's study of these materials must be diligent. Farkas (1956, p. 45) begins to characterize what this diligent, focused work entails: "In every difficult passage, there is one element which accounts for its difficulty. . . Whatever the difficulty, it is the player's duty to discover and conquer it." Likewise, Galamian (1985, p. 99) explicitly states that engaged practice involves finding the connection between the intended goal and a way of working on it:

> Wherever technical problems are encountered, they must be analyzed to determine the nature of the difficulty: intonation, shifting, rhythm, speed, a particular bowing, the coordination of the hands, and so on, or a combination of several of these. Each difficulty should be isolated and reduced to its simplest terms so that it will be easier to devise and to apply a practice procedure for it.

These directives specifically address the questions of the present study, of how musicians customize their behaviors in response to the challenges endemic to the music itself. Kreitman (1998), Wye (2000), and others similarly characterize effective practice as locating and solving individual problems. However, while their varying prescriptions demonstrate that each pedagogue has considered the many specific challenges that musicians must master, broad prescriptions do not describe the process of how musicians might discover what problem they are encountering in any particular instant and, having diagnosed the problem, how they might go about conquering it.

Other pedagogical resources address themselves more specifically to this point. Westney (2003) emphasizes that errors are valuable sources of information, and that effective practice depends on recognizing what each mistake reveals about the details of the related challenge (going so far as to name the book *The Perfect Wrong Note*). Kaplan (2004) outlines a systematic approach to diagnosing problems. Several recent books take a form similar to a trouble-shooting manual, organizing exercises and examples around the troubles they are intended to solve (Fischer, 2004; Kaplan, 2004; Nardolillo, 2015). Online resources have proliferated in recent years, and many of them take forms such as discussion forums wherein users can discuss specific problems, read articles and watch videos addressed to specific skills, and examine experts' presentations of one or another of their practice habits (Blackerby, n.d.; Editors of The Strad, 2014; Hahn, 2004; Niles, 2011; Owen, 2015).

These resources provide much guidance for players, students, and teachers, but few if any of them are rooted in organized research. Instead, many of the online materials are better characterized as collections of anecdotal observations, as techniques that have worked for one individual. The recommendations of renowned pedagogues (published or online) rest on years of experience training successful students, but they too are based on anecdotal observations that are typically collected informally. Such evidence presents a number of problems. Teachers know what they have assigned their students, but these

pedagogical works present little evidence demonstrating the extent to which students follow that advice when practicing, or whether the practice time spent engaged in assigned activities is indeed the time that leads to the greatest student progress. Students may simply figure out their own individual approaches, and even Farkas (1956, p. 30) acknowledged that basic repetition is the musician's "principal means of learning." Anecdotal evidence is subject to confirmation bias; teachers and musicians alike may remember the times when the recommended approach preceded massive learning gains while neglecting the times that using these strategies proved less effective. Moreover, even some of the world's most respected teachers' analyses are at times simply incorrect. For instance, many in the violin community assert that the perceived pitch of a note played with vibrato corresponds to the maximum rather than the mean of the oscillating fundamental frequency (Galamian, 1985; Nardolillo, 2015). This would mean that to be perceived as playing in tune, a musician should apply vibrato that begins at the intended pitch and then bends exclusively to the flat side. This myth persists in current publications, despite research demonstrating that it simply not the case. Humans do perceive the mean fundamental frequency as a note's true pitch, and performers ranging from students to concert soloists actually execute vibrato around rather than below the intended pitch, regardless of their beliefs to the contrary (Geringer & Allen, 2004; Geringer et al., 2005, 2010; Geringer & MacLeod, 2009).

Finally, even if pedagogues were completely accurate in their analyses of how musicians and music students should work on different types of material, systematic observations of private lessons suggest that teachers focus on what material to practice and what changes to make, but devote little explicit attention to teaching their students how to practice, how to effect these changes in the assigned music (Baughman, 2015; Koopman et al., 2007). The literature in music education research, however, has begun to explore how musicians and music students actually solve the specific problems they

encounter in the repertoire and the extent to which their approaches reflect the suggestions and assertions found in pedagogical sources.

RESEARCH ON PRACTICE

The idea that a vast amount of accumulated, deliberate practice is a fundamental prerequisite to developing expertise has emerged from research in several complicated domains of human performance, including chess and music performance (Ericsson, 2008; Ericsson et al., 1993; Lehmann & Ericsson, 1997; Simon & Chase, 1973). As a result of a series of books and articles intended for lay audiences, the theory that 10,000 hours of practice is the key to achieving expertise has become famous among the general public (Carter, 2014; Coyle, 2009; Gladwell, 2011, 2013). Ericsson has taken issue with the popular press's oversimplification or even misrepresentation of the research that he and others have performed. Objecting that popular authors treat the figure of 10,000 hours as a "magic number" rather than an average of the best performers' accumulated work, Ericcson (2012, p. 3) complains, "Gladwell (2008) does not even mention the concept of deliberate practice." Perhaps in response to the popular press surrounding the idea of expertise arising primarily as a function simply of practice, much recent research has highlighted the roles of other factors in determining individual skill, including the age at which individuals begin study (accounting for co-variation with accumulated practice) and stable cognitive traits such as working memory capacity (Campitelli & Gobet, 2011; Hambrick & Meinz, 2011a; Hambrick et al., 2008; Meinz & Hambrick, 2010).

The apparent conflict between these two positions—either that skill is fundamentally rooted in individuals' practice and hard work, or that it is primarily a function of historical or genetic factors beyond their control—has made the debate exceedingly popular in the press (Bennett, 2014; Carter, 2014; Hambrick & Meinz, 2011b; Stetka, 2014). However, despite the press's frequent presentation of the topic as a

dichotomy, researchers actually agree that complex relationships exist among (a) an individual's current skills and interests (including possibly innate abilities), (b) accumulated practice and its character, and (c) achievement in the field of study (Ericsson, 2008, 2012; Meinz & Hambrick, 2010). Meinz and Hambrick (2010) acknowledge this complexity explicitly, titling their paper "Deliberate Practice Is Necessary but Not Sufficient to Explain Individual Differences in Piano Sight-Reading Skill." Even Gladwell (2013) objects to the oversimplification of the relationship between expertise and practice:

> In cognitively demanding fields, there are no naturals. Nobody walks into an operating room, straight out of a surgical rotation, and does world-class neurosurgery. . . I was interested in the general finding, which was that the best violinists, on average and over time, practiced much *more* than the good ones. In other words, within a group of talented people, what separated the best from the rest was how long and how intently they worked [emphasis original].

It seems that despite how findings are reported to the general public, researchers agree that skill arises from the interplay of factors beyond individuals' control—hereditary contributions, early informal learning, the age at which they began formal study—and deliberate, focused practice. Given that a musician, student, or teacher has little or no ability to alter the first group of factors, what do we know about accumulated practice? Ericsson et al. (1993) found that expertise on piano- and music-related motor skills—but not on unrelated cognitive motor skills—correlates strongly with the amount of cumulative time an individual has spent engaged in deliberate practice. Similarly, this group found that violinists nominated by their conservatory faculty as having the potential to become international soloists ("best violinists") had accumulated more lifetime practice hours than those nominated only as good players, and that those good players had in turn accumulated more practice than violinists from the institution's music education department. However, the specific amount of accumulated practice time that different individuals require to achieve a given level is highly variable (Campitelli & Gobet, 2011; Hambrick & Meinz, 2011a, 2011b; Meinz & Hambrick, 2010).

At smaller time scales, Jørgensen (2002) found a positive relationship between the amount of time vocal, instrumental, and church music students spent practicing per week and scores on major examination recitals. A positive relationship between exam score and consistency of practice (number of days per week in which at least 30 minutes were devoted to individual practice) existed for instrumentalists, but not for vocalists or church musicians (who were considered separately from other instrumentalists). In contrast, a 30-year follow-up study found no correlation between the time that students recorded practicing while in college and the level of professional success that they achieved in their later careers, despite participants' belief that such a relationship existed (Madsen, 2004; Madsen, Greer, & Madsen, 1975).

At an even finer level, Duke et al. (2009) found no correlation between collegiate and graduate student pianists' amount of practice of a brief, difficult excerpt (measured either in terms of repetitions or time spent) and scores on a next-day retention test. Instead, the manner in which participants used whatever amount of time they took seemed to be the most relevant factor. A suite of three particular strategies or behaviors (accurately identifying and fixing errors, varying the tempo in a systematic way, and practicing trouble spots until the problem no longer presented itself in subsequent work) was present in combination only in the practice sessions of the top three performers on the retention test. Strong correlations were also present between performance rank and the percentage of trials during practice that were both completed and correct or near-correct, and inverse correlations between performance rank and incorrect practice attempts. That is, the best performers' practice may be indistinguishable from others' practice in terms of how long it lasts or how frequently the musician plays either entire passages or isolated excerpts; however, during effective practice, when musicians played complete trials, they were more likely to do so correctly.

These results suggest that, at least in a single practice session, the practice that leads to the best results is characterized by behaviors that limit mistakes and that facilitate

the identification and elimination of those errors that do occur. Maynard (2000, 2006) identified more than twice as many specifically targeted problems in the routine practice of artist- and graduate-level musicians than in undergraduate players' work, suggesting that individuals' tendencies to focus on such specific problems increase with experience. To the extent that isolating a specific problematic location enables the individual to avoid mistakes or prevent their recurrence, it can be considered a strategic behavior that promotes efficient learning, that is, lasting improvements in performance execution. Hallam (2001a, 2001b) likewise found a positive correlation ($r = 0.69,\ p = 0.001$) between participants' experience levels and their use of strategies labeled as highly sophisticated; professional participants' strategic decisions, for instance, reflected great awareness of their own strengths and weaknesses.

These findings contribute to a growing number of studies that suggest that self-regulation—the ability to monitor and adjust one's activity in response to the demands of the situation—is a critical skill that develops with musical experience (Austin & Berg, 2006; Christensen, 2010; McPherson & Renwick, 2001; Miksza, 2006, 2011, 2012; Mishra, 2002). Supporting the notion that strategy use is at least partially a function of experience, beginning students seem to know a relatively small number of practice approaches, and to actually use even fewer for these strategies (Christensen, 2010; Pitts & Davidson, 2000). Some of these studies, however, define *a priori* which behaviors to consider sophisticated and which less so. Interestingly, Hallam (2001a) found stronger correlations of high-level, sophisticated strategy use with experience level ($r = 0.69$, $p = 0.001$) and with age ($r = 0.56, p = 0.001$) than with the overall performance score that participants earned ($r = 0.44,\ p = 0.01$). Out of seven subcategories in which these students were scored, scores correlated more strongly with participants' experience level than with the sophistication of the strategies they used, and in the remaining two categories, only the correlations with experience level reached statistical significance. Experienced musicians with sophisticated practice skills also tend to incorporate

interpretive, musical (rather than purely technical) considerations into their practice earlier and more often than other musicians, whether or not they are aware of it (Chaffin & Imreh, 2001; Duke et al., 2009; Hallam, 2001a). Using sophisticated strategies may indeed help musicians master the difficulties in their music, but even more so, these behaviors may simply reflect the way that more experienced musicians practice, whether or not the behaviors lead to improved performance in any particular instance.

The recurring finding that high-level strategies or groups of specific behaviors are indeed associated with improved performance outcomes, together with the increased sophistication of the behaviors that musicians display as they gain experience, seems to provide functional definitions for the kind of focused work specified by pedagogues. These findings may also help define the focused nature of the accumulated practice that Ericsson and colleagues, Chase and Simon, or popular authors such as Gladwell suggest is a prerequisite to expertise. But so-called practice strategies' stronger associations with age and experience than with performance scores in Hallam (2001a) suggest that the particular behaviors in question may also be habits typical of advanced practice more so than they are individual, considered applications of an effective tool to effect change. That is, some of these behaviors may lead to improved performance less reliably than expected, but because of their prior experiences, advanced musicians become trained to use them.

Although Cavitt (2003) examined interactions between band teachers and students rather than individual practice, her findings suggest that musicians do indeed behave differently on a variety of measures when they work on different kinds of material. During periods of rehearsal that addressed qualitatively different errors (e.g., pitch, rhythm, etc.), different rates of teacher talking and modeling, student performance attempts, approximated performances that differed from the final version in a critical aspect (such as clapping rather than playing the music), and other rehearsal behaviors were observed. These data demonstrate that music teachers modify their approaches

when correcting students' errors as a response to the nature of the problem, much as pedagogues suggest individual musicians should do. However, the differences between ensemble instruction and individual practice are substantial. In an ensemble situation, the conductor—a relative expert in the classroom situation, and a specialist in group performance and interpretation even in the professional world—evaluates others' performances, while in individual practice, a single person fills both roles. In students' practice, that individual is a novice both musically and technically, and their abilities both to diagnose a problem and to prescribe a solution may be questionable. Moreover, the interactive nature of group rehearsal naturally segments behaviors into discrete groups separated by articulated directives, a behavior pattern that need not be present in individual work. Perhaps musicians engage in such discrete units of work, perhaps they do not, or perhaps this varies across a practice session; without the need to articulate an objective for the next period of work to other people, musicians may or may not analyze each attempt's successes or form definite plans for the next one. Although the findings of this study certainly support the idea that musicians vary their approaches in response to specific problems, they are not definitely applicable to private practice, and provide no information about how these behaviors may change with experience.

There is considerable variability in the specific kinds of behaviors that different authors consider when reporting on practice strategy use. Maynard (2000, 2006) focused primarily on the specific locations within the material that participants chose to repeat. Studies examining self-regulation report on a wide range of behaviors in young students, including time allocation (warming up and reviewing older music, as well as when and on what days to practice), cognitive skills (e.g., thinking about lessons from class, focusing on difficult sections, and learning one section before continuing to the next), and more discrete behaviors (e.g., playing under tempo, asking for advice from teachers, fingering without blowing, and using a metronome) (Austin & Berg, 2006; Bartolome, 2009). Duke et al. (2009) found that behaviors such as pauses at critical points and

appropriate choices of tempo function to mitigate, correct, and preempt, errors in the practice of the best-performing participants, demonstrating how advanced students leveraged these self-regulatory skills (including accurate assessment of their own prior efforts).

Many of these studies employ interviews and self-reports to collect their data, introducing the additional concern about the accuracy of participants' own recollections of and beliefs about their practice habits (Austin & Berg, 2006; Bartolome, 2009). Expert musicians' reports about their own practice behaviors sometimes diverge from what they actually do; likewise, even when teachers and students agree about how frequently some topics arise in lessons, observers at those lessons sometimes find that both groups overestimate that rate (Chaffin & Imreh, 2001; Koopman et al., 2007).

Other researchers have experimented with specific practice interventions. Cash (2009) found that introducing rest early and late in the practice session led to significant gains in performance of a short piano sequence, but that early rest stages were particularly useful in facilitating learning later in the practice session and in retaining that learning, or even improving, overnight. Distributing practice across multiple days, including sleep intervals, seems to facilitate acquisition and retention of the motor patterns that musicians acquire as part of learning a piece (Simmons, 2012; Simmons & Duke, 2006). Consistent with findings in other kinesthetic domains, musicians demonstrate greater performance gains when they focus on the outcomes of their actions rather than on the actions themselves, and a more removed, abstract target (e.g., the sound produced) is more effective than a more concrete one (e.g., the piano keys) (Duke et al., 2011). Listening to a model recording as part of practice can significantly improve rhythmic accuracy and the eventual performance speed gained over a practice session (Cash et al., 2014; Henley, 2001; Rosenthal, 1984). However, although in some studies participants in groups receiving an intervention out-performed control participants, measureable differences in performance rarely arise between one detailed, specific

intervention and another (Cassidy, Betts, & Hanberry, 2001; Henley, 2001; Kostka, 2000; Rosenthal, 1984; Rosenthal, Wilson, Evans, & Greenwalt, 1988; Sikes, 2013). That is, interventions that lead to significant improvements tend to be general strategies, such as structuring one's practice, beginning the practice session with a clear idea of the intended aural outcome, and focusing on that sonic product while playing. However, while giving musicians detailed, prescribed ways to pursue these goals may in some cases lead to better outcomes than no instructions at all (possibly by providing young musicians who lack self-regulatory skills with any form of plan), when one specific strategy or practice method is pitted against another, it is rare for one to emerge as superior.

Research examining musicians' practice behavior suggests that sophisticated practice strategies characterize the practice of advanced musicians, while less experienced musicians display fewer of these strategies. Sophisticated practice strategies, in fact, appear to be more strongly associated with expert practice than with performance gains in specific instances. When put to use by individuals whose performance is superior to other musicians, these behaviors allow the individual to avoid and effect lasting changes in their execution of the material—to actually solve problems such that errors do not recur, rather than merely "erasing" a mistake in one particular occurrence by correcting that note, only to have the mistake reappear later. This picture seems to be in line with the pedagogical literature, which overwhelmingly asserts that specific behaviors are tools to be used in solving problems, and that precisely identifying those problems is a vital aspect of the focus that characterizes effective practice.

OTHER PSYCHOLOGICAL RESEARCH RELATED TO MUSIC EDUCATION

Operant conditioning provides a model for how strategic practice behaviors could characterize the practice of experts more strongly than they correlate with specific instances of success. In behavioral psychology, reinforcement is defined as any

consequence of a behavior that increases the frequency or magnitude of individuals' future displays of that behavior; likewise, punishment is any outcome that leads to less intense or fewer occurrences of that behavior. Rather than specifying *a priori* what types of items or experiences should punish or reinforce a behavior, they are defined by what behavior outcomes follow. That is, whether an outcome serves as reward or punishment is a matter of individual perception; indeed, any outcome that an individual prefers to the behavior in question can serve as a reinforcement (Domjan, 2005).

These operational definitions are not simply a convenient way for measuring outcomes objectively or in subjects lacking verbal abilities, such as animals or infants, but instead they reflect the inherent nature of learning. The same outcome can be interpreted alternately as reinforcement, as punishment, or as irrelevant by different individuals or in different situations; the food item that one toddler is willing to work for may punish another if allergies are involved, a sticker that reinforces a child's behavior may prove underwhelming over time, and publicly rebuking misbehavior may reinforce individuals who are glad for the attention. Even the nature of the behavior that is being reinforced or punished depends on what aspects of the situation the individual in question perceives to be salient (Matute, 1994; Skinner, 1948). For example, animals learning which items represent food to be hunted are capable of using color, shape, or pattern to determine which objects to target. Although species may attend preferentially to one feature over the others, individuals can learn to distinguish and make food selections based on any of the factors (Kazemi, Gamberale-Stille, Tullberg, & Leimar, 2014). Features of the stimuli can draw individuals' attention in a pattern known as stimulus-driven attentional capture, but individuals' expectations also influence what they see or overlook in complex situations, particularly when engaged in goal-directed behaviors (Simons & Chabris, 1999; Yantis, 1993). In short, although stimuli and situations can have features that usually capture typical individuals' attention, each learner separately

makes connections between aspects of the situation, their behaviors and responses, and whether and to what extent the outcomes of their behaviors were rewarding or punishing.

Applying this model to music practice shows how strategic behaviors may come to be associated with expertise. As novice musicians practice, they sometimes make mistakes. Some individuals experience these mistakes as irritating, while for others they may simply be unimportant surface features; some individuals may even fail to perceive errors as problems. Individuals who perceive the problems and engage in further practice will choose some behavior—stopping and repeating a small or large bit of material with or without some other change, simply ignoring it and continuing, or any manner of other behaviors, including practicing other material or even ending the practice session. Each individual will interpret the outcome of those actions—improved performance, another instance of the mistake, or a total change of activity—as punishing, rewarding, or neither. The individual may associate that outcome with the specific behavior, with the act of carefully choosing a response to match the problem, with practice as an activity, with focused work in general, with the specific teacher or the concept of taking instruction, or with whatever aspects of the situation they perceive as salient.

Because strategic responses are indeed associated with improved learning, individuals who engage in these behaviors are likely to play more accurately in the future, but the extent to which they find improved performance rewarding will vary. Moreover, they may associate the reward with any one or more of the aspects of their behavior: practice itself, the specific behavior, the pairing of the behavior to the perceived problem, or whatever aspect of their behaviors they perceive as salient. Through repeated experience of successful outcomes following strategic responses to perceived problems, some individuals will become conditioned to use effective strategic behaviors to solve musical problems as they accumulate practice hours. Others will fail to use these behaviors in the first place, or will experience improvements without choosing these behaviors, and will become conditioned to practice without them. Some

individuals' cognitive characteristics will mitigate the lack of effective practice behaviors, while others will overcome this obstacle by investing extra time in the work. However, because these practice behaviors seem to actually promote the learning of specific instances of general skills, it is likely that individuals who become conditioned to incorporate them into their practice will eventually develop greater expertise than those who do not. Still other individuals will experience elements of the situation (practice itself, errors themselves, the need to stop and analyze, a teacher's telling them what to do) as less pleasant than the improvements they achieve, and therefore these strategic behaviors may not be reinforced. They may even be punished if the individual perceives the activity of practice as unpleasant and the outcome (improved performance) as unrewarding.

Over time, individuals will be conditioned to further perform behaviors that have led to reinforcing outcomes in the past. Those who have experienced successful practice outcomes—and for whom successful outcomes are actually rewarding—will practice more frequently than others; those whose successful outcomes have closely followed utilizing the behaviors referred to as practice strategies at least some of the time will exhibit these behaviors more frequently. The extent to which behavior conditioned through reinforcement persists in the absence of continued rewards varies depending on the schedule of those reinforcements. Intermittently reinforced behavior, that which does not consistently lead to reward but instead only occasionally and unpredictably leads to the desired outcome, actually persists more strongly than behavior that reliably elicits a reward (Domjan, 2005). Thus, we would expect expert musicians to have become conditioned to practice a great deal, using learned practice behaviors that at least sometimes lead to noticeable performance gains but that, counter-intuitively, do not always produce the desired results. We would also expect to see other experienced musicians who have also accumulated much practice time, but whose conditioned practice behaviors are less effective at producing results, even if some of them may have

gained significant skills through sheer volume of work or by virtue of favorable relevant traits such as working memory capacity. We would expect the best players to possess the full package: helpful traits, large amounts of accumulated practice reinforced by musical success, and a suite of learned practice behaviors matched to specific stimuli (types of errors to be corrected or tasks to be completed). These behaviors often lead to improved performance, but we would expect that the best individuals would persist in putting them to use even when success does not immediately result. We would further expect music practice to fade to extinction in individuals who perceive musical success as only mildly rewarding, who perceive the nature or amount of work required to earn it as punishment, or who learn practice behaviors too inefficient to allow them to continue earning musical success in the face of increasingly difficult material. That is, musicians who don't enjoy musical results enough to work for them, or whose practice skills are insufficient to allow them to earn those results when learning advanced music, will tend to quit before achieving expert-level skills through many hours of deliberate practice.

This model does not take into account every factor that may help shape individuals' practicing behavior. For instance, factors such as participating in music ensembles and lessons or growing up in a musical family introduce social elements that also contribute to a musician's practice habits. However, the operant conditioning scenario helps to explain how an individual's many granular experiences together create a practice history that includes not only an aggregate quantity of hours practiced, but also a set of particular habits formed through the interaction of that individual's traits, experiences, and perceptions.

Action Identification Theory

In the above narrative, the details of any practice situation consist of behaviors conditioned by prior learning experiences with practice. The extent to which individuals

experience reinforcement from positive musical outcomes and other sources of feedback helps determine whether or not they will persist in their studies long enough to accumulate both the skills and characteristic massive amounts of accumulated practice typical of experts. In each detailed situation, individuals are engaged in what a pedagogue might call focused practice, and that psychologists refer to as goal-directed behavior. Action Identification Theory provides a model for how successive goals and the actions intended to achieve them fit together into a larger pattern of activity (Vallacher & Wegner, 1987).

Developed by Vallacher, Wegner, and colleagues in the 1980s, Action Identification Theory describes how people understand what they are doing at any given moment when negotiating the sort of complex activities encountered in music practice. For example, a novice string player needs to identify out of tune notes and adjust them by consciously moving the exact placement of their fingers, but an expert will simply stay in tune, making small adjustments to compensate for an out of tune string or to match group intonation on the fly. Likewise, a novice may frequently need to mark accidentals to remember specific notes, but experts need such reminders only occasionally because playing in the specified key mandates these pitches. Action Identification Theory describes more abstract ideas such as playing in tune or staying in key as being at higher levels in a hierarchy of actions, since they allow a musician to automate multiple component activities and provide meaning or purpose for these details. These larger activities may in turn be integrated into yet higher level actions, such as playing musically, playing Edward Elgar's *Salut d'Amour*, or preparing for a recital.

Individuals optimize their performance when they understand their actions at a level that is abstract and inclusive enough to incorporate and automate as many lower level actions as possible, while not viewing their behavior so generally that important details begin to fail (Vallacher & Wegner, 1987). The theory posits three points that

together describe a mechanism by which people find the optimal level to consider their actions at any point in time:

1. People generally understand themselves to be doing only one thing at any given time, called the *prepotent activity* or, in later literature, simply the *action identification*.
2. When both a lower and a higher level way of thinking about one's actions are available, the higher level understanding of one's action tends to become prepotent.
3. When an action fails, there is a tendency for a lower level identity to become prepotent.

Taken together, these three principles describe a strategy for efficiently navigating a complex task. Rather than trying to concentrate simultaneously on the many discreet muscular motions and balance corrections necessary for even a relatively simple activity like walking, people just walk. Walking, in the vocabulary of these principles, becomes the individual's *action identification*. Walking itself may be considered part of a larger behavior, such as going to the store, and people tend to automatically think of themselves as doing the larger activity, and will thus carry on and make decisions based upon the store-going action identification. This higher level activity allows for the integration of walking (and its components steps) with other, simultaneous actions involved in going to the store, such as planning a route while avoiding vehicles and other pedestrians. When trouble arises in one of the component activities (a sidewalk is closed for repair, the footing is treacherous, the route involves crossing a busy street without a crosswalk), people may shift their conscious activity to a lower level (planning a new route, staying on their feet, looking for a safe chance to cross). After resolving the situation, though, the higher level activity becomes practical again, and people tend to resume thinking of themselves as simply going to the store, performing the details with some level of

automaticity. An identity X can be considered to be at a lower level than identity Y if one can say that doing X is a part of doing Y, or that one accomplishes Y by means of X. Another way to describe higher and lower level identities is that higher level identities are *why* a thing is done, while lower level identities are *how* that thing is accomplished (Wegner et al., 1984).

Action Identification Theory's proposed hierarchy also suggests a mechanism by which people could arrive at alternative, but not necessarily higher or lower level, understandings of their activities. Most behaviors that form the low-level actions for one behavior also arise in other situations. For example, diminished arpeggios occur frequently in the violin repertoire, and are also in my experience somewhat more physically difficult to execute than other types of arpeggios. A violinist playing the Preludio of Bach's *E minor Partita* may enter measure 43 thinking about phrasing, tempo, the piece as a whole, or any number of other things, only to find her attention momentarily drawn to the physical details of executing the passage with the fingers of the left hand. Although it is possible that the individual will return moments later to the original action identification, it is equally possible that the individual will understand herself to be practicing measure 43 in isolation, or encountering yet another place where diminished arpeggios complicate the material, or even experiencing frustration at having been distracted from execution by technical matters. To an external observer, such a change of action understanding may be easily recognizable if it leads to practicing the measure in isolation or playing similar material from another piece. Alternately, the changed perception of activity may be entirely covert if it merely redirects the musician's attention from the bow to the left hand fingers, or if she perceives herself now to be "hacking through the Bach," rather than practicing phrasing. Wegner et al. (1984) called this process *emergent action*.

Experimental evidence has confirmed the basic process described by Action Identification Theory at a variety of levels. Participants studied by Wegner et al. (1984)

proved more susceptible to being primed by a biased questionnaire to think of coffee drinking as a form of stimulus-seeking or -avoidance if they had first been drawn to the details of their actions by using an awkward cup than if they were served in a standard mug. Moreover, participants in this study and others have proven to engage in subsequent actions consistent with primed high-level action understandings, but again, only when such priming is delivered together with an activity that focuses their attention on the details of action (Wegner et al., 1989; Wegner, Vallacher, Kiersted, & Dizadji, 1986; Wegner et al., 1984). Focusing on the details of one's actions inhibits the smooth execution of well-practiced routines in experts and leads to impaired performance, but shows no similar effect for novices (Beilock & Gonso, 2008; Seidel, Stasser, & Collier, 1998). Conversely, maintaining a high-level understanding of their actions facilitates the self-destructive behaviors seen in alcoholics and individuals with Obsessive-Compulsive Disorder (Dar & Katz, 2005; Palfai & Ostafin, 2010; Wegner et al., 1989). Alcoholics, for instance, are more likely than others to think of their behaviors in terms of high-level actions such as "Relieving tension" rather than in terms of lower level actions such as "Lifting a glass." Meanwhile, individuals who had gone through treatment after experiencing how inappropriate high level understandings of their actions lead to failure (e.g., losing a job) were likely to perceive drinking also at a high level, but instead using negative understandings such as "Hurting myself" (Vallacher & Wegner, 1989). Like individuals with OCD, who tend to view their behaviors as parts of a routine with positive affect, maintaining a high-level understanding of their behaviors insulates alcoholics and those with other cognitive disorders from the details of their actions, allowing them to persist in a behavior they may very well know to be self-destructive (Dar & Katz, 2005; Palfai & Ostafin, 2010; Watkins, 2011).

Personal Agency is the term used in the literature to describe differences between individuals in their tendencies to consistently identify actions at higher or lower levels (Vallacher & Wegner, 1989). People, of course, have different levels of personal agency

in different tasks, and will operate at high levels in areas in which they have skill and experience, but they also seem to have a personal inclination to focus either on the questions of *how* to accomplish something or on *why* they should accomplish it. In addition to individuals' perceived expertise in the task at hand, cultural influences and the belief that one is a lucky individual influence individuals' level of personal agency (Menon, Morris, Chiu, & Hong, 1999; Young, Chen, & Morris, 2009). Even individuals' academic majors tend to predict their tendencies to view their actions using high or low level understandings, although it is unclear whether this is due to work within the field altering an individual's perceptions or instead due to differential selection of majors as a function of personal agency (Bishop, Thomas, & Peper, 2000). Critically for teachers, people who tend to focus on concrete steps tend to display lower consistency of action and less self-motivation over time, but are "quite ready to accept new possible directions for behavior" (Vallacher & Wegner, 1989, p. 669).

Related research on goals and goal-directed behavior

What do people think they *have done*? Understanding why people identify their actions at higher or lower levels can be informed by experimentally investigating their sense of influence on the outcome of real events. Aarts and collaborators explored how people acquire a sense of agency over events' outcomes—that is, how people know that it is their actions that have caused a given turn of events (Aarts, Custers, & Marien, 2008; Aarts, Custers, & Veltkamp, 2009). Prior research has led to the emergence of the comparator model, the idea that people assess whether or not they have accomplished a goal by comparing their cognitive expectations with their perceptions of the actual outcomes of their actions. Young musicians, for example, might compare the known tune of Twinkle, Twinkle Little Star with the sounds that actually came out of their violins, or might compare the finger motions they expected to make with those they actually felt;

these comparisons in many cases may not occur at the conscious level. Aarts and colleagues explored the possibility that exogenous factors influence not only individuals' perceptions of outcomes, but also their expectations, by using nonconscious priming to directly influence goal states in their participants.

Participants in Aarts et al. (2009) first watched a series of colors appear rapidly on a screen and attempted to stop the sequence when they were cued to do so, after which they saw the color on which they had stopped. After habituating to this routine, the rapidly changing colors were replaced by strings of letters, each of which supposedly represented a color; that is, instead of seeing the color blue or even the word "blue," participants saw a string of six letters, as one might if it were a foreign word for "blue." The color represented by the letter string on which participants pressed the stop button was still presented as a colored square. Finally, the subjects were told that half of the time, the final color would be their selection, and in the rest of the trials a computer would select the color. They were to indicate how strongly they felt that they had been the one who had chosen the color on each particular trial. In actuality, though, the computer always determined the color; any sense of agency in the participants could only result from a match with expectations, rather than any physical or other process involved with actually affecting an outcome. All colors and letter strings were presented for such brief durations that subjects were not consciously aware of real words planted among them (Aarts et al., 2009).

As expected, these researchers found that priming a given outcome (by presenting its name among the random letter strings) one second before subjects stopped the sequence created an expectation for this color, which led the participants to believe they had caused the outcome. This priming faded rapidly, however, such that with a 20 second delay between priming and outcome, participants no longer felt they had chosen the color. When the prime was placed next to a positive word (e.g., "beautiful"), though, the subjects once again were led to believe that they had influenced the outcome (Aarts et al.,

2009). The authors suggest that by pairing an outcome with a positive affect, they create a goal in participants' minds—one the participants are not even aware of—which participants actively maintain over time. Participants must measure the effect of their plan based on a comparison between this goal and the outcome rather than relying directly on motor cues, because their physical responses, even their response times, were identical in situations when they did or did not feel responsible for the outcome. The only thing that reliably varied along with their sense of agency was whether the researchers had implanted an expected, desired outcome.

Participants in Dewey et al. (2010) played a computer game in which they steered a boat towards a target. Findings show that when researchers added noise to the joystick signal, causing the boat to move in ways participants did not expect, individuals understandably felt less in control of the outcomes of their actions. However, when researchers added an autopilot element to the joystick signal—a situation in which outcomes also did not correspond completely with participants' actions, but were in fact closer to their goal than what their own actions would have accomplished—participants felt an increased sense of control. This suggests individuals do assess their level of control over the outcomes of their actions through a comparison of their intended and perceived result. People feel in control when expectations and perceived consequences match, but out of control when they do not, even when both outcomes result to some degree on external forces.

Exactly how we gain a sense that we have accomplished a goal remains a subject of ongoing research, but the comparator model—the idea that we perceive accomplishment and control when, following action, our perceptions of the external world match our expectations—is at present the accepted, most complete model to which new proposals are compared (Aarts et al., 2009; Carruthers, 2012; Dewey et al., 2010; Synofzik, Vosgerau, & Newen, 2008).

In many situations, the time delay between action and outcome precludes the use of one's own body feedback cues as indications of one's own agency. A golf ball may have a hang time of many seconds before its final position becomes clear; many days may elapse between purchasing a lottery ticket and knowing whether that purchase has led to a prize. Yet people with yet another non-winning lottery ticket will have a decidedly different view of their role in the outcome than the jackpot winner. Presumably, someone who buys a lottery ticket does so as part of *winning the lottery*, rather than as an isolated, purposeless action. Maintaining this positive expectation, however slight, allows someone to feel partly responsible for their own good fortune if they happen to win and reality turns out to match the expectation. When individuals fail to win the jackpot, however, they may attribute the mismatch between their hopes or expectations and reality to reduced control, as participants in Dewey et al. (2010) did when random noise interfered with their control over the boat's movements. In addition, individuals with a higher *locus of control*—those who more strongly believe they can control the outcome of events in their lives—are more likely to play the lottery (Sprott, Brumbaugh, & Miyazaki, 2001).

In the last few paragraphs, several technical terms with partially overlapping meanings have appeared, and because these studies form a background for much recent research into music practice, they warrant some clarification. Vallacher and Wegner (1989) used the term Personal Agency to refer to the individual tendency to work on the *how* of a problem—the low level identities of action—or to address the *why* of a problem—its high level identifications. Some recent work instead uses the term personal agency (or just agency) to refer to the belief that one can influence or has influenced the outcome of specific events. Dewey et al. (2010) used the term *judgment of control*, rather than agency, to describe participants' sense of how directly their actions had contributed to the outcomes in the video game task. This is highly related to the older concept of locus of control mentioned in the preceding paragraph. The main distinction seems to be

that agency or judgment of control seems to be used currently to describe individuals' assessments of their control over discrete events, as in the experiments stated above, while locus of control describes individuals' stable beliefs in their abilities to control events in their lives, including those in the future (Phillips & Gully, 1997; Rotter, 1990). Researchers working in related fields seem to use similar terms to describe related and interconnected ideas, but the specific terminology varies between subfields and over time; in considering the relevance of such research to music practice, one should take care to examine what meaning each author intends to express in using any given terminology.

That many motor patterns are controlled without conscious attention is obvious, whether they are simple biological functions such as heart rate or more complex skills like maintaining balance while walking. Recent work, though, has shown that many relatively complex behaviors, even social interaction, are regulated without conscious awareness. Priming people with ideas like rudeness leads them to actually interrupt conversations; priming them with labels for stereotypes (e.g., "professor") leads them to behave in accordance with that stereotype (e.g., asking more questions); priming them with a setting (e.g., a library) leads them to behave more appropriately for that setting (e.g., speaking more quietly) (Bargh & Williams, 2006). In addition to general modes of behavior, goals—that is, end states pursued over time, in the face of obstacles, with relevant information selectively attended to and processed—can be primed, and can guide individuals' behavior in the absence of conscious awareness. People primed with words relating to achievement and success find more words in a series of word searches than subjects who were not primed (Engeser, Wendland, & Rheinberg, 2006), and priming people to behave cooperatively in a fishing game (where one's final score was simply one's own catch count) proved as effective as explicit instructions to share, as measured by the number of fish restocked (Bargh, Gollwitzer, Lee-Chai, Barndollar, & Trötschel, 2001; Engeser et al., 2006).

The methods employed in laboratory studies to activate nonconscious goals—planting words with loaded meanings in puzzles (Bargh et al., 2001; Engeser et al., 2006) or flashing them on screens for less than a quarter of a second (Aarts et al., 2009)—are quite artificial. As such, their relevance for real world instances of goal-directed behavior such as music practice can seem minimal. However, natural settings abound in exogenous and endogenous prompts that influence our ongoing behavior. Such prompts include those that appeal to conscious decisions, but also others ranging from product placement to sidewalk cracks that influence our actions without our conscious consideration. Importantly, and posing a possible problem for Action Identification Theory, sometimes goals that appear to be at most minimally conscious in nature appear active even while people pursue detailed, component activities. That is, Action Identification proposes a mechanism for a high-level activity to allow for automatic maintenance of its steps, but not for steps to maintain the activity of which they are a part. Indeed, the concept of emergent action arises from the idea that moving lower in the action hierarchy leaves one free to later generalize one's actions to a different high-level activity. Yet, persistence in the face of obstacles is one of the definitive characteristics of goal-directed activity (Bargh et al., 2001). Violinists practicing Bach's Preludio to the *Partita in E major* may need to attend to the fingers of their left hand in measure 43, but they frequently are able to continue playing without consciously attending to other actions at higher, lower, and comparable levels of complexity. They continue shaping a phrase, they maintain their balance, and their bow arms keep executing the correct articulations, all while they briefly attend to a difficult fingering.

Research into goal-driven behavior suggests that when two activities each represent steps toward a broader goal, completing one of these steps influences a person's likelihood of pursuing the other (Fishbach, Dhar, & Zhang, 2006). When people successfully complete one step toward a goal, they express less interest in and are less persistent with activities leading to the same larger ends; they exhibit behaviors typical of

goal completion. However, this pattern changes when the larger goal itself has been primed. People who have been primed with the goal of becoming fit, for instance, express more interest in eating healthy foods after successfully working out, rather than less, as is the case without priming (Fishbach et al., 2006). Completing the component activity seems to signal some measure of goal achievement, leading to decreased motivation for further pursuit, unless the larger goal is active in the mind. In that case, it seems that success in the smaller goal is seen as a component of the larger goal and motivates further action towards that end. Moreover, the subtle priming employed in this study suggests that the larger goal need not be consciously perceived. Fishbach et al. (2006) chose goals (e.g., fitness and academic success) known to be important to the populations they studied (e.g., gym members and college students). Thus, researchers' actions in these studies presumably do not constitute the creation of new goals, but merely the activation of larger goals that participants already held at the time when its component steps were examined. The authors argue that the larger goals' preexistence makes them more accessible to (although not consciously identified by) the participants.

The tasks and goals studied by Fishbach et al. (2006) were all somewhat tedious in nature. That is, studying to better one's grades or eating vegetables to be healthier were at least mildly burdensome, if only in terms of opportunity cost, the more pleasurable activities (or foods) one must pass up in order to pursue these goals. If the activity in question were something enjoyable to the subjects, would the same pattern of results emerge? That is, if football players were asked about their interest in reading Sports Illustrated after practice, would they still decide that this related activity was less desirable than it would have been had they not just played the game? The authors of this study suggest that, in the presence of an active, more encompassing goal, lower level goals are viewed as complementary; completing one leads to greater commitment to the larger goal and an inclination to pursue related substeps. Without the larger goal being active in participants' minds, accomplishing each step gives a sense of completion that

inhibits further work. An alternative explanation, though, is that the particular substeps in question are not pleasant, and unless they are connected to the positive associations of the larger goal, they are unlikely to be pursued on their own in any case. In both explanations, the connection to the larger goal is relevant, but the nature of the connection, particularly as it regards potentially competing lower level goals or actions, is fundamentally different. Do goals that contribute to an overarching, higher-level goal actually compete with each other so that accomplishing one step gives one satisfaction unless one is focusing on the larger ends of which these goals are a part? Or are some of the goals simply less worth pursuing on their own unless some larger reward connected to the overarching goal is present?

Action Identification, Goal-Directed Imitation, and mirror neurons

Goals and the actions undertaken to accomplish them are one of the central ideas in the field of Goal Directed Imitation (GOADI). Research in this field explores how people understand and imitate the actions of others (Becker, 2008). The central finding of goal directed imitation is that people tend to copy an action based on its effects, the goal of the action, rather than on the means and specific physical movements involved (Becker, 2008; Wohlschläger, Gattis, & Bekkering, 2003). Children, for instance, will copy the act of covering a dot on a table or touching an ear, but they will do so with whichever hand is easiest, usually the one on the same side of the body as the target, regardless of which hand the model used. This tendency to ignore the specific details of an action can be overcome, though, when the model exaggerates the movements involved or the easier hand is already occupied. Children will also copy the specifics of an action when no target is available, such as when the model touches a point on a table in the absence of distinguishing features such as dots, or holds a hand in midair near, but not touching, the ear (Wohlschläger et al., 2003). Much of the research on Goal Directed

Imitation has used children as participants, but the key findings have been replicated in adults, although the effect sizes are quite small.

Research on Goal Directed Imitation, in essence, has found a very similar pattern of behavior to what Action Identification theory suggests should arise from its proposed set of cognitive processes. People see a model perform an action and seem to conceive of the other person's action in terms of its broadest relevant sense, creating an effect upon an object. When the action is viewed at this high level, selection of specific component behaviors, such as using one hand or the other, becomes automated: the imitator selects the easiest, most efficient hand for the perceived task. Deliberately exaggerating the motions involved necessarily highlights these component steps, allowing the imitator to copy the details of the action as well as its outcome. When the easiest hand is already engaged, the imitator may consciously employ the other hand, although this could also still be performed with relative automaticity. When no target is present, there is no higher level immediately available to generalize to, and so the specific movements become the identified action.

Like Action Identification Theory, one of the key principles of GOADI is that the observer understands aspects of the goal hierarchically, with ends and effects taking precedence over the means (Wohlschläger et al., 2003). GOADI theory also proposes several of the same ideas in understanding others' goals that Action Identification proposes for understanding one's own, including the understanding that actions have different aspects, that we select only a few to attend to, and that these aspects are hierarchically organized (Bird, Brindley, Leighton, & Heyes, 2007). The proposed mechanism for recognizing actions in others is the mirror neuron system, a set of brain cells that respond identically both when we perform an action and when we observe others performing the same action (Becker, 2008; Costantini, Committeri, & Galati, 2008; Iacoboni et al., 2005; J. T. Kaplan & Iacoboni, 2006). Mirror neurons provide the neural correlates of the psychological theory of common coding, the idea that we

represent our own and others' abstract actions using the same systems and resources (Costantini et al., 2008). Given that many mirror neurons have been found in the motor areas of monkeys, they seem also related to the Ideomotor Principle, that observing an action automatically triggers our simulation of that action (Becker, 2008). Neuroimaging studies have shown activation in analogous brain areas in humans (J. T. Kaplan & Iacoboni, 2006), although naturally detecting individual human neurons behaving in precisely the mirroring manner observed in monkeys is presently beyond any ethically acceptable experimental design. The Ideomotor Principle provides an additional connection to the above description of goal-directed behavior: once again people appear to employ comparisons between mental modeling or simulations and observed effects to assess the relationships between people, their intentions, and the actions needed to realize these intents.

Context is important to the understanding of others' intentions mediated by the mirror neuron system (Iacoboni et al., 2005). Physical motions alone do not convey much about what a person intends to do. The same physical positions are involved in eating with chopsticks or in writing with certain pen grips, and the exact same gesture may be used to shoot a friend with a water gun or to shoot an enemy in battle; the intentions and high level actions that a person understands themselves to be accomplishing with those identical actions, though, are markedly different. However, the mirror neuron seems to truly identify actions, activities intended to enact goals, rather than to respond to specific physical gestures. Neuroimaging studies have shown that response in the brain areas containing mirror neurons is independent of both the effector (the specific body parts and their manipulations) used to perform an action and the target of that action (Costantini et al., 2008). Furthermore, identifying these actions is a fully automated process, one that happens very quickly and that does not require attention, much like recognizing speech sounds from among the various noises in any environment.

From an evolutionary perspective, it makes sense that we would identify another's high-level action in the abstract quickly and automatically without being constrained by the specific body parts, tools, and targets involved. Whether faced with another person or a bear, if this other has just attacked one's friend, one must quickly respond defensively to sudden movements in one's own direction if one is to survive. It makes little sense to assume that a different target (especially oneself) will be treated differently, and the end will be the same regardless of whether the bear uses its teeth, its claws, or both during the attack. There are still many unresolved, even problematic questions in our understanding of mirror neurons (Hickok, 2009), but the presence of an evolutionarily adaptive mirror neuron system would explain why we quite literally see goals, high level actions, in others' behaviors.

The present understanding of the workings of the mirror neuron system support and help to explain the main findings of research in goal directed imitation. We imitate action because we see action; specifically, we see the level of action that is most inclusive while still being relevant to us. Although we see the bear raise a paw and can try to avoid specifically those claws, we more importantly see the bear attacking and act in anticipation of the attack continuing after that paw has fallen; at the same time, we do not immediately perceive the bear defending her cubs, because this information will not be relevant unless we succeed in fending her off long enough to consider our next move. Today, the functioning of the mirror neuron system is understood mainly in terms of allowing us to understand the goals and intentions of others, although it appears also to be critical in imitation learning. There is also considerable evidence that the system's development may be intimately related to learning processes (Del Giudice, Manera, & Keysers, 2009).

In keeping with the suggestion that we perceive others' actions abstractly—in terms of their effects rather than means—simple visual perspective seems to be intimately related to the level at which one identifies an action. Whether imagining themselves

performing an action or seeing pictures of someone else performing the same action, participants reliably indicated that a third person perspective was more indicative of why an action is performed and a first-person perspective was better at showing how it was performed (Libby, Shaeffer, & Eibach, 2009). When asked either to imagine or to choose a picture showing how activities were done, subjects chose images from the first person perspective, but chose the third person when either imagining or choosing pictures depicting why things were done. Seeing action (even imagining one's own action) from a distance evokes high level concepts of why things are done, and evoking these concepts leads people to take a third-person perspective; in the same reciprocal relationship, the details of how actions are accomplished and the first person perspective seem to be linked, regardless of whether one is observing another person or imagining one's own actions (Libby et al., 2009). Indeed, other researchers have found that participants tend to interpret others' actions at more abstract, intent-oriented levels than their own actions, although the effect was moderated by whether the other person was liked or not (Kozak, Marsh, & Wegner, 2006).

Libby et al. (2009) discuss people's tendencies to attribute high level, outcome-oriented goals in others' actions, while focusing on the detailed process when imagining one's own acts, within the broader context of psychological distance. In general, greater psychological distance corresponds to higher levels of abstraction; from a distance, we see the bigger picture. Viewing a scene from the third-person perspective necessarily places the action at a greater distance in the sense that the action must be performed by another person, regardless of the physical distance involved. Fishbach et al. (2006) also explored the connection between psychological distance and goal abstraction, manipulating psychological distance by altering the time at which a task was to be completed. They found that people perceive steps in a process to be more connected to the larger goals of which they are a part when those steps were still months away than when these sub-goals were in the near future. Further, people are more inclined to pursue

additional related sub-goals after completing one component step when they are considering action in the more distant future. It may be easier to commit to goals when they do not require immediate effort, and a portion of the results from Fishbach et al. (2006) are explained directly by temporal proximity. However, these results also suggest that an activity in the near future is considered an end in its own, reducing the desire to pursue activities related to a higher level goal, whereas activities in the future are considered as part of a larger structure of activities. Perhaps contemplating or engaging in a step towards a broad goal in the immediate future elevates one's awareness of that step's own components, thus making it seem like a more inclusive, higher level action than it otherwise would.

Focus of attention

The term Focus of Attention is used by researchers in several fields to describe ideas closely related to goal-driven behavior (including imitation). In kinesiology and athletic performance, this phrase has been applied very specifically to the contrasts in performance and efficiency between people focusing either on the specific bodily movements undertaken when executing an action or on the effects of that action upon an external object. Researchers in the area of visual perception have used this phrase to address what we focus upon in our visual field, while a few investigators have investigated allocations of attention among the various aspects of musical stimuli.

The results of work on focus of attention as addressed by researchers in kinesiology have been both quite clear and very much in agreement with the topics discussed thus far. In essence, research on attentional focus in this setting has found that people perform optimally when their attention is consciously directed toward the external object on which they are acting (Wulf, 2007a, 2007b). This finding obtains in a variety of situations, including some as simple as a jumping task, as well as other, more

sophisticated actions, such as shooting free throws. Moreover, directing attention toward an external object is more effective both in the initial instructions given for a task and in the feedback given about one's attempts. Wulf (2007b) suggests that "adapting an external focus allows unconscious, fast and reflexive processes to control the movement, with the result that the desired outcome is achieved almost as a by-product" (p. 9) and further suggests that focusing on one's own movements and processes actively disrupts these actions that would otherwise be automated. While this area of research does suggest that there may be some special effect generated by crossing the line between one's own bodily movements and the outside world, this division is essentially a particular point along the spectrum of action identifications. Coupling this broad, robust finding with those from goal directed imitation, actions seem to be more meaningful when they are dealt with at the level of effects upon an object, and that the automation granted by removing conscious attention from the body improves efficiency and effectiveness.

Scientists investigating the human visual system have also explored focus of attention. Until recently, visual attention has been understood as a sort of cognitive zoom lens, allowing people to pick up increased detail in specific portions of the visual field. More recent work, however, suggests that visual attention tracks actual objects rather than heightening sensitivity to particular regions of space as seen from one's own perspective (Scholl, 2001). Individuals can track the motions of up to five different objects among 10 identical samples moving independently and unpredictably, and can demonstrate this by reliably identifying whether an item selected from among the 10 was one of those they were instructed to monitor. At the same time, they cannot supply information about unmonitored objects that move through the same areas of the visual field, suggesting that attention must follow specific items rather than parts of space. These results seem to be a form of attentional blindness, a phenomenon in which people remain unaware of sometimes painfully obvious events because they are attending to something else, even when the unnoticed event occurs in the same region of space as the

attended one. In a famous demonstration of this phenomenon, participants watching a recording of two teams playing catch with a basketball were assigned to count the number of passes made by one team while ignoring passes made by another team. They were quite accurate in this task, but most participants failed to notice that, in the middle of the video, someone in a gorilla suit walked into the very center of the screen, turned to face the camera, pounded his chest a la King Kong, then proceeded on his way (Simons & Chabris, 1999).

People do, in fact, also attend to spaces in the visual field. While people are waiting for presentation of a target, they attend to the area in which they expect the target to appear. Effects due to this attentional activity have been seen using fMRI in extremely early areas of visual cortex, areas that are known to be cortical maps of the visual field (Silver, Ress, & Heeger, 2007). Areas V1, V2, and V3, some the first cortical areas in the portions of our brain devoted to vision processing to receive input from our eyes, all have areas that work harder—in the absence of actual stimuli—because the individual is attending to an area in the expectation that something will appear there. This parallels the ability of children imitating a model to copy the exact motions of an act when that act does not have any object involved; when no object is involved, attention is directed to more basic things such as movements or monitoring an area (Wohlschläger et al., 2003). These results suggest that people attend to objects in the visual world, which mirrors the facts that (1) people perform better when focusing on the change they wish to enact upon external objects instead of how they will effect that change and that (2) people see discrete, high level actions rather than component physical processes in observing and imitating actions.

Focus of attention has been minimally examined in a musical context, but the one study of which I am aware echoes the trends identified in other fields (Duke et al., 2011). Non-keyboard musicians learning a short passage on a piano were instructed alternately to focus on their fingers, the piano's keys, the hammers inside the piano, or the sound. In

a transfer test, those musicians instructed to attend to the hammers or the sound displayed more accurate, steady rhythm than those instructed to focus on their fingers or the keys. Additional trends (non-significant differences in means) show that the steadiest rhythm occurred when musicians focused on the sound they produced in both the transfer test and a final test of the original task. No differences were found between conditions for the four pianists in the study, although the authors speculate that this is due primarily to the pianists' extensive training, either through sheer levels of prior practice in maintaining even rhythm, or through a developed habit of attending to different aspects of their performance that persisted despite instructions in the experiment.

The common thread throughout these fields is that people deal best with things that are high-level but discreet—objects to watch, effects to create upon objects, actions other people are doing. Perceptual details relating to these objects or actions may be available and accessible to us; we can actively watch empty space while waiting for something to appear, we can consider our arm motions when swinging a baseball bat, we can notice with which hand someone picks up a mug. But unless there is a reason to attend to these details, we do not bother, and as shown in kinesiology, attending to them makes us less efficient. Action Identification Theory essentially describes the same principle, but since carrying out our own actions brings with it the possibility of disruptions forcing us to consider details, people have a concrete method for negotiating these levels of complexity.

PURPOSES OF THE PRESENT STUDY

All of the research described above paints a picture of music practice as a complex activity rich in goals, the actions that individuals undertake to accomplish them, and new goals and behaviors constantly emerging from the perceived results of prior activities. The collected evidence suggests that through prior practicing experience,

musicians should, in the language of behavioral psychology, become conditioned to engage in certain behaviors, some general and some idiosyncratic, in response to specific situations and types of perceived challenges. More cognitively-oriented fields of psychology might instead identify specific practice behaviors as being components of broader goals and practice targets; acting in pursuit of more general targets may somewhat reflexively evoke well-learned routines, the specifics of which may be less accessible to a musician's conscious awareness.

Pedagogues strongly suggest that focused work, characterized by detailed and conscious analysis of the problems in the music and the selection of appropriate practice tools and strategies to solve each specific challenge, is necessary for optimal practice. However, although researchers in music education have demonstrated that experienced musicians tend to display high-level strategic practice behaviors more frequently than do less experience individuals, the fundamental pairing of different ways of practicing—specific strategies or practice tools—with qualitatively different musical problems has yet to be demonstrated. Moreover, pedagogues consistently emphasize the need for constant analysis and detailed work, but many of the findings discussed above suggest we perceive our own actions and goals, others' behaviors, and even visual objects at the broadest sustainable level. That is, evidence from a variety of fields would suggest that musicians typically think about their behaviors in very general ways, and that these broad goals and intentions may actually make it more difficult for them to consistently monitor for problems in their playing and select optimal, tailored practice approaches to each perceived problem.

Particularly to pedagogues, pairing each problem to an optimal practice behavior may seem self-evident, but of course the history of science is defined by updates to our conclusions based on new evidence that contradicts what was previously believed. Moreover, because in most cases authors do not specify a mechanism of action, it is unclear why some recommended practice strategies should work or how these behaviors

fit into goal-directed human behavior more generally. An understanding of these underlying processes could enable students and teachers to more effectively practice recognizing situations in which one or another practice behavior is appropriate, or could point to practice habits that experts display that students should actually avoid emulating. For example, if a particular practice strategy serves primarily to draw attention to an easy-to-overlook problem, perhaps individuals who have already developed effective diagnostic skills will actually avoid that strategy; students should not take this as an indicator that such behaviors are unnecessary. Indeed, chess grandmasters perceive game situations differently than others, rapidly identifying structures that less experienced players see more as constellations of discrete units (Chase & Simon, 1973). Grandmasters, then, should rely less than others upon strategies and processes that facilitate conscious structural recognition; we might expect the same to be true of expert musicians' identification of challenges. The persistence of conditioned practice responses, even after an individual has acquired sophisticated skill sets that should obviate the need for behaviors that facilitate problem diagnosis, might help explain the finding that strategic practice behaviors are more closely associated with experience than they are with gains in musical performance (Hallam, 2001a). Perhaps advanced music students would benefit from specific training to recognize when to abandon certain previously advantageous practice behaviors.

Before any of these questions can be addressed, however, the extent to which musicians' actual practice truly relies on specific problem-behavior pairings must be assessed. The present study was designed to answer two specific questions. (1) Do musicians use different behaviors to practice material presenting qualitatively different challenges? (2) If so, do musicians' approaches to the same type of challenge vary as a function of their experience level?

Chapter 3: Method

There is ample evidence that practice is an essential activity for developing expertise in any field, including music (Ericsson, 2008; Ericsson et al., 1993; Lehmann & Ericsson, 1997). An extensive body of pedagogical literature has been developed to help musicians practice effectively, including entire books devoted to practice ideas for specific instruments (e.g., Carney, 1980; Fischer, 2004; Morganstern, 2002; Nardolillo, 2015). However, as discussed in previous chapters, the research literature exploring whether, how, and to what effect musicians actually employ pedagogues' advice—or even what behaviors occur in the practice room at all—is remarkably limited.

One point that the pedagogical literature stresses is that practice must be conditional. That is, what and how much a musician accomplishes depends not only on how much time a musician spends in the practice room, but on what happens during that time, and musicians trying to accomplish different things should work differently. Many pedagogues spend time focusing on the variety of material to be practiced and the overall structure of the practice session, and sometimes disagree with each other (Farkas, 1956; Galamian, 1985; Wye, 2000). However, other sources concern themselves with moment-to-moment decisions, and in some ways resemble the trouble-shooting section of an appliance owners' manual: when you encounter problem X, try steps A, B, and C before calling technical support (Fischer, 2004; Nardolillo, 2015).

Sheer, aggregated practice quantity is important (Ericsson, 2008; Ericsson et al., 1993; Lehmann & Ericsson, 1997), but cannot alone explain musicians' success either in a single practice session or across a career (Duke et al., 2009; Madsen, 2004). Other factors, including stable individual traits such as working memory, seem to play a major role in determining success rates in music and other highly skilled activities, even among highly experienced individuals (Hambrick & Meinz, 2011a). Taken together, the results

seem contradictory: (1) large amounts of accumulated, focused practice seem to be essential to become an expert musician, but (2) aggregate practice time explains little about musical success in specific cases and tasks, while (3) other individual differences that could collectively be called "talent" are often highly correlated with success in particular instances. This apparent conflict is often both simplified and exaggerated in the popular press, where practice and innate ability are sometimes presented as mutually exclusive candidates for the role of most important factor in musical success (Hambrick & Meinz, 2011b).

The pedagogical literature's focus on responsive, situational practice behaviors suggests a different relationship: practice sessions, preparation for a recital, and a lifetime of musical experience are composed of individual, particular tasks and challenges. A musician's success in each task may result from the approaches they choose, but stable cognitive traits may also influence the result; cognitive skills may even affect the approaches an individual selects to apply to any given problem. The pedagogical literature helps musicians choose appropriate tools to resolve each problem when the individual's prior learning and individual cognitive profile do not generate a solution through a less overt process. Experiencing success or failure on a particular problem while using a particular approach (whether the musician adopted that approach spontaneously or after referring to a book) may condition the musician to use that approach in that context more or less readily in the future.

In short, aggregate practice consists of many singular instances; in those many instances, details—individual differences, behavior choices, and other factors—affect success, and success in one instance affects choices and outcomes in future instances. Researchers have begun to look at the many kinds of events that happen inside a practice session, the details of how musicians work on *this* challenge, *now*. The manual-style pedagogical resources (Fischer, 2004; Nardolillo, 2015) often refer to their suggestions as "practice strategies," and present the ideas the way one would describe proper use of a

tool: when you experience this problem, apply that behavior. For example, practicing more slowly than the final performance tempo might be a useful tactic when trying to learn fast material such as the Presto from Bach's *Sonata in G minor* for violin. The same behavior might be an ineffective tool for working on the qualitatively different challenges present in another piece, such as Bach's *Air on the G String*.

Pursuing the implication that proper selection and application of practice strategies is important to effective instances of practice, researchers have begun to examine participants' practice sessions in detail, but the present understanding of these details of practice is limited for several reasons. Primarily, there are many situations to which musicians may adapt their practice behaviors, but there are still relatively few studies examining them. Some of the research literature takes the form of case studies, and as such is quite illustrative but of limited generalizability (Chaffin & Imreh, 1997, 2001, 2002, Chaffin et al., 2003, 2009; Ginsborg & Chaffin, 2011). Some studies use proxy measures of practice behavior, such as students' cognitive awareness of a variety of practice strategies, as a proxy measure of their practice abilities (Miksza, 2007).

Critically, some studies have compared individuals' practice in controlled situations, using multiple participants while actually measuring aspects of their practice behaviors (Duke et al., 2009; Maynard, 2000, 2006; Miksza, 2007). However, in these studies either participants have all practiced their own selection of music, allowing little direct comparison between individuals (Maynard, 2000, 2006), or else participants have all practiced the same excerpt or etude, limiting the possibility of comparing between situations (Duke et al., 2009; Miksza, 2007). Specifically, studies in which participants practice only one excerpt preclude researchers' ability to examine the type of situational contrasts that are central to much of the pedagogical literature, that musicians change their practice approach in response to the material in the music they are learning.

In my own teaching and practicing experience, practice strategies can be useful, but students often fail to apply them, apply strategies at inopportune or seemingly

haphazard times, or otherwise misuse the tools. Also, most of the pedagogical literature recommending the use of explicit strategies is written for student musicians and their teachers, rather than for practicing, experienced players. Therefore, the purposes of this study were twofold. I wanted to identify whether musicians' practice behaviors differ in response to qualitatively different challenges present in the music, and if so, to characterize those differences. I also wanted to identify whether any such differences vary between musicians of different experience levels.

PARTICIPANTS

Participants were high school students (n = 11, female = 8), college music majors (n = 12, female = 4), and professional musicians (n = 12, female = 3) whose principal performance medium was violin. Teachers from private studios and chamber music programs recommended high school musicians with sufficient experience to play in high positions. One of the original 12 participants, though first contacted when in high school, did not complete the protocol until the following year after entering university as a non-music major, and was therefore excluded from any analysis. College participants were music majors at two large, public, research universities, and were recruited both directly and by reference from university faculty. Collegiate participants included violin performance majors (n = 9), music education majors (n = 2), and one bachelor's of arts in music student; the group included two master's level and 10 undergraduate violinists. Professional musicians were defined as individuals who had secured employment as violinists through competitive processes with symphonies and universities, and who continued to perform in that capacity. In addition to full time university studio faculty, the professional participants in this study include members and concertmasters of their regions' premier symphonies, as well as members of a full time resident chamber ensemble at a major university.

PROCEDURES FOR DATA COLLECTION

After completing informed consent documents approved by The University of Texas at Austin Institutional Review Board (IRB), each participant received overall instructions describing the following sequence of activities, then completed three practice blocks. Several questions followed each practice block, both supplying background information and creating a break between practice sessions for the participants. In each practice block:

1. The participant received a copy of the music excerpt they would practice.
2. I played a computer-generated model recording of the excerpt at the target tempo three times. This recording was generated using Finale 2008 notation software with the Garritan Personal Orchestra instrument samples.
3. I reminded the participant of two elements from the overall instructions. I reiterated that the target tempo was extremely fast, and the task was to prepare to play the excerpt as close to the target tempo as possible while still playing well. I also reminded the participant that the provided metronome and pencil could be used as much or as little as desired (see "Instructions and Questions" below).
4. The participant practiced the excerpt for approximately 10 minutes. I stayed in the room, seated out of their direct line of sight, and alerted the participant when approximately five minutes and one minute remained. The exact timing of both the warnings and the end of the practice session varied; I waited to speak until the participant paused, rather than interrupting an activity.
5. The participant performed the excerpt three times.
6. I collected the sheet music for the excerpt and asked the questions from the appropriate list (see "Instructions and Questions" below).

I recorded all of the participant's activities after the informed consent procedure (including model recordings, practice, performances, and questions) for later analysis

using a portable video camera. I supplied a pencil, music stand, and metronome but allowed participants to use their own materials if they preferred.

Instructions and questions

The overall instructions that participants received immediately after completing their informed consent document read as follows:

> This is a study exploring how musicians practice. I will ask you to practice three short excerpts for 10 minutes each; after you have practiced each excerpt, you will perform it three times. I will record your work so that I can examine it in detail later. You are allowed to withdraw your participation—that is, stop participating in the study—at any time.
>
> Before each practice session, I will play a recording of the excerpt at its target tempo. The target tempos are very fast. With only 10 minutes to practice, I understand that you will probably not get the material up to the same speed as the recordings, but your goal is to get each excerpt as close to the target tempo as possible while playing well. If you feel ready to perform at the target tempo before your 10 minutes are over, just let me know.
>
> I have provided a pencil and a metronome; you may use them as much or as little as you need. Do you have any questions?

Before each excerpt, I gave participants reminder instructions, which included playing the model recording for them three times. The instructions were:

> Here is the [first/second/third] excerpt. You may look at the music while listening to the recording if you think that would be helpful. [Play model three times.]
>
> As a reminder, the target tempo is very fast; prepare to play the excerpt as close to the tempo as you can while playing well. Whenever you are ready, you may begin practicing. I will give you about 10 minutes to work.

After the first practice session and set of performances, I asked participants approximately how long they had played the violin; whether violin was their first instrument and if not, how long they had been studying music; and whether they played any other instruments. I also asked them at that time to list their previous and (when applicable) current violin teachers; primarily I wanted to verify that my participants

represented a variety of teachers, and therefore that the practice I observed did not simply reflect the teaching of one or two pedagogues. Secondarily, this question often became the longest part of this block of questions, creating a mental and physical practice break.

After the second practice session and performances, I asked high school and college participants about their grade and degree program. In place of this question, I asked professional participants how long they had been playing professionally, which proved more difficult to answer than I had expected because many professionals had begun touring during or even before college. I also asked whether either of the preceding excerpts had seemed familiar and asked participants to tell me if the third one also looked like something they had seen before. Although I had composed the excerpts for the purpose of the study, I wanted to know if the excerpts resembled other material that participants might have previously studied but of which I was unaware. I also asked participants what repertoire they were working on currently.

After the third practice session and performances, I thanked participants for their efforts and told them, "The goal of this study is to determine how musicians practice material with different technical challenges." I then asked them if they felt like they had practiced each excerpt differently. I told them that I had composed each excerpt to highlight one particular technique or skill, and I asked them to identify that signature challenge for each of the excerpts. I also asked them to rate each excerpt's difficulty on a scale of one to six, with six being difficult. Finally, I asked them if they had any questions or comments.

Excerpts

For this experiment, I composed a variety of music excerpts. In consultation with my advisors, I then selected three that best fulfilled the following requirements:

1. Each excerpt should primarily feature one type of technical challenge characteristic of violin playing, and the set should feature three different challenges.
2. Excerpts should be authentically musical and violinistic. That is, the musical material—implied harmonies, melodies, rhythms, etc.—should be representative of the body of western literature that violinists typically learn.
3. Excerpts should be difficult enough that professionals could genuinely work for at least 10 minutes to perform them at the target tempo, yet approachable enough that advanced high school students would be able to perform them at some (slower) speed.

These three criteria helped to ensure the study's validity, that is, that I was studying the differences in practice behaviors that I wanted to study. Because case studies have shown that at least some musicians' practice activities change as they gain familiarity with the material (Chaffin & Imreh, 2001), I composed excerpts rather than using preexisting material. Although preparing completely new material for performance in 10 minutes is somewhat atypical of musical practice, it is a task violinists do sometimes face (e.g., when preparing for a one-time orchestral performance, 10 minutes may be all the time they can devote to a single passage). Presenting them with unfamiliar music is thus not a foreign challenge.

Criterion 2 was included to ensure that the behaviors I observed were representative of participants' typical practice behaviors. Chess masters perform differently than novices at recalling chess board positions only when those positions are meaningful (Chase & Simon, 1973). Similarly, I expected that excerpts bearing little resemblance to typical violin music would be unlikely to evoke typical violin practice behaviors in any of the three groups of participants, so I avoided random sequences of notes or excerpts from non-standard, atonal literature. Composing characteristic, musical violin excerpts that feature a single signature challenge in the absence of other challenges

was problematic, and all three excerpts that I finally selected do necessarily include material that introduces other problems. However, the magnitude and quantity of each excerpt's characteristic challenge overwhelm other problems; in the final question block, participants were reliably able to identify each excerpt's intended challenge.

Criterion 3 was included to facilitate comparisons across groups, but creates the inherent problem of presenting musical challenges difficult enough to occupy professionals for 10 minutes without overwhelming less experienced participants. To address this problem, I gave each excerpt an extremely fast target tempo, but included initial instructions and reminders before each practice session that participants' task was to "prepare to play as close to the tempo as you can while playing well." This wording was chosen to articulate speed as a goal while still stating that preparing for a high-quality performance should take precedence. This wording gave all players permission to adjust their performance tempos to the fastest personally manageable speed, in effect allowing them to self-select a customized difficulty level for each excerpt. Precisely because (a) the target tempos were selected to provide a flexible level of difficulty and (b) I would be providing a metronome, I did not want to emphasize the exact target metronome marking too heavily, out of concern that this would pressure less advanced students to sacrifice quality for speed. Therefore, I established these tempos only by playing the model recordings at the target speed, and I did not include the metronome marking on their printed excerpts. In addition to setting the target tempos, the model recordings were intended to mitigate the effects of individual differences in sight-reading ability, giving all participants a chance to hear each excerpt executed correctly several times before starting practice.

The technique of violin, or of any instrument, includes a wide variety of technical challenges, any three of which could represent the target technique for the excerpts in this study. Because the primary purpose of the study was simply to ascertain whether players do in fact work on different types of challenges differently, and whether those approaches

change with experience, I selected three dissimilar technical problems and composed excerpts that maximized the prevalence of each signature challenge. I did not make any attempt to select three of the most difficult challenges in violin technique, nor three of the most common or important types of problems. I specifically avoided choosing similar challenges; information distinguishing the subtle differences between working on bariolage beginning with an up bow versus that beginning on a down bow may be an interesting topic for future research, but would simply complicate the task of distinguishing whether violinists work on different types of challenges using different approaches at all. I also wanted to choose technical problems that could be built into material that varied minimally in other respects: if one of the challenges were to be bow control in prolonged phrases, for instance, an excerpt incorporating it might require far fewer notes or far fewer measures than a challenge commonly found in fast music. Ultimately, I composed excerpts that targeted (1) slurring patterns that do not correspond with the metrical pattern, (2) string crossings, and (3) shifts.

Excerpt I: cross-beat slurs

The primary, signature challenge inherent in this excerpt is executing smooth, rhythmically even slurs that do not correspond with the excerpt's metric pattern. Although sometimes found in fiddle music and other non-classical styles, this is an atypical pattern in Western art music. Particularly at fast tempos, it can be difficult to execute without adding unwanted accents, or without changing the rhythm to a dotted figure. This technical challenge is primarily a problem for the right (bow) arm. Depending on a player's choice of fingerings, this example of cross-beat slurs also may employ a limited number of small shifts, several string crossings, lateral motion of the second finger to change between G-naturals and G-sharps, among others, but the primary, salient feature of the excerpt is coordinating the slurs in the bow arm.

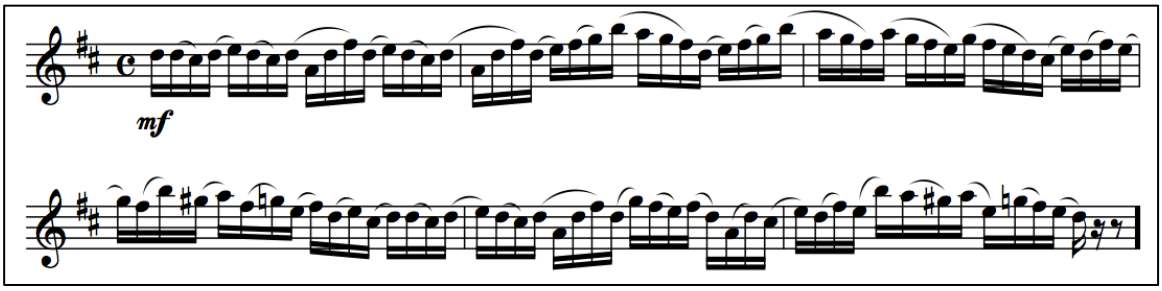

Figure 1: The slurring excerpt.

Model recording

The model recording demonstrated this excerpt at 144 beats per minute. Therefore, the smallest subdivision, the sixteenth note, occurred at a rate of 576 notes per minute.

Excerpt II: string crossings

String crossings frequently complicate passage work for string players. Addressing the bow to each string so as to produce a clear tone presents a challenge to the bow arm. At the same time, the fingers of the left hand must also move between strings, and passages based on arpeggiated chords, such as this one, may encourage players to think about the physical execution of the chords within the left hand. Typically, however, string crossings are considered to be primarily a right (bow) arm problem, with some added left hand element. For example, Fischer (2004) discusses string crossings in approximately twenty different places (the exact number depending on which are considered parts of the same discussion). Of these, only one (p. 122) focuses on the left hand aspects of string crossings; five (pp. 34, 83, 92, 105, and 270) address both hands jointly, mention the left hand as a complicating factor to the right hand, or mention left hand aspects as part of a right hand discussion; the rest focus on the bow arm alone, either mentioning the left hand in passing or ignoring it completely.

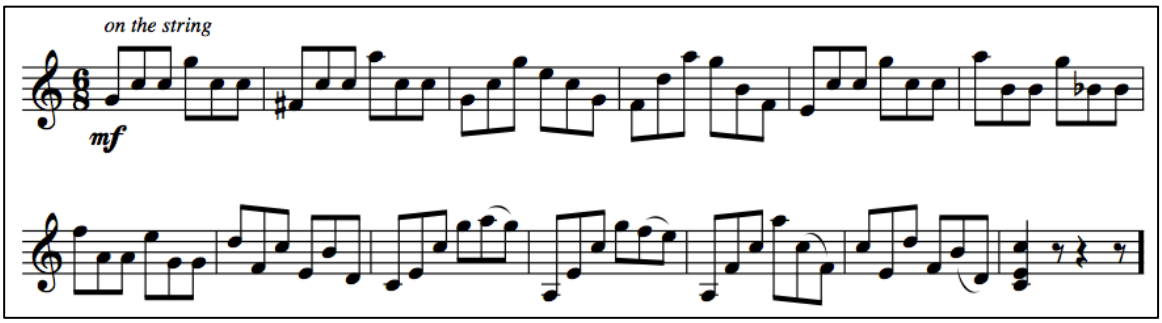

Figure 2: The string crossing excerpt.

I marked this excerpt "on the string" to ensure that players would not attempt to play it using either spiccato or sautillé bowing techniques (bow strokes that to varying degrees employ a bouncing motion). This technique, while musically appropriate to certain contexts, adds another technical factor across the entire excerpt, a potential confounding technical problem that would have also been found exclusively in this excerpt. Worse, if some but not all of the players had chosen an off-the-string bowing style, it could have led to a great deal of unexplained variability within practice on this single excerpt. Left unmarked, the passage is stylistically ambiguous; with the marking, the intended bow stroke is clear.

Model Recording

The model recording demonstrated this example at 196 beats per minute. Therefore, the eighth note, the smallest subdivision, occurred at a rate of 588 notes per minute.

Excerpt III: shifts

This excerpt's extreme register changes require the player to shift. Shifting is a string technique that extends the pitch range available on any of the instrument's strings. By default, a player typically plays in "first position," with the hand positioned near the

instrument's scroll; when shifting to another position, the player moves the left hand closer to the face, so that when a finger is placed on any string, the resultant pitch is higher than it would be if that same finger were used in first position. I anticipated that some participants would choose to execute lower-pitched notes by playing on lower-pitched strings in order to minimize shifts; in composing the lower-register gestures, and in choosing the overall descending shape of the high-register notes, I chose pitch sets that did not fit easily into any one position. Even players who chose to stay in higher positions, rather than leap to and from first position, would still need to execute small shifts, though they would also introduce some degree of string crossing to their practice.

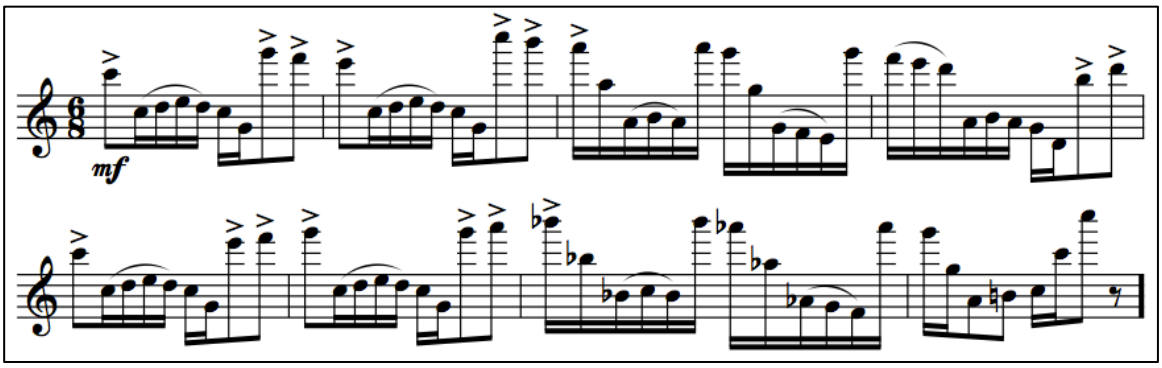

Figure 3: The shifting excerpt.

Deciphering the pitches in high registers can be a separate reading challenge, and even with shifts, this excerpt includes a few necessary string crossings. I considered employing less drastic register changes, coupled with a marking indicating that the entire passage should be executed on a single string, as a way to remove this problem, but rejected this idea for several reasons. First, if an alternative passage were to confine players to the E string, it would still include the high notes. If an alternative passage were not to be performed on the E string, it would entail playing it on one of the other, lower strings; playing in high positions on lower strings is a much less common task in violin music than playing high on the E string, and introduces the new, potentially significant technical problem of tone production in high positions on low strings. Second, whereas

professionals and advanced students may have encountered fewer prior instances of reading extremely high pitches than of reading pitches in the staff, they should still be sufficiently familiar with these notes to be able to read them relatively quickly.

Third and most important, a marking requiring the material to be performed all on one string seemed to be a more invasive marking than, for instance, indicating that the String Crossing excerpt was to be played on the string. The "on the string" marking dictates a technical aspect to the player, but it also indicates a composer's intended articulation, a routine situation in classical music. However, the choice of where on the instrument to execute a passage is usually left to the player; exceptions tend to be dramatic melodies in which the composer specifically selects the tone of the high G (or occasionally D) strings. Instructions that a fast passage with many register changes was specifically to be executed on the G string would be highly atypical of the violin repertoire. In addition to introducing the new technical problem of tone production in high positions on low strings described above, I thought it would be highly likely that many participants would simply disregard this uncharacteristic instruction. Thus, I chose to compose an excerpt that involves shifts more typical of violin music, wherein the high register itself demands some movement into high positions, and to intersperse lower-register material that did not fit conveniently into the same positions as the higher-register material, even when executed on lower strings.

Model Recording

The model recording demonstrated this excerpt at 64 beats per minute. Therefore, the sixteenth note, the smallest subdivision, occurred at a rate of 384 notes per minute. This is somewhat slower than the subdivision rate of the other two excerpts, but the physical action of shifting to high positions at the other excerpts' tempos seemed unrealistic. I wanted the model recordings to demonstrate the music at an extremely fast tempo, but not one so far from playability that participants would immediately dismiss it.

Even this tempo pushed that limit; several participants (particularly those in the professional group) actually giggled at the first playing of the model recording. Additionally, I made slight modifications to the articulations used in this excerpt's model recording. Specifically, I added staccato dots to the accents on the first notes of measures one, two, five, and six, and added accented staccato marks to the final two sixteenth notes. Without these modifications, Finale's playback feature rendered these six notes with an unnatural legato that was uncharacteristic of real violin playing. Participants saw the excerpt as printed above, but they heard the example with the indicated extra articulations.

Excerpt IIIa: shifts (high school variant)

After a pilot participant representing the high school level had exceptional difficulties with the shifting excerpt, I created a modified version of the excerpt to be used with this group. I transposed it a third lower, from the key of C to A. This change did not remove the need to shift, nor bring the register into familiar territory that participants could play without practice. However, it did remove a full ledger line, and it made the entire excerpt reachable from seventh position and below; because seventh position is where a violinist's first finger is located on the string's first harmonic (its midpoint), this is not an uncommon position for developing violinists to practice. The key of A is also moderately more familiar to many student violinists than the key of C.

The slightly lower register also pushed a few portions of the lower-octave material from the A string onto the D string. That is, the new version was too low to be performed without adding yet more string crossings. Therefore, I rearranged a few of these lower voices such that they still required shifting up and down the instrument, but were in a middle octave that did not require these extra string crossings. I made a new model recording of the excerpt using the same tempo settings and added articulations.

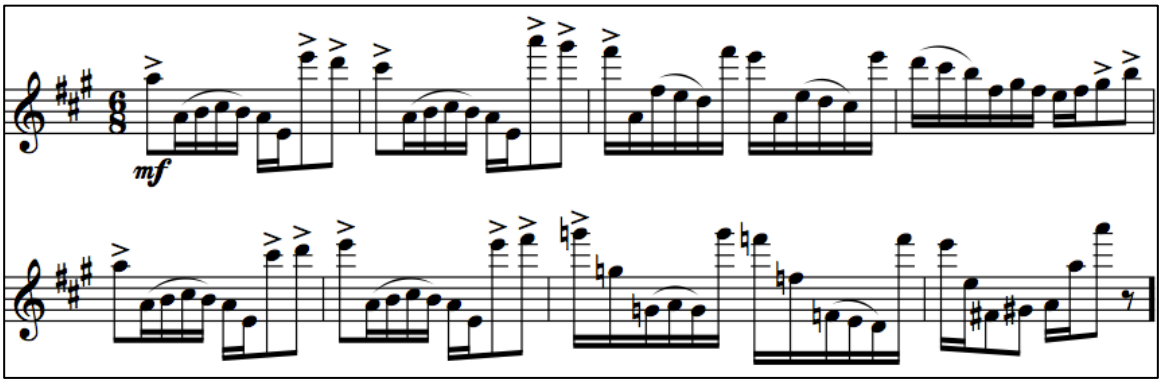

Figure 4: The shifting excerpt, high school version.

Transcribing practice videos

I watched the videos of participants' practice sessions multiple times. Particularly near the beginning of data collection, I tried several analysis methods, watching the video at a variety of detail levels, including just watching, watching while taking notes, and actually transcribing what participants played. It became clear to me that choosing semi-structured procedures for taking notes on participants' behaviors was very comfortable for selecting salient pedagogical features. That is, many of the procedures I tried amounted to watching the video while determining what looked important, resembling a teacher's perspective during a lesson. However, I also found that I tended to selectively attend to these salient features at the expense of others, features that nonetheless were usually present to varying degrees and that at other times themselves became my focus. In short, I seemed to be generating both incomplete and highly subjective descriptions.

Ultimately I settled on the finest-grained, most detailed approach because I felt that this technique of analysis allowed me to capture events in the videos the most consistently and reliably. I watched each video with a transcription foot pedal operating F4 transcription software. I described what I saw in the videos, breaking the descriptions into units reflecting natural units of activity as much as possible. When I saw participants play material from the excerpt, I wrote what I saw them play, as well as any prominent

features of the performance. When they engaged in other behaviors, I wrote what I saw them doing. From time to time, I wrote notes to myself enclosed within [brackets]. Each time I saw a clear transition of activity, I hit enter, prompting the transcription software to insert an end-of-line time code. Each paragraph—that is, each description of a coherent unit of activity separated by a time code and a new paragraph—I called an Event.

I quickly developed both a set of different types of events and a system for describing what happened during each event. I simply transcribed dialogue, both in the question blocks and at instances when participants spoke during their practice. For most other types of activity except for playing, I simply wrote, in as few words as possible, what the participant was doing ("Marks Part," "Adjusts Metronome," etc.). When participants played, my description was somewhat more involved. If they played material that was not present in the excerpt they were practicing, I described as succinctly as possible what it was they played (e.g., "Plays two open Gs, then an F on the D string"). Most of the time, though, participants' playing events consisted of a portion of the excerpt, played to a greater or lesser degree of accuracy, and sometimes played in ways that did not exactly match the score.

For these playing events in which participants played material from the excerpt, which accounted for the majority of all events, I wrote "Play:" followed by a code of the form "$X_1.Y_1.Z_1$ to $X_2.Y_2.Z_2$." In this code, each X corresponds to a measure number, each Y to the beat within the measure, and each Z to the subdivision within the beat; the first code (subscript 1) was the first note, while the last code (subscript 2) was the last note. For example, the accented B and D at the end of the first line in the shifting excerpt (Figure 3) are located at 4.2.3 and 4.2.5. Applying only to the shifting excerpt and the last note of the string crossing excerpt, when a note extended more than one subdivision, I referred to the last subdivision of the note when using it as an ending point. Thus, if a participant played only the accented B and D in measure 4 of the shifting excerpt, I would write "Play: 4.2.3 to 4.2.6." Finally, I added sentences to the end of the description

as needed to record any other notable features present in the participant's playing. Figure 5 shows a brief extract of a practice transcription, including several different types of descriptors.

Play: 1.1.1 to 6.4.1. <00:23:45>

Play: 1.1.1 to 6.4.1. Tempo: q=106. <00:23:59>

One minute warning. <00:24:00>

Play: 1.1.1 to 6.4.1. <00:24:15>

Play: 1.1.1 to 6.4.1. Starts around q=112. Includes 5.1.2 in preceding slur, then includes 5.1.3 in the following slur. 5.3.1 is unclear [coordination problems]. <00:24:29>

Play: 2.4.4 to 6.4.1. Repeats first note once. <00:24:40>

Play: 4.4.1 to 6.4.1. Much slower. Tempo: q=69. <00:24:50>

Play: 4.4.1 to 6.4.1. Alters rhythm: Plays pairs of notes as long-short. <00:24:57>

Play: 5.1.4 to 6.4.1. Alters rhythm: same as previous event. Plays 5.2.3 as an E rather than an F#. <00:25:04>

Performances. <00:25:07>

Performance 1. <00:25:20>

Figure 5: An excerpt from a practice transcription of the slurring excerpt. The time codes in brackets (< >) were added by the transcription software, and represent the time in the video at which I pressed the enter button, at the end of the event being described.

I developed rules governing when to begin a new event. For part marking, metronome use, or other behaviors that did not involve playing, choosing where to begin or end an event was usually self-evident. Participants would stop what they had been doing, pick up a tool and use it, then set it down and do something else. When participants picked up a pencil or metronome, but then did not make any marks or adjust the metronome, I still recorded that behavior as a part marking or metronome event, but made a note that no actual changes were made. In rare instances where participants stopped one non-playing activity, engaged in another, then went back to the first, I included notations for each event, as seen in Figure 6. When participants stopped playing, sometimes lowering their instrument, and simply looked at the score for a noticeable period of time, I wrote "Inspects part." I did not define an exact duration that such a pause was required to last before I labeled it as inspecting the part, because individuals

displayed considerable variability in the pace of their activities. Instead, I labeled these events when they represented a noticeable interruption in participants' established sream of behavior.

Play: 9.1.1 to 12.1.3. Inserts grace-note C (11.1.3) before 11.1.2. Plays 12.1.3 as a C rather than a D. Tempo: dq=66. <00:28:29>
Play: 12.1.1 to 13.1.2. Plays only bottom two pitches of last chord. <00:28:32>
Marks part. <00:28:39>
Puts instrument up as if to play, then right back down. <00:28:40>
Marks part. <00:28:46>
Play: 3.1.1 to 3.2.3. <00:28:48>
Play: 3.1.1 to 4.2.3. Faster. Tempo: dq=92. <00:28:51>
Play: 3.1.1 to 4.1.3. Staccato. Plays 4.1.3 as a G rather than an A. <00:28:53>

Figure 6: An excerpt from a practice transcription of string crossing excerpt, from the same participant as the material in Figure 5.

Deciding when to start and stop playing events was also fairly clear most of the time. For example, during the practice session described in Figure 5, each time the participant played, he or she reached note 6.4.1, the last note of this particular excerpt. Thus, subsequent material clearly represented a new unit of activity, a new decision to play something. Even when participants did not reach the end of the excerpt, they typically stopped playing at some point X, then resumed playing at a point in the score Y that was at least several notes prior to X, clearly suggesting an interruption of activity, as seen in Figure 6.

At times, it was less clear whether to record a playing behavior as a single event or as multiple, discrete events. Often this ambiguity arose from repeated notes. Participants would play a single pitch multiple times, a pitch that would then turn out to be the first pitch of the material that would follow. They would also often repeat the final pitch several times after finishing, and when they made an apparent pitch error on that last note, the repetitions would often be played at the corrected pitch. Sometimes, participants would similarly repeat notes internal to the material, possibly including pitch

adjustments, before continuing without any other interruption. In all of these situations, I counted the behaviors as single events, noting the repeated notes in the event's description. Like internal repetitions, sometimes participants' pauses made it ambiguous whether to divide an event. Again, unless some other behavior such as lowering the instrument intervened, I created only a single event and noted the pause in the description. In general, as long as the forward motion through the musical material continued after a pause or internal repetition, I created one playing event.

When a participant actually backed up in the music, though, I created a new event. That is, if a participant played 10.1.1 (beat 1, note 1 of measure 10) of the string crossing excerpt (Figure 2, page 69) as a C, then repeated it as an A and continued without otherwise interrupting their activities, I recorded a single event, noting the repetition with a corrected pitch in the description. However, if the participant continued and played the E on 10.1.2 before returning to the beginning of the measure, I recorded two events, the first including a wrong note and ending on 10.1.2, the next starting on 10.1.1 and including only the correct pitch. Skips forward in the music were uncommon, and I considered them to trigger new events unless they were part of a pattern of skipping material systematically. For example, participants occasionally isolated the upper voice of the shifting excerpt, skipping all of the music in the lower register. I recorded these skips as parts of a single event, noting the behavior as, "Omits notes: Plays upper voice only." Likewise, if a participant skipped just a single note, I would record, "Omits note: skips X.Y.Z."

As a rule, I did not assign playing events with labeled (coded) locations in the music to single notes. In most situations, repeated single notes occurred as repetitions of the first or last note of an event, and I noted them as described above. In other situations, I usually could not unambiguously say where in the music a participant played if they only played one note or repeated a single pitch multiple times. For example, if a high school student, having just finished the shifting excerpt, played the A on the E string

twice, then started on the pickup to measure 4, it was unclear if they were playing the first note of the excerpt, the first note of the second line, or perhaps even the penultimate note of the excerpt. One could even argue that in this situation, the participant was not even playing one of the three notes from the excerpt, but was instead playing the A as a tonic reference before starting the excerpt. In general, therefore, I simply described this behavior as "Play: Plays an A in first position on the E string twice." (Sometimes, I made a bracketed note to myself that this pitch could correspond to notes in the excerpt, in this case 1.1.1 or 5.1.1.) There were two exceptions to the rule that I did not assign locations to single notes. First, the chord at the end of the string crossing excerpt was recognizable as the only instance of a chord. Moreover, as a chord, the argument that a participant could simply have been playing the note as a reference pitch rather than a specific location in the music was unconvincing. So if participants played the chord in isolation, I recorded an event starting at 13.1.1 and continuing to 13.1.2. Second, if a participant (1) started at the same location repeatedly, (2) one repetition included only one note, and (3) that repetition was followed by a non-playing behavior, so that I could not describe it as repeating the first note of the next event before starting, I considered the contextual clues compelling enough evidence to say that I knew where specifically the participant was playing.

In this and other respects, I used context when needed to describe behaviors. Figure 7 shows a hypothetical example. If a participant's practice of the string crossing excerpt included material that could be notated as shown, I would have recorded four events, here separated by double bars. The first, second, and fourth events clearly represent the first two measures played with a systematically altered rhythm. I would have created events with the description, "Play: 1.1.1 to 2.2.3. Alters rhythms: plays each beat as long-short-short." (The exact description might vary from instance to instance; I describe my method for resolving such differences below.) The third event, though, is only one beat. In isolation, one could argue that the rhythm was unaltered, the tempo was

faster, and the participant merely did not rigorously constrain the last note to its printed value (a common enough problem on last notes). In context, though, it is clear that the same rhythmic alteration that is present in surrounding events is still in operation on the third event, and I would have recorded it as such.

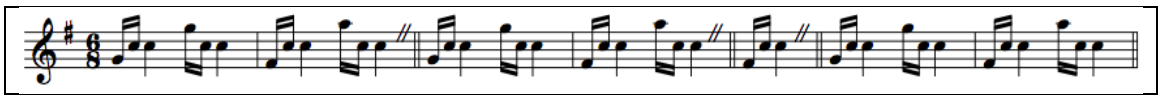

Figure 7: A hypothetical example of rhythmic alterations to the string crossing excerpt. Material that I would have recorded as distinct playing events is separated by double lines. In this situation, I would have described all four events as including the same systematic rhythmic alteration.

A full, exhaustive list of the descriptors I used in transcribing practice behaviors or definitions of each behavior would be neither practical nor particularly informative here. The procedure described above led to the creation of nearly 12,900 events just from portions of the videos that included practice, excluding performances, question blocks, or instructions. Many of these events included unique mistakes, idiosyncratic behaviors from a single participant, and other behaviors that led to unique descriptions. Rather than rigorously define behaviors, I tried to use as regular, repetitive descriptions as possible while still making distinctions between behaviors that could become important to distinguish. I planned to consolidate descriptions, to collapse categories, later in the analysis procedure. Thus, in transcribing the earliest recordings, I often specifically noted exactly how many repetitions of the first note the participant made, as well as whether or not they seemed to be in rhythm with the subsequent material. As it became clear that this system (1) was overly detailed, (2) was inconsistent due to participants' rhythmic variation, and (3) would require extensive reliability work, I switched to only noting whether participants repeated the note once, twice, or several times. By the time I reached the analysis phase described below, I collapsed even these three descriptions, only including "repeats first note" in the final description.

Behavior coding and analysis

After transcribing the videos, I had 35 text files that totaled over 295,000 words and nearly 17,000 paragraphs. Given this enormous quantity of text, I did not want to engage in the error-prone process of copying it into a spreadsheet. Neither did I want to hand-code the descriptions in that much code, even using Excel, Atlas.ti, or another program. My concerns obviously involved efficiency—the process could get very long. But also, I was concerned that, in addition to simple copying errors, I would introduce changing standards in coding as I worked through the documents, and that I would spend a great deal of time making decisions and distinctions about which narrowly-defined categories to keep and which to collapse.

To address these concerns while efficiently moving the data into a more analysis-friendly format, I wrote two Python scripts. As an inexperienced programmer, I am sure that these scripts represent inelegant work, but they served to split the text file, to extract relevant information from each line, and to help me begin to analyze the data across participants.

The first script took each practice description as input and created an Excel workbook containing a worksheet with data on all the events and the practice session as a whole, another set of worksheets for each practice session, worksheets for specific non-playing behaviors that seemed promising for analysis, and graphs of each practice session similar to those created by Maynard (2000). In the process, this script added an index to each event, extracted first and last notes of playing events (when applicable), converted these from the X.Y.Z format to single integers, converted the time codes at the end of each event to an integer measured in seconds, and performed various other transformations to facilitate further analysis. I took the output for each participants' three practice sessions and compiled them into one master, composite spreadsheet. This process allowed for the direct comparison of many of the variables described by prior researchers including Duke et al. (2009) that I report in the next chapter.

Additionally, in analyzing the videos, I saw many examples of apparently planned behaviors, including ways of playing the music that varied systematically from the notated material I had presented participants. In the pedagogical literature, such behaviors are commonly referred to as "practice strategies." In the discussion above, for example, Figure 7 depicts a literal notation of the string crossing excerpt, played with a systematically, strategically altered rhythm. This technique "is very helpful for mastering fast passages with complex string crossings or other coordination challenges" (Nardolillo, 2015, p. 108). Although I had not until this point specified which strategic behaviors I would be looking for, I had expected an assortment to be present and to be among the behaviors of interest, behaviors distinguishing practice of the different excerpts, and possibly distinguishing the practice habits of the differing groups as well.

Besides "practice strategies," I also saw a variety of behaviors during practice that consistently recurred and that also seemed noteworthy, even if they neither were frequently mentioned as strategies in the pedagogical literature nor appeared intentional. The most common of these were repetitions of the first, last and select internal notes in a passage.

To facilitate analysis of noteworthy practice strategies, both those that could be considered strategic and others, I wrote a second Python script. This script took the compiled list of almost 13,000 practice events (as a comma-separated text file) and returned a similar list of events, with the specifics and details replaced with more general behavior tags. It operated in several steps. First, all of the text was scanned sentence by sentence, and certain words and phrases, specified *a priori*, were replaced with tags (e.g., changing "4.2.1" to "<<NoteTag>>"). After replacements were made, the sentence was rescanned to determine whether any of the resultant phrases were in the dictionary of replacement phrases (e.g., changing "Slight <<SwingTag>>" to "<<SwingTag>>"). This process was applied recursively; as long as the sentence that emerged from the procedure was different from the one that went in, it was scanned again.

Once the sentence had stabilized, it was compared to a second dictionary of behavior codes. These codes included phrases such as “Repeats <<FirstNoteTag>>.” For each phrase in the dictionary, if that phrase was present in the sentence being examined, a note was made in the entries for both the phrase and the sentence, linking the two to each other. In addition, if other phrases were found within the sentence, or if the sentence as a whole represented a new combination of preexisting codes, the new sentence was assigned a code number and added to the dictionary. The resulting dictionary was exhaustive; only exact duplicate entries were assigned to a code rather than being added to the dictionary. It was also extremely long, as each unique combination of behaviors and each time I described something with a new wording led to a new entry in the dictionary.

After I ran the composite spreadsheet of practice behaviors through this second algorithm, I noticed that several similar behaviors each accumulated a small number of repeated entries; this occurred when I had used similar but not identical wordings in my original video transcription. By adding one or another phrase to the dictionary of replacement phrases, I could consolidate or collapse these categories. Likewise, by adding a phrase to the list of behavior codes, I could capture every instance of it, not merely those that matched exactly. That is, on its own, the algorithm would create new codes for “Repeats <<FirstNoteTag>> once,” “Repeats <<FirstNoteTag>> twice,” “Repeats <<FirstNoteTag>> several times,” etc. By seeding the list with “Repeats <<FirstNoteTag>>,” though, I could preemptively create a single category to catch all these variants, even if new codes were created for each sub-category as it arose. By repeatedly running this script after editing it by adding to the seed dictionaries for tags/replacement text and behavior codes, I was able to collapse across categories both efficiently and in a consistent manner.

The resulting Excel document contained over 10,000 distinct event codes. Almost 85% of these were unique descriptions, occurring only once in the dataset, and another

7.8% occurred only twice. For the purposes of this study, I was interested only in codes that occurred often enough to be considered a trend, and that also seemed to reflect a "behavior," that is, a distinct activity that participants engaged in, as opposed to minor variations or artifacts of my descriptions. I was not interested in analyzing things that only happened once, twice, or a dozen times across almost 13,000 distinct practice events. I chose to include only behavior codes that occurred in a minimum of 0.5% of practice events, which for this dataset translated to codes seen in at least 65 events. I based the cutoff on individual instances of the behavior code across the entire dataset, not on how many individual participants displayed it. Although this was to some extent an arbitrary cutoff point, it seemed to match the data fairly well; codes close to but failing to reach this cutoff point generally were also excluded by the other rules described below. The most frequent codes that did not make this cut but that would otherwise have been included were "inspects music" (51 events) and "staccato" (35 events).

I was not interested in counting specific variations of classes of behaviors, such as "Repeats the first note [a number of] times." Collapsing such details was one of the purposes of writing this code in the first place. By seeding the Python script that I used to collapse categories, I had introduced blanket behavior codes (in this case, "Repeats <<FirstNoteTag>>") that would capture all descriptions that included those seeds. In this situation, even if there were many instances of the specific behavior, the entire collection would be a subset of a broader behavior; that is, every event that had been labeled as an example of the behavior code "Repeats <<FirstNoteTag>> twice" would also be included in the seeded code "Repeats <<FirstNoteTag>>". For this reason, I excluded from further analysis any behavior codes that were entirely subsets of other codes, even when there were quite a few instances of that behavior. I also manually collapsed two categories that the Python script retained as distinct behavior codes: "includes <<LastNoteTag>> in preceding slur" and "includes <<NoteTag>> in preceding slur." These two categories

reflected the script's early labeling of the first and last notes of a playing event separately from other notes, but in this case such a distinction did not seem warranted.

Several frequent codes reflected notes and clarifications rather than participants' behaviors. For instance, I had written "correct pitch" when a participant played something correctly after making a repeated error, and had similarly written "printed rhythms" when participants stopped using systematically altered rhythmic variations. Other frequent codes related to the protocol itself, such as those that were created when the Python script encountered the five-minute and one-minute warnings. Both of these types of tags reflected my decisions in designing the protocol or recording the data rather than participants' practice behaviors, so I omitted them from any analysis.

For approximately the middle half of the data collection process, I had taken quite a few notes on exactly when and to what positions participants chose to shift. It became clear, though, that these data were of limited reliability because participants sometimes moved in the camera frame, turning themselves away so that determining exactly in what position they were playing was impossible. Also, almost all shifting descriptions were naturally situated in the excerpt that I had expressly designed to include shifts, so any findings related to shifting would be more tautological than informative. Moreover, after taking these detailed notes on a significant subset of participants, it became clear that in addition to being of limited accuracy, this information was far more detailed than needed to answer the present research questions, and was also extraordinarily time consumptive. I ceased trying to assess shifting decisions to the same level of accuracy, and decided not to go back and add shifting information to early participants' video transcriptions. I also therefore excluded codes relating only to shifting descriptions from analysis.

Finally, in deciding which codes to include or exclude from analysis, I had to confront one limitation imparted by my choice of participants. Because many detailed practice studies have used pianists as the musician sample, and because I am a violinist and string educator and felt that some of the results of practice studies did not reflect

typical string practice behavior, I chose to conduct this study using violinist participants. As such, I had them play on their own instruments and recorded their performances rather than using MIDI-enabled equipment. Therefore, unlike some previous researchers, I do not have detailed data on note timing or pitch. Although I did keep records of the deviations I perceived from regular timing or notated pitch, I do not have regular measurements of either. I experimented with Apple's Logic and other commercially available programs with advertised capacities to extract MIDI (or comparable) data from audio recordings, but I found that these programs generated copious false positives and incorrect pitches, and were incapable of recording slurring or other articulation information. The advice I received from colleagues and numerous online resources also suggested that, despite progress and the development of programs that can partially do the task, the creation of a computer algorithm to reliably take dictation is still an unsolved challenge in computer science (Mauch et al., 2015; Sukhostat & Imamverdiyev, 2015). Consequently, for the present purposes, I will avoid outcomes and focus on behaviors that seem to reflect decided intent. That is, I focus on data that reflects the decisive, proactive behaviors that participants engaged in, and I avoid reporting the outcomes of those decisions. Likewise, I will abstain from addressing hesitations, pauses, or timing of notes, except where it is assessable because the participant used a metronome.

To summarize, after extracting general behavior codes using the Python script, I eliminated those codes that (1) appeared too infrequently to represent patterns of behavior, (2) were entirely subsets of another, already included behavior, (3) reflected my decisions rather than participants' behaviors, (4) pertained only to shifting decisions, or (5) both relied on my subjective assessments of participants' pitch or timing accuracy and reflected participants' success in what they chose to do rather than the choice itself. The remaining behavior codes, those included for analysis, are listed below. Each item in the list first describes the behavior, followed by the computer's extracted label in parentheses.

- Repeats first note (Repeats <<firstnotetag>>)
- Repeats last note (Repeats <<lastnotetag>>)
- Repeats an internal note (Repeats <<notetag>>)
- Marks part (<<markingtag>>.)
- Adjusts metronome (<<metronometag>>.)
- Plays with systematically altered rhythms (<<altersrhythmtag>>)
- Plays with different bowings (<<altersbowingstag>>)
- Systematically adds double stops (<<doublestoptag>>)
- Plays the music pizzicato (<<pizztag>>)
- Plays in a different octave than the printed one (<<octavetag>>)
- Plays only the required open strings, omitting left hand fingers (plays open strings only.)
- Plays the material backwards, with the first note played being the last one printed (<<backwardstag>>.)
- Includes a note in the slur preceding it (includes <<notetag>> in preceding slur.)
- Plays with the metronome on, but at a different tempo (ignores metronome.)

In addition to these behavior codes collected by the second Python script, I included behaviors in my analysis that I extracted directly from the practice transcriptions by the first Python script. These behaviors included:

- The practice session duration in seconds. Although I aimed to stop participants at 10 minutes, I also allowed them to reach a breaking point before stopping them, and wanted to verify that there were no systematic differences between groups or excerpts in the actual amount of time participants were allowed to practice.
- The number of playing events (performance trials) in the practice session.
- The number of complete playing events in the practice session, those that started at the beginning of the excerpt and went all the way to the end.

- The amount of time in seconds spent in playing events, as opposed to marking the part or other non-playing activity.
- The amount of time in seconds during which the metronome was turned on.

Having extracted count of total playing events, the amount of time spent playing, and the total time in the practice session, I converted all extracted variables from raw numbers to percentages.

Finally, in watching the videos, I identified two behavior patterns that I wanted to investigate more thoroughly, and that in some respects represent opposite forms of behavior. While other behavior codes were defined by observable actions and deviations from simply playing what was on the page, these patterns were instead characterized by sequences of events that together created the behavioral structure of interest.

The first pattern I saw is what Maynard (2000, 2006) identified as Practice Frames, a concept derived from the Rehearsal Frame described by Duke (2009). A rehearsal frame is an analytical construct describing a sequence of activities that an observer identifies within a class or lesson, activities that are all executed in pursuit of a common goal. In a rehearsal frame, the teacher identifies a target behavior, whether that be a specific section of the music, a technical or stylistic change of execution, or some other way in which she would like her students to perform differently, then engages in a series of activities that give her students the opportunity to effect that change. At some point thereafter, the teacher allows the flow of activity to continue and attention moves away from the target behavior; in an effective rehearsal frame, this only happens once the students have demonstrated reliable change in the target behavior. I have described rehearsal frames in terms of the teacher's intentions and goals, and identifying these targets together with the effectiveness of the teacher's behaviors in effecting the desired changes is one of the primary reasons for creating the analytical framework; however, it is important to remember that it is the observer who identifies this structure in the

interactive behavior of the teacher and the student or class. The observer infers the teacher's intentions and targets from the things she chooses to say and to direct her students to do, and from the changes that do or do not actually happen before the flow of action moves to a new section or aspect of the music.

Maynard (2000, 2006) adapted this analytical technique to individual practice. Practice frames are more difficult to assess than rehearsal frames, because while a teacher gives instructions about what to do and possibly how to do it, musicians in a practice session almost never verbalize their intentions. Perhaps for this reason, Maynard chose to focus on one form of frame, or one subset of frames—those in which the target is identified by *what part* of the music the musician was practicing, not *how* it was practiced or *what change* that musician wanted to make. That is, Maynard identified spots within the practice session wherein individuals focused repeatedly on the same small subset of a larger piece. While this pattern of behavior is indeed interesting, it is important to realize that it is only one class of practice frame. Playing an entire work repeatedly—or even once—could count as a practice frame if, by analogy to Duke's rehearsal frame, the time period during which that work occurred was characterized by pursuit of a common target (e.g., lyrical phrasing). For this reason, when talking about the kind of practice frame that Maynard identified, one characterized by repeated work on a small subset of the music, I have chosen to use the term Detail Frame. With that caveat, the occurrence of detail frames seemed to be a potentially important practice trait in distinguishing practice on one or another type of material or by individuals with differing experience levels. Frames seemed relevant both because they signaled a transition to a specific mode of working and because they provided direct evidence of what material the individuals in question were working on.

In many respects, the opposite of a detail frame is a complete, beginning to end performance. Listed above, this was one of the behaviors that I had already identified for analysis. However, in watching the practice videos, I frequently saw a behavior that could

be considered an interrupted performance, complete or otherwise. As described earlier, when a participant played a portion of the music, played an incorrect note and then repeated it at the correct pitch, and then continued, I described this as a repeated note with a pitch alteration within a single event. Likewise, if a participant hesitated or paused before continuing, I described the behavior as a single event. However, if that person backtracked in the music after the pause or repeated note—if the participant moved backward in the score even one note—I recorded two separate events. This system created consistent rules for describing practice behavior, but in events where participants backtracked by only a single note, it may not have reflected participants' understandings of their own behaviors.

For example, early in one practice session of the slurring excerpt (see Figure 1 on page 68), one of the high school participants played what appeared to be an attempt at a complete, beginning to end performance. Figure 8 (below) shows an approximate literal transcription of what she actually played. This example illustrates how my rules for defining the starts and ends of a playing event may or may not have arbitrarily split behaviors that the participants thought of as single performances into multiple events. Comparing the two figures also shows why I chose not to analyze details of pitch and rhythmic accuracy: there are numerous places where I had to make judgment calls, such as whether the marked G-natural in the last measure was actually a G or a quite out of tune G#. Such detailed assessments seemed beyond what the present research questions called for, particularly when they were both subjective and of limited informative value.

In Figure 8, the participant plays from the beginning to the first note of the fourth beat of the second measure (as notated in the original music, Figure 1). Along the way, she hesitates before beat 3 of measure 1 and before the final subdivision of beat 3 of measure 2. She also slurs incorrectly and has a coordination problem on beat 2 of the second measure that resulted in an open A sounding briefly, after which she repeated the last note played before continuing. However, what the participant may have perceived as

a second hesitation around beat 4 of measure 2 actually manifested as playing D-E, pausing, then returning to the D and playing it again. Because of this backtracking, I recorded one playing event that ended after the first note of the fourth beat of measure 2 (shown in Figure 8 as the bracketed material labeled "A"), then recorded a new event beginning one note earlier (the bracketed material labeled "B").

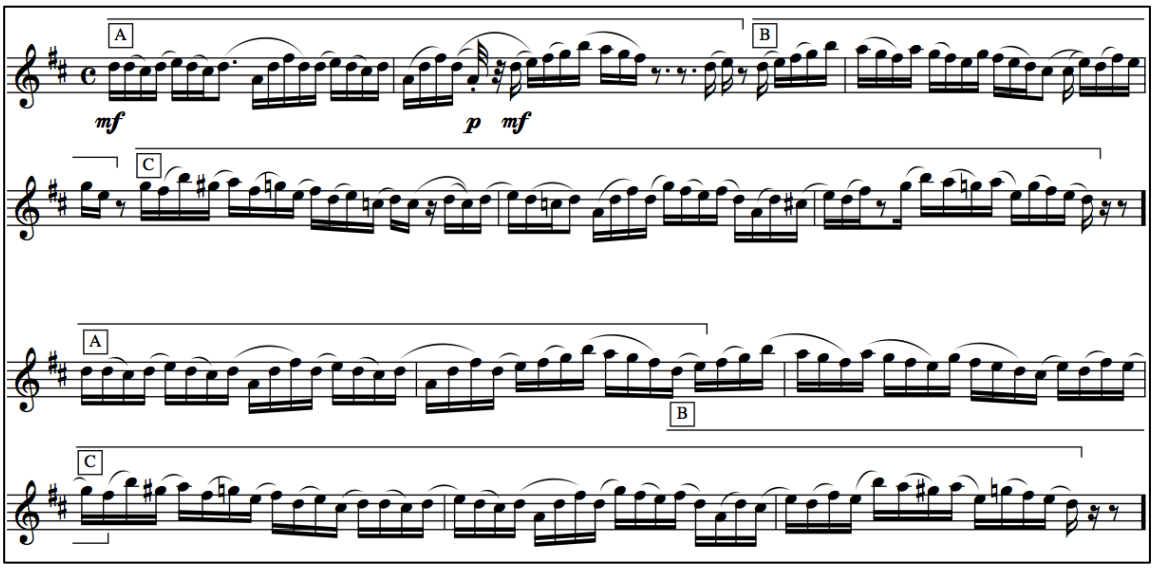

Figure 8: Above: Literal transcription of an excerpt from a practice session displaying "ratcheted" practice behavior, together with numerous errors. Below: When attempts A, B, and C are mapped onto the original score, the participant's apparent intent to play from beginning to end is more clearly visible.

One could object to my breaking this material here, drawing a somewhat arbitrary dividing line in what otherwise looked like a single activity, but as I explain above, I wanted consistent rules that I could apply both to clean, organized practice sessions as well as to practice like this that was more difficult to describe. One could also object to my decision not to create a new event after the *piano* A in measure 2, particularly if it were interpreted as a wrong note (A rather than E) instead of as an incidental sound resulting from a coordination problem, in which case backtracking would be evident here too.

Continuing on, the participant holds and then repeats the last note of beat 3 in measure 3, then plays a solid, confident, and incorrect E on the second note of measure 4. She pauses, starts at the beginning of the measure (one note earlier), then proceeds. At the end of the measure, in beat 4, she plays the second, repeated D as a C, then repeats it at the correct pitch and continues. Because repeating a single note did not count as moving backward, I did not create a new event; again, one could reanalyze that material as *skipping* the repeated D and playing the note after, then restarting one note earlier, which would have warranted a new event. She then proceeds to the end of the excerpt, albeit again with pauses, hesitations, wrong notes, and altered slurs.

It is precisely because of the ambiguity of these distinctions that (1) I decided not to rigorously analyze behavior codes that arose from these subjective assessments, and (2) I became interested in practice characterized by broken, almost staggering forward progress. This behavior seemed more common in the slurring excerpt, and perhaps in the shifting one, than in the string crossing excerpt; I also suspected that professional participants engaged in less of it than other participants. To some extent, the details of the analysis are inconsequential. By changing one rule (allowing one-note backpedalling without creating a new event) or altering an interpretation or two, this example could have been described using as few as one or as many as five different events. It is precisely the complex, struggling behavior, rather than the exact product of my analytical rules, that is of interest in this episode.

It seems clear that the participant intended to play from the beginning to the end, but that calling this behavior just one event without further explanation would omit a critical aspect of the behavior. I have seen this behavior in my students as well. They have often explicitly described the inference I made about this participant's intentions: they often construe similar performances as one complete event. The moments where they backpedal, repeating a note or two before continuing, seem almost like mental erasures, as if the original mistake simply did not contribute to their practice; my students

often do not even recall having interrupted their performance at all. I have begun to call this behavior pattern "ratcheted" practice, because although small backwards moves interrupt the performance, only the forward motion seems to be perceived by the person practicing as counting towards the output of their work. Just like detail frames seem to indicate a distinct mode of behavior, these ratcheted practice events seem to warrant further investigation. I therefore created rules for deciding whether each playing event was part of a detail frame, an example of ratcheted practice, or neither.

To be considered part of a detail frame, an event had to be part of a series of repetitions of a small portion of the excerpt, as defined by four criteria. (1) A series of repetitions was defined as at least three playing events in a row that all shared common material. Playing exactly the same music three or more times in a row counted, naturally, but so did playing material that started or ended on different notes but that shared a core, an overlapping section of the music. (2) Marking the part, adjusting the metronome, and other non-playing events that intervened between performance trials would not break up a detail frame. (3) Because this definition centers on detail work, the event under consideration could not include more than 20% of the total length of the excerpt. Finally, (4) at least one of the neighboring, overlapping playing events had to also be a detail repetition including no more than 20% of the excerpt, since a single short repetition sandwiched between two longer events did not match the behavior pattern I was trying to investigate.

To be considered an example of ratcheted practice, an event had to be part of a sequence of playing events that overlapped slightly and that, taken as a whole, represented one interrupted forward performance. Such sequences were also defined by four specific criteria. (1) The event itself had to be a playing event. Unlike in a detail frame, in which the focused pattern of behavior could encompass making marks in the score or adjusting a metronome and then getting back to work, ratcheting behavior is interesting precisely because the participant seems to perceive it as uninterrupted.

However, events that reflected my own transcription behaviors (particularly notes to myself between other events) of course did not break a series of ratcheted events. (2) The characteristic staggered forward motion between events had to be present. (a) The first note of the event in question had to be between the first and last notes of the previous playing event, the last note of the event in question had to between the first and last notes of the next playing event, or both. For the first and last events in a ratcheted series, this rule applied only to the one end of the event linking it to the other performance trials in the sequence. (b) The overlap between two events contributing to a ratcheted playing series had to be small, which I defined here to be no more than one beat. (c) If the participant had reached the end of the excerpt in the previous event, that overlap did not count. Completing the excerpt certainly precluded the possibility that the participant's subsequent actions were intended to simply extend that performance, even if they included shared material. (3) As with detail frames, single events were excluded from consideration, even if overlap was present. Events were only considered as examples of ratcheted practice when they appeared in overlapping sets of at least two playing events that individually satisfied the other rules in this paragraph. (4) Events that were part of detail frames were not considered as examples of ratcheted practice.

In order to apply the above criteria defining ratcheted practice and detail frames to my data, I created a new spreadsheet containing the relevant data from my compiled spreadsheet—the first and last notes of each event, the event types (playing, marking, note, etc.), the line index numbers, the participant number, and the excerpt being practiced, along with several other variables that ultimately did not figure into the calculations. I then created Excel formulas that tested each event for each of the rules listed in the previous two paragraphs and that ultimately created two new binary, true-false variables describing whether each event was or was not part of either a detail frame or a series of ratcheted practice events. To verify that the binary values generated by these formulas matched the patterns that I had intuitively sensed, I wrote a third Python

script that took the relevant data as input and created a new set of practice diagrams modeled on those used by Maynard (2000), but color coded such that events' classification as frame or ratchet events could be visually assessed. Inspecting the resulting graphs showed that, although refinement of these rules might be needed if these behaviors were the sole focus of the present study, they do capture the bulk of the behaviors in question. The exceptions, the individual instances where one might take issue with one event's being categorized (or failing to be categorized) as representing one or the other of these patterns, seemed acceptable as a minimal source of noise in the data.

Ultimately, in addition to the practice behaviors extracted *a priori* and those collected by the Python script as general patterns that frequently occurred in my transcriptions (see lists on pages 86 and 87), I included the following information about practice patterns across multiple events in my statistical analysis:

- The percentage of playing events in each practice session that were part of detail frames.
- The percentage of playing events in each practice session that were part of a ratcheted series of events.

Reliability

My initial collection of behavioral data from participants' practice videos had employed verbal narratives of each behavior, and my method for converting those narratives into numerical form had relied on a computer script to recognize common elements and recurring patterns. I had designed the script to raise errors if it encountered structural irregularities in my descriptions (for example, if I forgot the colon in "Play: 3.1.1 to 4.2.3."), allowing me to correct many potential problems. Nonetheless, it was possible that inconsistent wordings or spelling errors would create inaccuracies in my

numerical data, on top of the usual need to assess the validity and consistency of subjectively assessed phenomena. A measure of reliability was clearly necessary.

Having determined which behaviors were to be measured, it was hardly necessary to require another professional to narrate every aspect of participants' behaviors as I had initially done. Instead, I created an assessment form with a space for a reliability judge to mark what subset of the excerpt was performed in each playing event and check boxes indicating which if any of the measured behaviors were present in each event. Figure 9 depicts one line of this form for the string crossing excerpt, and shows the reliability judge's markings for a typical event. Each event in the practice session was scored on a separate line on the form. I also created an instruction sheet with definitions of each behavior and instructions regarding the procedure; these instructions and a full page of the reliability scoring sheet for each excerpt can be found in Appendix B (pages 203-206).

I converted my event data for 20% of participants (two high school, three college, and two professional, with the specific individuals randomly selected from within each group) from Excel spreadsheets into an XML Scribe file. Scribe is "an optimally flexible data analysis program that permits users to label events in live observations or in digital video recordings, summarize event timings, and play back labeled events in customized configurations" (Center for Music Learning, n.d.; Duke & Stammen, 2011). In this case, I created four behavior types, one for events within each of the three practice sessions and a fourth for notes I had made to myself while watching the videos and that still appeared within the record. Each behavior instance corresponded to an event in my data and included only the start time, end time, and practice session; the reliability judge had no indication of what material or other behaviors I had marked. Thus, for every event, the reliability judge independently indicated whether the participant had played, marked the music, adjusted the metronome, or engaged in another behavior; for playing events, the judge also independently labeled with brackets what subset of the excerpt was played or

if the participant had instead played other material, and whether or not the participant engaged in any of the 12 behaviors under consideration. The reliability judge also indicated whether or not the metronome was active during each event.

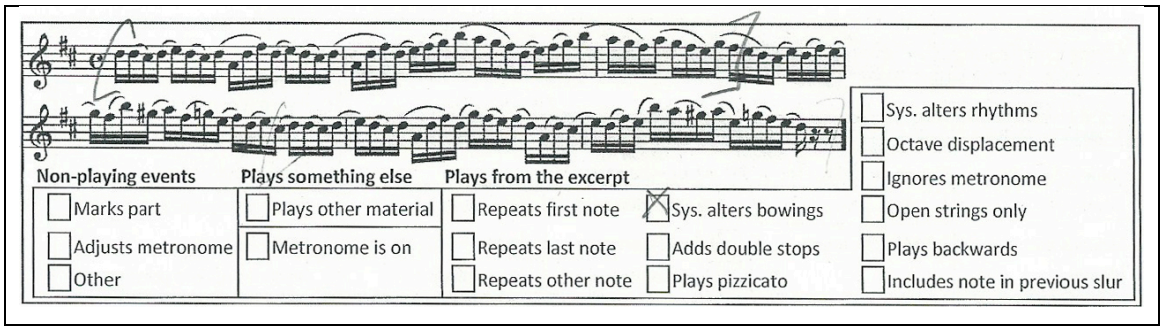

Figure 9. One completed line of the reliability form, showing the slurring excerpt. Here the reliability judge has marked a section of material, and has checked "Systematically alters bowings," reflecting the participant's omission of all slurs. An erasure is also visible.

The reliability judge was a tenured full professor of music with a DMA in violin performance who, in addition to teaching violin and ensembles, maintains a regular national and international performance schedule. The judge volunteered his services and was not paid. After a training session in which we went over the rules and the software using the first several dozen events as examples, the reliability judge scored the remaining material independently. The judge returned the completed score sheets to me, and I imported both my original data and the reliability data into a new spreadsheet, enabling a line-by-line comparison. Data from 20% of participants (seven; two each in the high school and professional groups, and three from the college group), including over 2,500 events, were included in the reliability sample.

An initial comparison showed that the great majority of disagreements were due to two consistent, recurring problems. First, technical violations of scoring rules led to many events appearing as disagreements when we clearly actually agreed in principle. For example, when extracting data pertaining to metronome use from my descriptions, I

had generated two distinct measures: I created a class of events labeled "Adjusts Metronome" that centered on the participant interacting with the metronome (adjusts metronome), and I also recorded whether or not the metronome was activated in all events. For "Adjusts Metronome" events themselves, I recorded the metronome as being active for events in which participants turned it on or adjusted the tempo; I recorded it as inactive for events in which participants turned it off, since this seemed to reflect their intent. It became clear, however, that the reliability judge had recorded an active metronome also for events in which the participant deactivated it, creating an apparent disagreement when we actually agreed about the actions we had seen. The second category of common disagreements arose from the process of translating data between formats. For example, Scribe records timing data down to the millisecond, but my original data was only accurate to whole seconds, and sometimes the first or last few notes of an event were cut out of Scribe's playback, appearing in a neighboring clip instead. In addition, I found a number of disagreements that arose from behaviors that I marked as present while the reliability judge did not, but that on specific review were indeed present.

To correct these errors and ensure that the reliability score reflected what it is intended to measure—the accuracy of the data—rather than technical flaws in the process, I went through all disagreements and sorted them into confirmed disagreements and items up for review. I marked for review any disagreements that arose from the technical errors described above, or when the reliability judge's marking seemed to be inaccurate, and recorded the exact nature of each disagreement (e.g., "Repeats first note disagreement: I marked it, RJ [reliability judge] didn't. It's there."). All disagreements that arose from any error of mine while watching the original video (e.g., incorrectly entered measures) or from the transcription algorithm creating false positives or negatives (e.g., failing to record "Plays against an open A drone" as a double stop because of the unusual wording) were confirmed as disagreements. In addition, I confirmed a number of

disagreements that involved either complicated or ambiguous behaviors because (a) these few events did not seem worth intensive scrutiny, and (b) the ambiguity itself seemed to be a reasonable reason to consider them as true disagreements. The reliability judge then reviewed only the events I had indicated, paying particular attention to the specific aspects of the behavior I indicated. He marked each event in which he agreed that my original extracted data accurately reflected the participant's behavior in the video, as described by the behavioral rules in the instructions, as a corrected agreement, and marked any event in which he still disagreed with my original analysis as a confirmed disagreement.

After completing the review process, reliability (agreements/all events) was 92.7%.

Chapter 4: Results

The main purpose of the present study was to determine whether musicians practice differently as a function of the different kinds of challenges present in the music they are learning. The secondary purpose was to determine whether any practice patterns observed in answer to the first question vary as a function of experience. To answer these questions, I recorded participants representing violinists of three different experience levels (high school: n = 11, female = 8; college: n = 12, female = 4; and professional: n =12, female = 3) as they practiced three different excerpts, for a total of 105 practice sessions of approximately 10 minutes each. Each excerpt focused on a different technical challenge: one required frequent, dramatic shifts; another involved many string crossings across all four strings; and the last featured a syncopated slurring pattern. The examples themselves and a more complete description of their contents can be found in Chapter 3 (Figures 1, 2, 3 and 4).

Designing an experiment around these two independent variables—group and excerpt—was a fairly straight-forward task. However, the question of dependent variables was more complicated. Exactly what should one measure to determine whether people "practice differently" in response to these or some other variables? I chose to focus on two distinct ways to ask the question: What do musicians work on, and how do they work on it? In other words, are there particular places within each example that draw musicians' attention, and what behaviors do they engage in during practice? In deciding exactly which behaviors to study, I specified *a priori* a short list of behaviors either borrowed from or related to those studied by Duke et al. (2009) and collected another list of frequently occurring behaviors from my transcriptions with the assistance of a purpose-written Python script. Most of these behaviors occurred in the context of a "playing event," a time within the practice session in which a participant played a subset of the material, and the behavior represented a salient way in which that playing differed

from simply reproducing the music represented by the score (e.g., playing the music in a different octave). Some of the behaviors, though, represented non-playing events (e.g., making marks in the score). In addition to behaviors that present as aspects or characteristics of single events, I also looked at occurrences of two distinct patterns of sequential behaviors (detail frames and ratcheted practice) that stood out to me as I watched the practice videos. A complete description of each of these behaviors, as well as the procedures for extracting data from the video recordings of each practice session, can be found in Behavior Coding and Analysis in Chapter 3 (page 80).

OBSERVATION AND FIRST IMPRESSIONS

In music practice, the methods of work—how musicians accomplish things—are intimately connected to the outcomes—the amount and rate of progress they make. This is because each step is made in response to, or in the context of, the perceived outcomes of earlier steps. Even the initial events seen in a practice session, upon which subsequent actions build, depend upon pre-existing skill sets: Each individual's initial attempt at playing a given piece of material will vary with their existing musical and technical skill sets, experiences with similar material, and general (i.e., non-musical) cognitive abilities. The primary purpose of the present study was to determine whether these actions also depend upon the content of the material being learned.

In watching participants practice, my first, overall impressions were that the problems inherent to the material indeed dictated many practice behaviors; musicians seemed to respond differently to different kinds of technical challenges, confirming pedagogical assertions. When working on the shifting excerpt, participants in all groups spent much of their time experimenting with different fingering options and formulating a plan to make the register changes accessible. This was evident from their executing successive attempts at the same material with different fingerings, then marking the part,

and in their interviews at the end of their participation, most participants confirmed that this was their intent. Shifts are technical challenges that exist at discrete points in the score, each between two notes. A violinist plays material up to that point in one position on the instrument and to play the next note must move to a different location on the violin's neck; that move is by definition the challenge. In contrast, slurring and string crossing patterns, particularly those I presented to participants, are accumulated challenges. Moving from the A string to the D string once is not difficult, but repeatedly changing strings in one pattern then changing patterns may create problems. This contrast was evident in participants' practice, as they appeared to engage in more extended playing attempts when practicing these two excerpts. My impression was also that they engaged in more of the behaviors that the pedagogical (and some research) literature refers to as practice strategies, organized and systematic deviations from the music specified in the score. Moreover, participants seemed to employ different practice strategies between their work on each of these two excerpts.

Intimately linked to differences between both excerpts and experiences, each excerpt's subjective difficulty seemed to drive both choices of behavior and outcomes. That is, it was clear that each that each participant experienced the three excerpts' difficulty levels differently and that their responses seemed to vary accordingly. Specifically, although I did not intend to measure their performance outcomes, professional participants unsurprisingly played more accurately and more musically in general than college students, who in turn sounded better than high school students. Similar patterns seemed evident between excerpts: all groups' initial and subsequent attempts at the shifting excerpt were less successful than their performances of the other excerpts. Participants seemed to concur, nearly unanimously agreeing that the shifting excerpt was more challenging than the other two, although their perceptions of the relative difficulty of the slurring and string crossing excerpts were more varied (see Figure 10 and Appendix C).

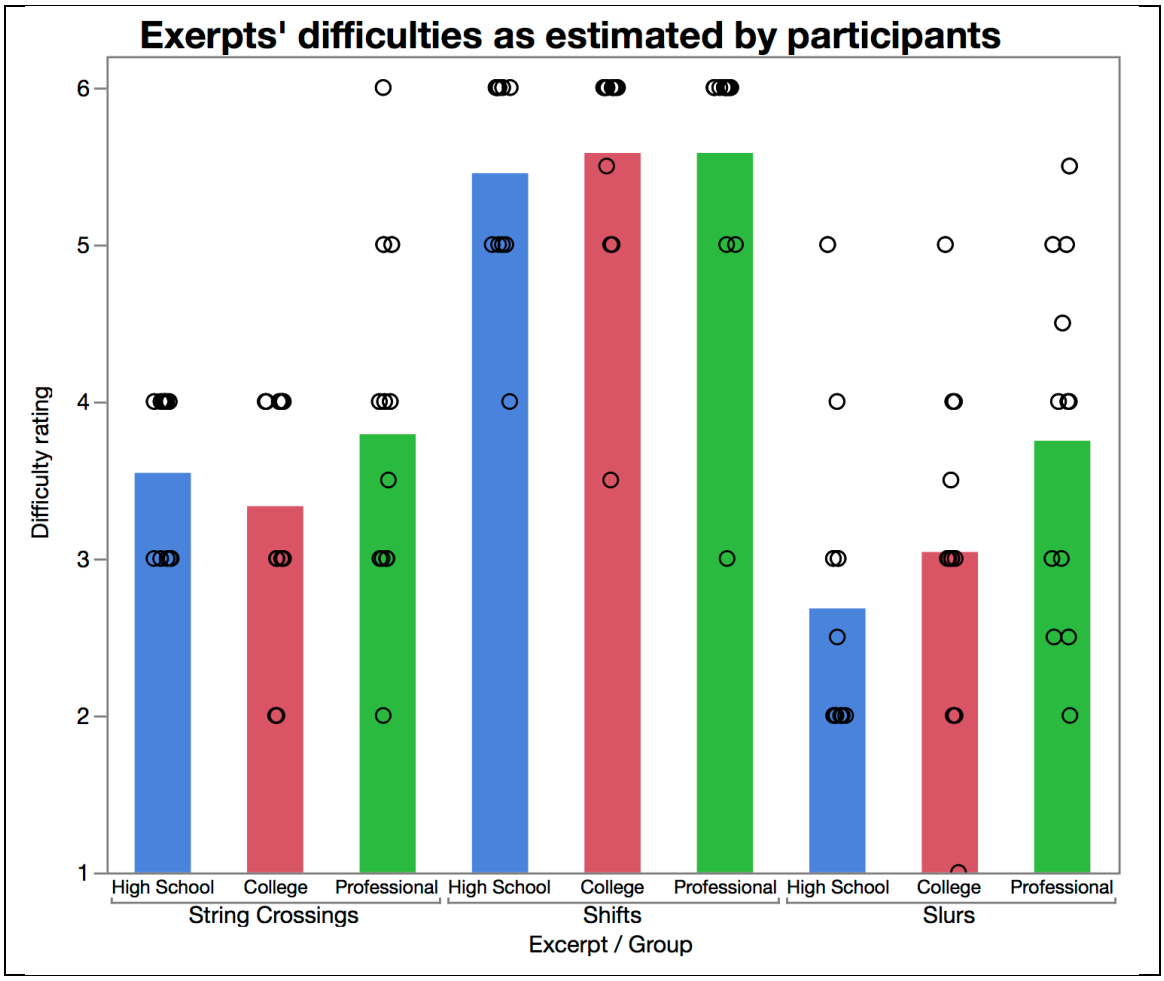

Figure 10: Participants' estimates of each excerpt's difficulty, on a scale of one to six.

Interestingly, however, there did not seem to be excessive disagreement between groups about how difficult each excerpt was. I had expected participants in the professional group to rate the shifting excerpt at a lower difficulty level than the other two groups, even if they still considered it to be the most challenging of the three excerpts. As shown in Figure 10, this was not actually the case; even if they experienced greater success than the other groups, professionals still considered it extremely challenging material. Professional participants tended to vary more than others in their assessments of the other two excerpts, perhaps reflecting their awareness of their own strengths. Professionals were indeed the only group in which individuals rated the string crossing excerpt a five or six on a six-point difficulty scale. However, the fact that

participants across groups all found the shifting excerpt quite a bit more difficult than the other two suggested that I would need to consider difficulty when performing any further analysis of the data.

It is important to recall that participants' perceptions of both the challenges that each excerpt presented and the relative success of each of their actions during practice drive their subsequent choices of action. That is, if a participant plays a note out of tune or with the wrong bowing, that observable error will not affect their subsequent decisions unless they both perceive it and choose to act on it. Likewise, different participants may make different distinctions concerning the nature of each problem, which will affect their subsequent behaviors. One participant may identify the shift between two notes as the fundamental problem to be solved; another participant may look at the same music and instead focus on the high-register music following the shift. One participant may focus on the bow arm when practicing a string crossing, while another may perceive the issue of changing strings in the left hand as more problematic.

Although participants' perceptions were not directly available to me as an outside observer, I had hoped to be able to infer possible perceptual patterns between groups or excerpts by closely inspecting exactly what locations within the material participants chose to practice, or the specific behaviors they employed while working on each location. Clearly, some between-excerpt differences in problem assessment would be tautological: I simply presented them with vastly different pieces to learn, and particularly challenging bits of material might not occur at the same locations in each excerpt. More interesting to explore would be differences between groups, especially if such differences arose only on one or two of the excerpts. If between-group differences arose only on the shifting excerpt for example, it might suggest that although professionals still considered that music to be as difficult as less experienced players did, they either had learned different ways to deal with the challenges, or even perceived the challenges in a fundamentally different manner. However, my initial impressions while

watching participants' practice and while later reviewing the videos suggested that evidence of differential problem assessments, if it existed, would be challenging to tease out. That is, I did not see obvious differences in the challenges that participants in different groups chose to practice. While it seemed more plausible that participants at different experience levels might be applying the behaviors referred to as practice strategies differently, I wanted to withhold judgment until completing a more detailed analysis, in part because each specific behavior occurred infrequently. Most of participants' work seemed to constitute attempts to perform some or all of the excerpt in question in its original, unaltered form.

All the analyses presented hereafter attempt to ascertain the validity of the impressions described above. Is there evidence that the excerpts varied in difficulty? Would my impression that different recognizable practice strategies characterized work on each of the excerpts withstand scrutiny? And could evidence be found suggesting that participants in different groups responded differently to the same material in part because they perceived its inherent challenges differently?

One final overall observation is warranted concerning individual variability. In watching the videos, it was clear that, at all levels of experience, musicians had their own practice habits. One individual worked slowly from the beginning to the end of the shifting excerpt across the entire practice session, rather than jumping around the excerpt as most did. A few engaged in extensive pizzicato practice, while others never did. Some marked their parts extensively, others minimally. Many of the behavioral variables I measured displayed great individual variability, to the extent that the tendency of a few participants within each group to contribute the bulk of each behavior's occurrences will become a theme in the following sections. Clearly, personal practice habits deeply influence each individual violinist's practice behaviors.

WHAT DO MUSICIANS PRACTICE? LOCATIONS IN THE SCORE

Perhaps the most obvious indicator of different approaches to material is what parts or subsections of the material participants spent time and attention practicing. If participants' practice truly reflects their decisions about what to work on—salient features they identified in the music—individuals' practice should cluster around these points. The locations within each excerpt where participants chose to begin each attempt, as well as the cumulative practice that each location received over a practice session, provide two good measures of where they devote their attention.

To get a preliminary look at the data and assess the need for further analysis, I graphed each note's frequency as a starting point for a performance trial (Figure 11) and its accumulated practice (Figure 12), that is, the number of times it was played over the course of a practice session. Both figures show these results as a percentage of all the starting points or all the notes played in each practice session, respectively. The clearest trend in both figures is how similar the contours were across groups. In terms of what features of the music drew participants' attention, there does not seem to be great variability. It seems that high school violinists played more repetitions of the difficult spot near the beginning of the string crossing excerpt (measures 3 and 4, notes 13 to 24) than did participants in the other groups, who instead spent more time on the last five measures (notes 43 to 73). Collegiate participants accumulated somewhat more practice than did participants in the other two groups on the last measure of the shifting excerpt (note 81 to the end). However, the general trend was for participants across groups to start at the same locations in the music and to accumulate multiple repetitions at similar points. One can identify the first notes of difficult measures from spikes in all charts of both figures.

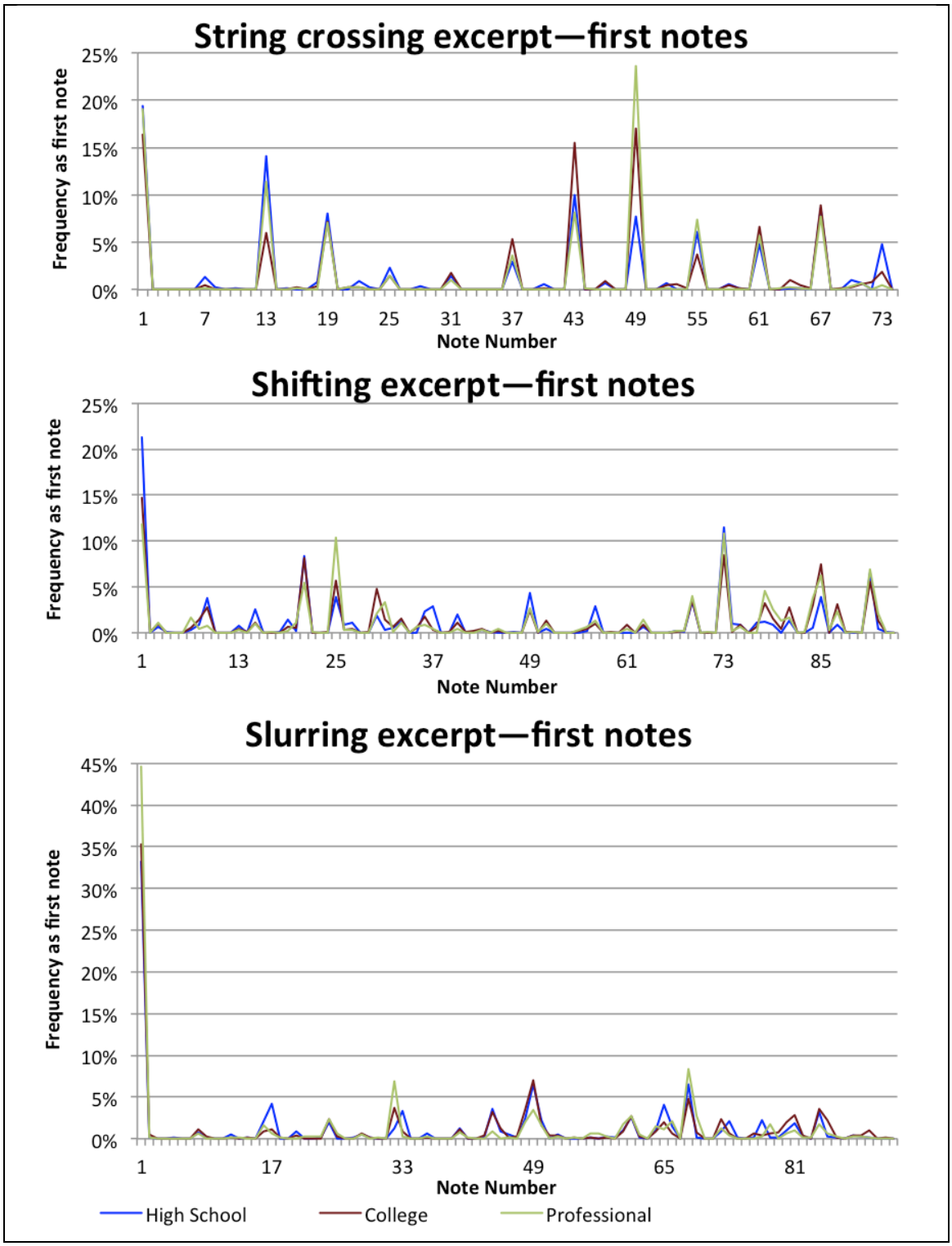

Figure 11: Frequency with which playing events started on each note.

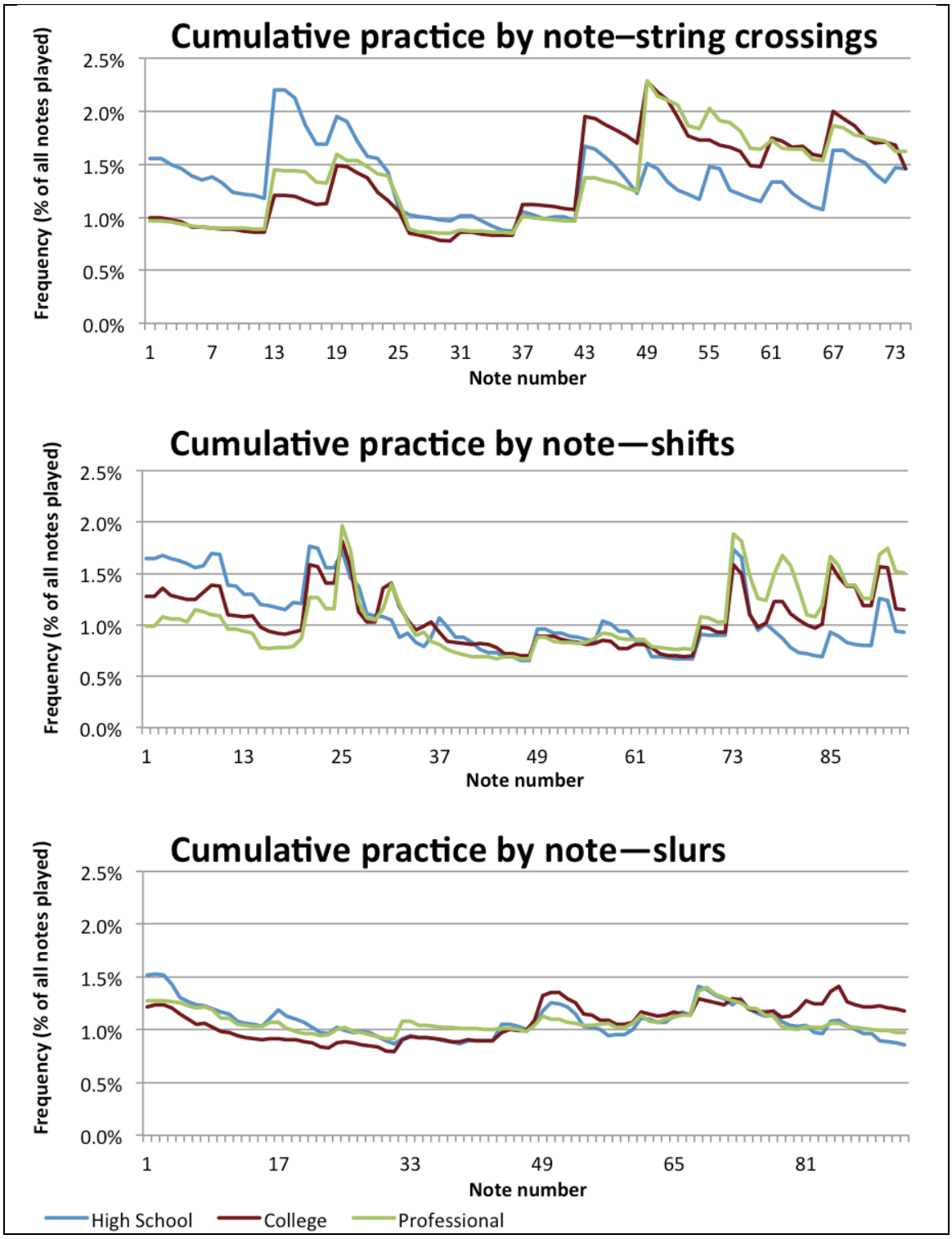

Figure 12: Aggregate practice for each note as a percentage of all notes played in the practice session.

Particularly in Figure 12 (showing cumulative practice by note), even the small contours within each measure are similar across groups. On all excerpts, downbeats tended to show spikes, areas of high accumulated practice relative to the notes around them, presumably because they served not only as starting points as seen in Figure 11, but also as ending points of some performances, as well as appearing in the middle of other attempts. There are exceptions, but even those exceptions are usually shared by all three groups of participants. For example, notes 84 and 85 in the slurring excerpt correspond to beat 2 with its pickup in the last measure, and in all three groups, these notes accumulated more practice than the downbeat of that measure. In the shifting excerpt, the two-note pickups to measures 2 and 3 accumulated extra practice; again, this trend applies to all three groups.

In terms of starting points, participants in all three groups again showed very similar trends. When practicing measure 3 of the slurring excerpt, high school students tended to start on the downbeat (note 33), whereas other participants tended to start on the pickup (note 32). But otherwise, participants across groups chose very similar places to start each performance attempt. The most noticeable difference arose between excerpts, not between groups.

When practicing the string crossing excerpt, participants initiated playing events on the first notes of measures nearly all the time, especially measures 1, 3, 8, and 9 (notes 1, 13, 43, and 49 respectively), but did not often begin a performance attempt at measures 2, 5, and 6 (notes 7, 25, and 31). Their choice of starting note while practicing the other two excerpts diverged in opposite patterns.

In the shifting excerpt, they chose many different starting locations, frequently not corresponding with downbeats. Figure 13, showing the 15 most popular starting locations within each group for the shifting excerpt, shows why: most of the starting locations that are not on downbeats are either (1) on beat 2 of the measure (a secondary structural point), or (2) both serve as a pickup to a strong beat and are the first note in a new

register, following a shift. At least among professional participants, I had expected to see more instances of starting points immediately *before* register changes, rather than after them, but it is possible, given how densely shifts are packed into this example, that these points were chosen as approaches to the next register change a few notes later.

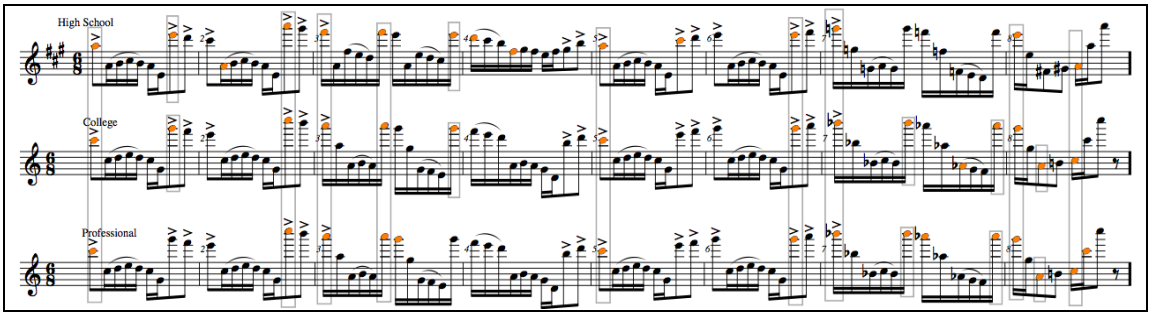

Figure 13: Each group's most frequent starting points in the shifting excerpt. The fifteen most frequent locations to initiate a playing event are highlighted in orange. Shared starting points are indicated by gray boxes.

There are several minor exceptions to the cross-group homogeneity, but one notable example in the shifting excerpt attracted my attention. Though it was not among their 15 most frequent starting points, professionals did exhibit a slight tendency to start before the shift in the second beat of measure 1, in contrast to those from other groups. Local high points are visible in both the starting point and accumulated practice data on note 7 for professionals, while the other two groups show this pattern on note 9 instead (after the shift). It is possible that this is indeed evidence of professionals diverging from the other two groups in their problem identification, perceiving the shift rather than the high material that follows. However, distinguishing between such evidence and a mere anomaly is impossible without additional data.

If participants' chosen starting points showed greater variety when they practiced the shifting rather than the slurring excerpt, they showed the opposite extreme during practice sessions focused on the slurring excerpt. Across all three excerpts, the first note was naturally a common starting point, but when they practiced the slurring excerpt,

participants started on the first note in a far higher percentage of their playing trials than either of the other two excerpts. High school and college participants started at the beginning 33% and 35% of the time, respectively; professionals played from the beginning on 45% of playing attempts. No other one point served as the starting location for more than 10% of trials. Together with the relatively flat contour of the cumulative practice graph compared with those of the other two examples, this suggests that participants likely made longer, more comprehensive playing attempts when playing this excerpt than the other two. Although their motives cannot be definitively concluded from analysis only of their behaviors, this result comports nicely with the proposal that musicians match their practice behaviors to the nature of the challenges they encounter, particularly when taken together with the apparently more even distribution of cumulative practice across this excerpt. The slurring excerpt's signature challenge is maintaining a counterintuitive bowing pattern across extended sections of the music, while the other two excerpts' challenges tended to be focused in more concrete locations. On those other two passages, the specific locations of difficult spots can be located from the graphs of both where musicians started and where they accumulated more practice, but for the slurring excerpt, they distributed their work more evenly across the material.

Two overall trends emerged in where within the material participants chose to start and to accumulate practice attempts. There were more similarities than differences between groups. A few anomalous locations where one group differed from the others hinted at a possibly different problem identification, there did not seem to be enough examples to warrant further analysis. Between excerpts, however, it was clear that participants started at the beginning and practiced the entire excerpt more evenly when they worked on slurs. When working on string crossings, starting points were more distributed across the excerpt, and cumulative practice totals clearly showed which sections of the material were more difficult than others; this trend was even more

pronounced for the shifting excerpt. This suggests that musicians do indeed tailor their behaviors to the nature of the material, choosing to engage in more continuous practice on the string crossing excerpt while focusing on specific points within the other two examples.

Identifying exactly which notes attracted the most attention would say more about specifically which shifts, for example, were perceived as more difficult than others than it would about musicians' responses to shifting as a whole. However, the difference between excerpts in terms of the frequency with which people started at the beginning of the excerpt seemed to warrant further investigation. Likewise, participants' tendency to start at the beginning more often, and to distribute practice more evenly, when practicing the slurring excerpt than the other two suggests that they were playing longer, more continuous excerpts. Because I had actually recorded the length of each event, I could assess this tendency more directly. I therefore added these two measurements—the percentage of playing events starting from the beginning and the average percentage of the excerpt played in each event—in the overall analysis of practice behaviors.

HOW DO MUSICIANS PRACTICE? SPECIFIC PRACTICE BEHAVIORS

The pedagogical literature suggests that the answer to my primary research question—whether musicians respond differently to different types of challenges in the music—relates not only to what material they choose to work on, but also to alternate methods of working. As detailed in Chapter 2, many pedagogues recommend using specific practice strategies, ways of altering or simplifying the material, tailored to the nature of the content. My initial observations, moreover, suggested that while musicians might not exhibit these behaviors extensively, they were indeed present, and most behaviors seemed to cluster in the practice sessions devoted to one or another of the excerpts.

The numerical data I had extracted from my transcriptions of participants' practice videos took the form of almost 13,000 data points, each representing a discrete unit of activity, a time when a participant played a section of the music, marked the part, etc. Most of these events were playing events, with data for each describing a section of the music played, the event's duration, and a binary label indicating whether behaviors of interest were present. While an omnibus statistical test to determine whether overall trends were present in the data might be desirable, selecting such a test proved problematic. The data were a mixture of binary and scale data, some behaviors of interest (e.g., the length of each practice session) could only be measured across entire practice sessions, and it seemed more appropriate to treat each session as a statistical case, rather than each event. However, collapsing the data for events into counts for entire practice sessions reduced the number of cases from more than 12,800 to only 105. For an otherwise appropriate statistical test such as a MANCOVA to analyze as many dependent measures (the individual practice behaviors) as I had gathered would require far more than 105 data points.

As such, below I present several descriptive statistics for each variable of interest. Table 1 (page 116) shows how frequently each group employed or displayed each behavior in each of the practice contexts, measured both by the percentage of participants who showed the behavior at all and by the rate at which those individuals displayed it. In many cases, the data for particular behaviors seem not only to reflect group tendencies to use or display that behavior in certain contexts, but also to demonstrate that those behaviors are evidence of highly individualized personal practice habits or eccentricities. When individual variability is a notable feature in its own right, I present that data too. In the absence of rigorous statistical tests, legitimate concerns may be raised concerning the generalizability of any particular measure to the musical population as a whole; however, the overall picture painted by the data as a whole is compelling.

Practice sessions varied in length, both because I treated the 10-minute window as a guide rather than a strict limitation, and because some of the participants had elected to perform before exhausting their allotted time. Moreover, participants' paces varied between individuals and groups. As such, it seemed more appropriate to examine the data not as a count, but as a frequency, as the rate at which participants displayed the behavior. I therefore converted the amount of time participants spent playing to a percentage of the practice session and the amount of time participants used the metronome to a percentage of their playing time (these data had originally been computed by adding the times of only the playing events during which the metronome was active). Most other behaviors occurred as features of particular playing events, and I labeled them as being either present or absent; I used a similar dichotomous system to label them as being part of detailed frames or ratcheted practice series. I converted all such variables, ones with dichotomous labels for each playing event, to the percentage of all playing events to which the label applied. Event length—the amount of material played in an average playing event—was already measured as a percentage of the length of the excerpt.

Results of specific behavior analyses suggest three primary themes. Participants' choices of where to begin each playing event and the cumulative practice data demonstrate that across groups, they identified specific target locations in the shifting excerpt, they practiced for continuity in the slurring excerpt, and for locally distributed problems in the string crossing excerpt. The data from specific behaviors add support to this picture. Differences exist between groups in how they worked on the material, but they seem to reflect groups' varying abilities to execute rather than different plans. Finally, the specific behaviors commonly referred to as "practice strategies" are used in response to specific problems, but they are used sparingly, appear in some cases to be matters of personal preference, and their use tends to increase with participants' experience level.

The number of individuals in each group who displayed each behavior in each practice context is presented in Table 1 (page 116). Also included in this table are mean rates for each behavior. The rates presented in this table only reflect the data for practice sessions in which the behavior was present. The means and standard deviations displayed for each behavior in Table 1 only reflect participants within each group that displayed the behavior in question during that practice session; the data for non-inclusion, for individuals who did not display each behavior, will be seen later in behavioral data graphics.

When examining the data on where within the material participants devoted their attention, as measured by cumulative repetitions and playing events' starting points within the material, I suggested that participants identified different goals in approaching the three excerpts. Specifically, I suggested that when they worked on the shifting excerpt, they identified discrete problematic locations; when they practiced the slurring excerpt, they worked for continuity across long sections of material; and when they worked on the string crossing excerpt, they identified target locations, but those locations encompassed more material than in the shifting excerpt, requiring that they be practiced in longer sections. If this were the case, we would expect that participants' average playing event would cover a small portion of the excerpt, perhaps just a few notes, during their work on the shifting excerpt, that it would be somewhat longer in the string crossing excerpt, and that an average playing event in the slurring practice session would encompass a much larger section of the material. With the same amount of time to work, but with each attempt covering a large section of material, we would expect participants to execute the fewest individual playing events within their practice sessions on the slurring excerpt; we would likewise expect the most playing events during sessions focusing on the shifting excerpt, and that string crossing practice would fall between. We would also clearly expect that practice sessions devoted to the slurring excerpt would generate more complete performances and performance attempts from the beginning than

other practice sessions. Whether practice of the shifting excerpt should lead to fewer complete playing events or trials starting from the beginning of the material than practice focused on the string crossing excerpt is unclear, because both excerpts seem to lead participants to work at discrete problematic spots.

The data in Table 1 mostly confirm this picture. Across all groups, practice sessions focused on the slurring excerpt featured noticeably more playing events, more playing events starting from the beginning, and more complete playing events than the other two sessions; the average playing event was also considerably longer in this practice session than in other contexts. These data seem to confirm that all participants practiced this excerpt for continuity more so than the other excerpts. Among professional participants, these same measures also distinguish work on the shifting excerpt from string crossing practice. Professionals made more individual playing attempts, fewer complete attempts, and started playing at the beginning of the excerpt less often when working on shifts than on string crossings, and the average playing event covered a smaller section of the material during their shifting practice than when they practiced string crossings. Among student participants, however, these two contexts were less clearly distinguished. Like professionals, college students did play shorter sections of the material and started playing at the beginning of the excerpt less frequently during shifting practice than when working on the string crossing excerpt, but otherwise student participants treated the shifting and string crossing excerpts similarly. One notable exception is that high school students engaged in about 20% fewer playing events when practicing the shifting excerpt; in this regard, their work in this context more closely resembled their slurring than string crossing practice. It may be that the difficulty of the excerpt forced them to play more slowly or to pause before starting.

		Session Duration	Play Events (n)	Plays from beginning	Time spent playing	Average material played	Complete trials	Events in detail frames	Events in ratcheted series	Playing time using met.	Adjustments	Adjustment rate †	Events played while ignoring the metronome
String Crossings													
	users (out of 11)	.	.	.	.	.	7	11	11		5		1
High School	mean (among users)	630	113	21.7%	84.9%	18.6%	2.38%	58.5%	16.4%	38.0%	7	.085	3.64%
	SD (among users)	14.2	39.3	9.41%	8.71%	6.30%	1.72%	22.6%	14.7%	23.5%	5	.097	.
	users (out of 12)	.	.	.	.	.	10	12	11		7		0
College	mean (among users)	604	115	17.5%	86.5%	24.6%	7.63%	54.9%	6.25%	59.9%	7	.095	.
	SD (among users)	25.2	39.6	7.30%	6.04%	8.68%	8.01%	14.7%	3.58%	23.9%	4	.065	.
	users (out of 12)	.	.	.	.	.	12	12	6		9		2
Professional	mean (among users)	598	115	21.9%	85.9%	29.0%	9.80%	52.5%	3.94%	56.3%	11	.109	2.39%
	SD (among users)	61.2	40.5	10.5%	6.81%	8.74%	7.53%	14.9%	3.00%	29.7%	5	.067	2.14%
Shifts													
	users (out of 11)	.	.	.	.	.	3	11	11		9		0%
High School	mean (among users)	646	89	21.5%	82.8%	16.5%	5.05%	58.1%	15.2%	14.4%	4	.025	.
	SD (among users)	25.8	41.1	8.28%	14.0%	8.06%	4.33%	18.2%	6.59%	9.47%	4	.027	.
	users (out of 12)	.	.	.	.	.	3	12	12		4		0%
College	mean (among users)	648	115	14.8%	84.8%	12.7%	1.0%	65.7%	16.3%	38.6%	5	.061	.
	SD (among users)	41.1	41.3	5.89%	5.04%	3.08%	0.37%	15.1%	11.9%	30.6%	3	.035	.
	users (out of 12)	.	.	.	.	.	5	12	12		8		4
Professional	mean (among users)	615	127	12.1%	80.8%	13.6%	2.96%	68.7%	11.1%	24.8%	4	.037	8.78%
	SD (among users)	40.1	48.6	5.48%	9.30%	4.61%	2.90%	9.34%	6.53%	18.0%	2	.021	7.38%
Slurs													
	users (out of 11)	.	.	.	.	.	8	11	11	4*	5*		1
High School	mean (among users)	612	87	37.6%	88.7%	26.5%	8.08%	31.1%	19.1%	44.3%	9	.132	1.47%
	SD (among users)	65.1	35.2	18.3%	7.36%	10.3%	9.39%	13.3%	13.7%	32.6%	5	.076	.
	users (out of 12)	.	.	.	.	.	11	12	12		8		1
College	mean (among users)	606	83	34.5%	84.6%	33.8%	12.5%	30.2%	14.6%	63.7%	9	.134	6.36%
	SD (among users)	38.2	26.5	14.1%	6.67%	10.7%	9.02%	17.3%	10.0%	27.4%	3	.077	.
	users (out of 12)	.	.	.	.	.	12	12	10	8*	10*		1
Professional	mean (among users)	626	73	45.0%	78.6%	40.2%	17.0%	19.2%	8.93%	58.5%	11	.162	1.27%
	SD (among users)	92.8	21.7	15.7%	12.3%	11.1%	11.3%	12.0%	5.81%	25.1%	6	.107	.

* Individual participants turned the metronome on and back off again without playing. † Rate expressed as the ratio of adjustment events to playing events.

Table 1: Rates of displaying each practice behavior. Metronome behaviors are shown collapsed when possible, because they measure different aspects of the same behavior. Non-applicable calculations or values that are necessarily 100% are not shown.

		Part marks per play event	Events w/ repeated first note	Events w/ repeated last note	Events w/ repeated other note	Events w/ altered rhythms	Events w/ altered bowings	Events w/ added double stops	Events played pizzicato	Events w/ octave displacement	Events w/ isolated open strings	Events w/ played backwards	Events w/ note in preceding slur
String Crossings													
	users (out of 11)	10	10	11	9	5	5	9	3	0	0	2	0
High School	mean (among users)	0.07	7.59%	3.90%	6.95%	11.9%	6.44%	2.61%	6.30%	.	.	0.86%	.
	SD (among users)	0.07	6.88%	2.11%	6.70%	5.09%	9.60%	1.09%	8.98%	.	.	0.07%	.
	users (out of 12)	12	12	8	9	7	6	11	3	0	2	3	0
College	mean (among users)	0.05	10.4%	4.31%	2.12%	12.9%	2.81%	6.61%	9.72%	.	4.53%	1.12%	.
	SD (among users)	0.04	12.2%	3.23%	1.19%	20.8%	2.37%	5.66%	12.3%	.	2.51%	0.41%	.
	users (out of 12)	10	10	9	6	5	6	10	3	0	4	1	0
Professional	mean (among users)	0.07	6.49%	6.14%	2.67%	10.2%	10.8%	4.17%	4.65%	.	12.0%	1.52%	.
	SD (among users)	0.04	4.43%	7.56%	0.72%	5.48%	17.9%	5.21%	5.50%	.	7.67%	.	.
Shifts													
	users (out of 11)	9	11	11	11	0	2	3	4	3	0	4	7
High School	mean (among users)	0.07	17.7%	15.2%	17.5%	.	2.20%	3.41%	14.0%	2.40%	.	2.65%	12.2%
	SD (among users)	0.05	13.8%	8.58%	8.77%	.	1.36%	1.94%	23.2%	1.08%	.	1.85%	22.3%
	users (out of 12)	12	12	12	12	3	4	5	3	10	0	4	4
College	mean (among users)	0.07	24.8%	17.5%	17.7%	9.61%	2.91%	4.83%	2.57%	6.10%	.	3.56%	1.18%
	SD (among users)	0.05	11.7%	12.3%	13.8%	8.50%	2.79%	3.96%	3.27%	5.90%	.	4.14%	0.54%
	users (out of 12)	12	12	12	11	3	4	7	7	9	1	7	1
Professional	mean (among users)	0.08	25.9%	18.7%	18.4%	2.25%	1.30%	1.56%	10.6%	2.95%	1.88%	2.89%	1.35%
	SD (among users)	0.05	12.4%	13.1%	10.0%	2.01%	0.84%	0.90%	24.5%	1.74%	.	2.81%	.
Slurs													
	users (out of 11)	7	7	6	8	5	6	1	4	0	0	0	9
High School	mean (among users)	0.07	15.5%	2.44%	8.84%	15.5%	14.9%	0.74%	3.88%	.	.	.	3.65%
	SD (among users)	0.07	19.3%	1.99%	10.2%	14.9%	17.7%	.	4.83%	.	.	.	3.28%
	users (out of 12)	11	10	8	6	3	6	3	2	0	0	1	8
College	mean (among users)	0.08	7.97%	7.96%	2.23%	14.0%	19.0%	4.02%	13.4%	.	.	2.27%	6.15%
	SD (among users)	0.05	4.56%	5.62%	0.93%	16.7%	22.4%	1.15%	17.4%	.	.	.	6.58%
	users (out of 12)	11	12	8	6	8	6	3	5	0	0	1	4
Professional	mean (among users)	0.10	11.0%	10.4%	4.85%	13.4%	13.6%	1.5%	1.3%	.	.	6.25%	1.92%
	SD (among users)	0.06	7.25%	9.79%	3.66%	7.93%	15.4%	0.7%	0.5%	.	.	.	0.92%

Table 1 continued.

Several of the conclusions drawn in the preceding paragraph were predicated on the assumption that participants worked on each excerpt for a comparable amount of time. As seen in Figure 14, although individual outliers are present, practice session durations seem stable across groups and practice contexts.

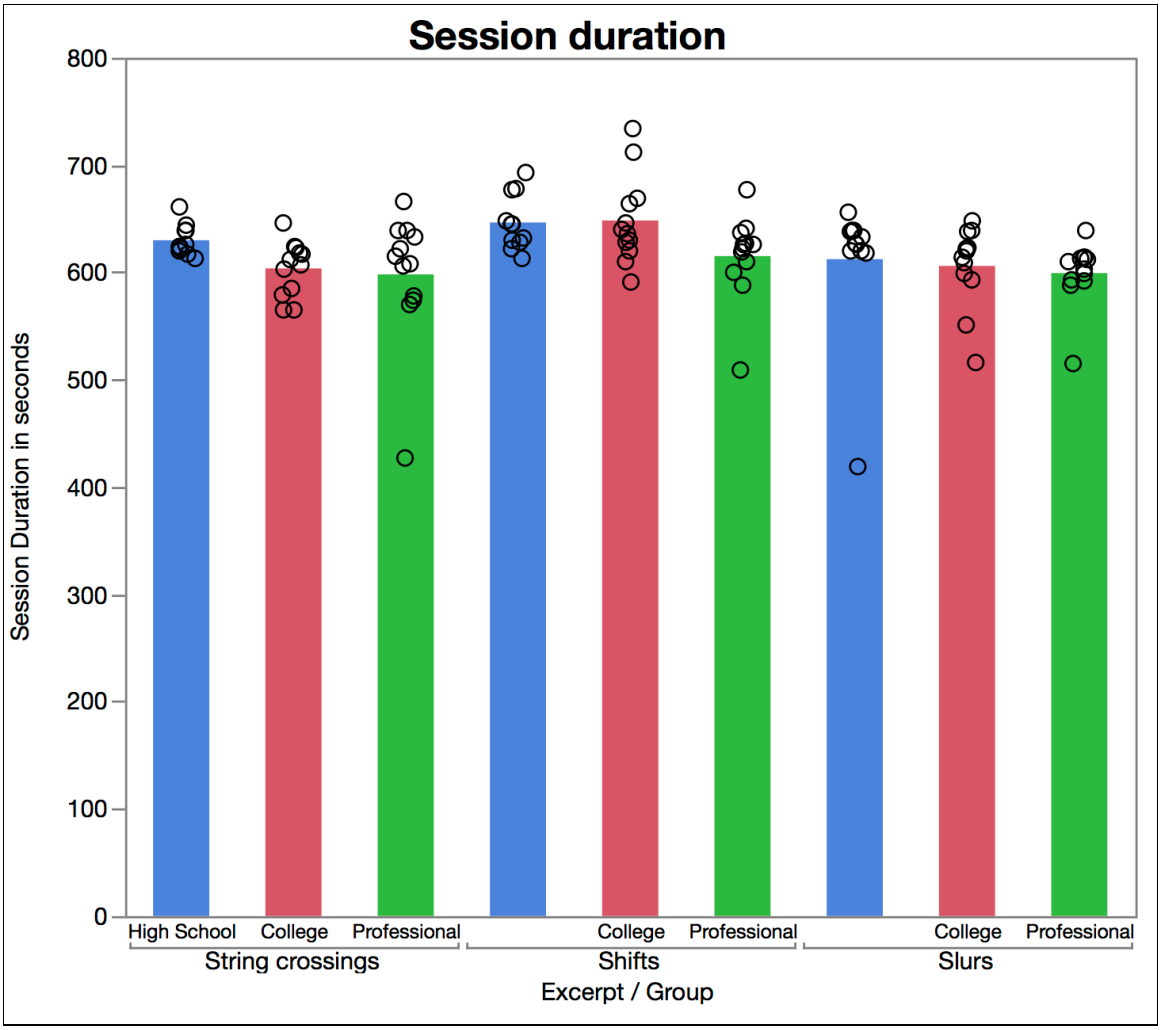

Figure 14: Practice session duration.

If participants did in fact choose to work on discrete problematic points within the shifting and string crossing excerpts but strove for continuity on the slurring excerpt, we would also expect that practice of the former two excerpts would feature more events in detail frames than the latter. This indeed was the case in all groups. Additionally,

professional violinists and college students appear to have played somewhat more playing events within detail frames when learning the shifting excerpt than the string crossing one; the rather high standards of deviation complicate this picture, however.

A metronome is a device designed to regulate tempo, and tempo is an emergent property, describing how quickly beats occur through time. By definition, a single note has no tempo, and the tempo of just two or three notes is poorly defined. Although musicians may have an internal idea of an intended tempo when they play even a few notes, the accuracy of their executions are difficult to assess unless they play at least a few beats. As such, we would expect practice sessions dominated by work on discrete, localized problems to feature metronome usage less prominently than those containing more extended performances. In the present study, we would expect the shifting excerpt to be an unlikely setting for metronome use, but we would expect to see participants use it more often in the slurring context. Expectations for the string crossing excerpt are unclear; the problems here appear to be local, but to be spread out over larger sections of the material than in the shifting excerpt, sections that may be long enough to warrant metronome use.

The data seem to confirm expectations, and they also suggest that participants' identified targets within the string crossing excerpt long enough to warrant metronome work. In all groups, fewer participants used the metronome at all when learning the shifting excerpt than in either of the other practice settings, and among those who did, they used the metronome for about half as much time when working on shifts. A somewhat higher percentage of participants in the professional group used the metronome in all contexts than college students, and more college students in turn used the metronome than high school students. The percentage differences typically were around 15% between each level; given the sample size, this represents only two or sometimes three individuals. Differences in participation rates therefore may be due to a few individuals' proclivities, but it is worth noting too that the tendency for more

professionals than college students to use the metronome and more college students than high school students was nearly identical across all three excerpts. Also, the difference between extremes—between percentages of professionals and high school students who used the metronome—was smallest at 30% in the string crossing excerpt, and reached almost 50% during practice on the shifting excerpt.

Among participants who did elect to use the metronome, college and professional participants seemed to use it for a similar amount of time on average, while high school students appear to have used it about for about half as much time. As an exception, college students used the metronome for a greater share of their shifting practice session than professionals; the high standard deviation and low participation rate, though, suggest that one or two individuals may have greatly influenced this apparent anomaly. Although the counts of metronome adjustments were in general higher among professionals than others outside of shifting practice, when measured as a rate—adjustments per playing event in the practice session—participants across groups appear more comparable. Professionals were also the only group to consistently ignore the metronome, and then only in the shifting excerpt; other instances where this is seen represent isolated incidents displayed by a few individuals. Overall, it seems that playing with the metronome is a behavior that increases with experience, both in terms of choosing to use it at all and in terms of how much time individuals spend with it active; it also seems that some experienced individuals may overextend this tool's use in the shifting excerpt, opting to ignore it while playing.

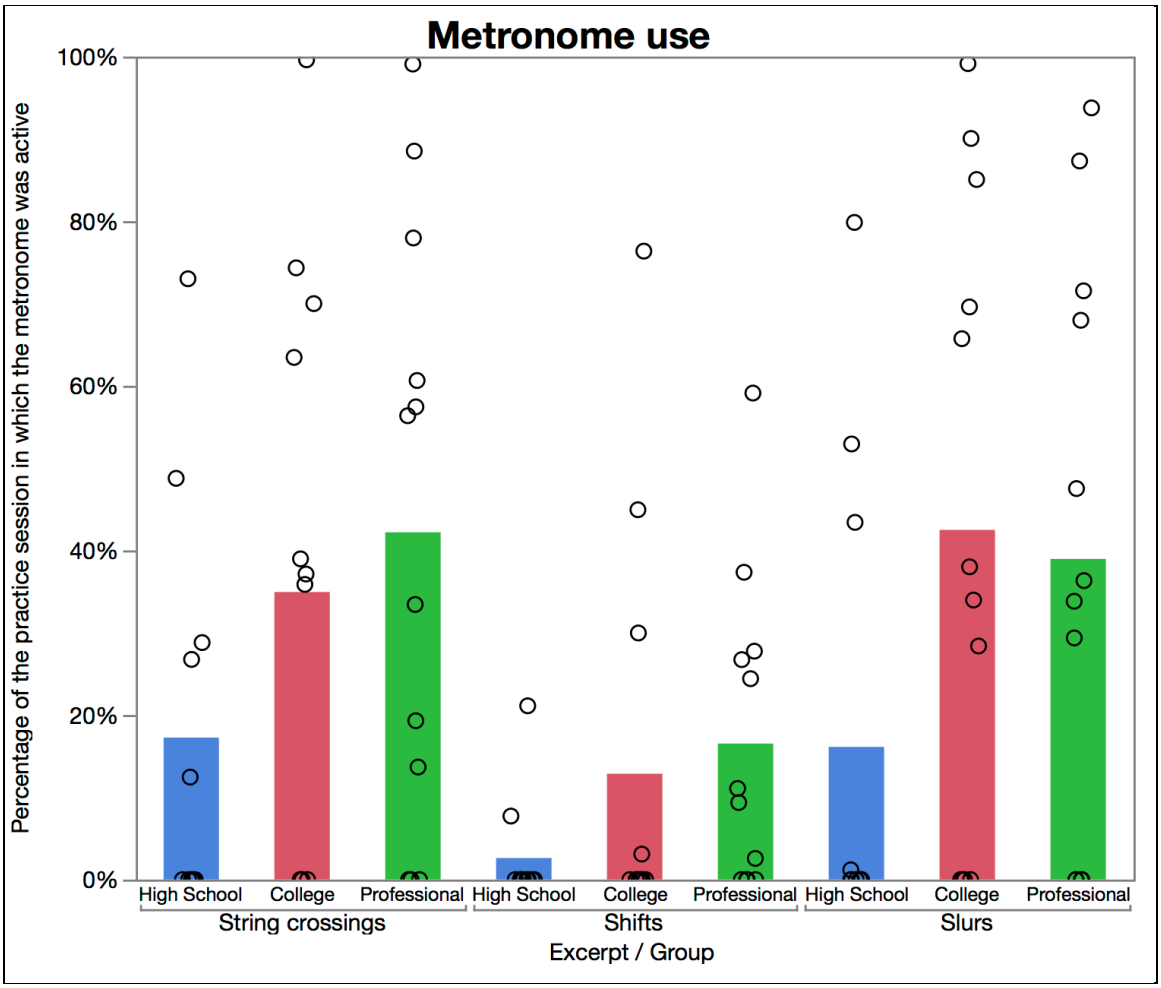

Figure 15: Percentage of playing time in which the metronome was active. Mean values shown are those for the entire group, not only the individuals who showed this behavior.

It is also possible that it is was the excerpts' relative difficulty that explained the different rates of metronome use. The metronome was used by fewer individuals in all groups, and used less extensively by those who did, when they practiced the shifting excerpt, which they also concurred was the most difficult (see Figure 15); it was used at comparable rates in the other two practice sessions. Participants themselves expressed concerns regarding the stages of practice with respect to the shifting excerpt that they did not raise in other contexts; specifically, many mentioned that unlike the other two excerpts, this material required the extra step of forming a plan. It may be that

participants found a metronome inappropriate for this stage of preparation. However, given the nature of the metronome as a tempo-regulation tool together with the exceedingly short, localized repetitions with which participants responded to the shifting excerpt, it seems unwise to attribute the differential metronome use entirely to difficulty level. Disentangling the exact appropriate contexts for musicians to use a metronome may be a matter for future research; for the present study it is enough to note that its use seems to increase with experience and to be less popular among participants engaged in speeded learning tasks when they were working on material featuring shifts.

Another behavior that distinguished between groups and that may reflect material's difficulty was the percentage of events within ratcheted series. Every high school participant exhibited this behavior in all three practice contexts, and among college students, only one participant went an entire practice session without ratcheting, and then only in the string crossing excerpt. Among students, then, this interrupted forward motion through the material is a nearly universal feature. Among professionals, however, the only context in which this behavior appeared in all individuals' practice was in the shifting excerpt; when practicing the slurring excerpt, two individuals completed entire practice sessions without ratcheting, and the pattern was completely absent from fully half of professionals' string crossing practice sessions.

In terms of the mean values among participants who displayed the behavior, ratcheting was quite rare among professionals; it was most common in shifting practice, where 11% of playing events were part of ratcheted series, while in the string crossing practice, even the half of professionals who showed this behavior at all exhibited it on just 4% of their playing events. High school violinists, by contrast displayed this behavior frequently. Series of ratcheted events included over 19% of their playing events in slurring practice and no fewer than 15% of playing events in any session. College students displayed a somewhat more complicated pattern. Their string crossing practice, where only 6% of their playing events fell inside ratcheted series, resembled

professionals' rates; in the other two contexts, their ratcheting rates were closer to high school students.

Overall, ratcheted practice appears to arise when the material's challenges or musicians' limitations in ability lead them to attempt to play extended sections of the music but fail. Although professional participants were selected because they are experienced, this group certainly also comprised the group with the most capable players. In general, they accumulated a greater percentage of complete performance trials and played a larger section of the material in each trial than other groups outside of the shifting practice session; in these same contexts, they also exhibited lower rates of ratcheting, and some individuals avoided ratcheting at all. Likewise, college students were selected for having greater experience than high school violinists, but it is again reasonable to assume that group membership again correlates with violinistic ability. Outside of the shifting excerpt, college students executed more complete events and larger sections of the material in each attempt than did high school students, and they also generated fewer ratcheted series, although the distinctions between groups are less strong here than they had been for professionals.

In the shifting excerpt, all three groups showed ratcheted practice at similar rates. It is important to remember that the definition I used to label an event as part of a ratcheted series required that at least two consecutive playing events, if strung together, constituted a single forward performance of a larger section of material, and that they be joined together by a small backtrack of no more than a beat. There was no requirement that the overall series add up to a complete performance, only one that was more extended than the individual playing events that made it up. It is possible that the difficulty of the shifting excerpt or something in the nature of shifts as a technical challenge created challenges for participants in all groups that led them to exhibit ratcheted practice at similar rates. These series themselves may have still been relatively small compared with the length of playing events in participants' other sections; this one

result does not seem sufficient to question the idea that participants were working on specific problem locations when practicing this excerpt. It is also possible that defining the maximum small backtrack that would not interrupt a ratcheted series as one beat may have contributed to this result. The shifting excerpt was composed in 6/8 time featuring sixteenth-note subdivisions, and as such many of its beats included six notes, the most of any excerpt.

Overt practice strategies

Data for the overt behaviors commonly known as practice strategies show that they are indeed treated as tools that are appropriate for certain practice contexts and not appropriate for others. Experienced participants are in general more likely to put these tools to use than are their less experienced counterparts. They also show that participants employ these behaviors sparingly and idiosyncratically, with a few individuals often contributing the bulk of the data for a given behavior in one group or context. As outliers, these individuals would often be excluded from further analysis; however, within this category of behaviors, the consistent presence of several outliers appears itself to be a notable trend. Practice habits and routines are highly individualized.

Perhaps the clearest example of participants' use of overt practice strategies comes from the data on open string isolation—playing only the bowing motions required by the printed material, but omitting the left hand execution required to produce the indicated pitches. Only six individuals across the entire group of 35 participants ever displayed this behavior at all; it appears to be an activity that some individuals find useful, but many do not. Four of these individuals were professionals, two were college students, and none were high school students. Using this practice tool at all, in other words, seems to increase with experience, but remains a distinctive trait of certain individuals' practice habits, rather than a group-wide phenomenon. All six participants

who showed this behavior did so exclusively when practicing the string crossing excerpt, with the exception of a few isolated events by one professional learning the shifting excerpt. Even among those participants who did employ this technique to practice string crossings, mean rates were low, with the two college students applying it to only 3% and 6% of playing events, and professionals averaging 12% of events.

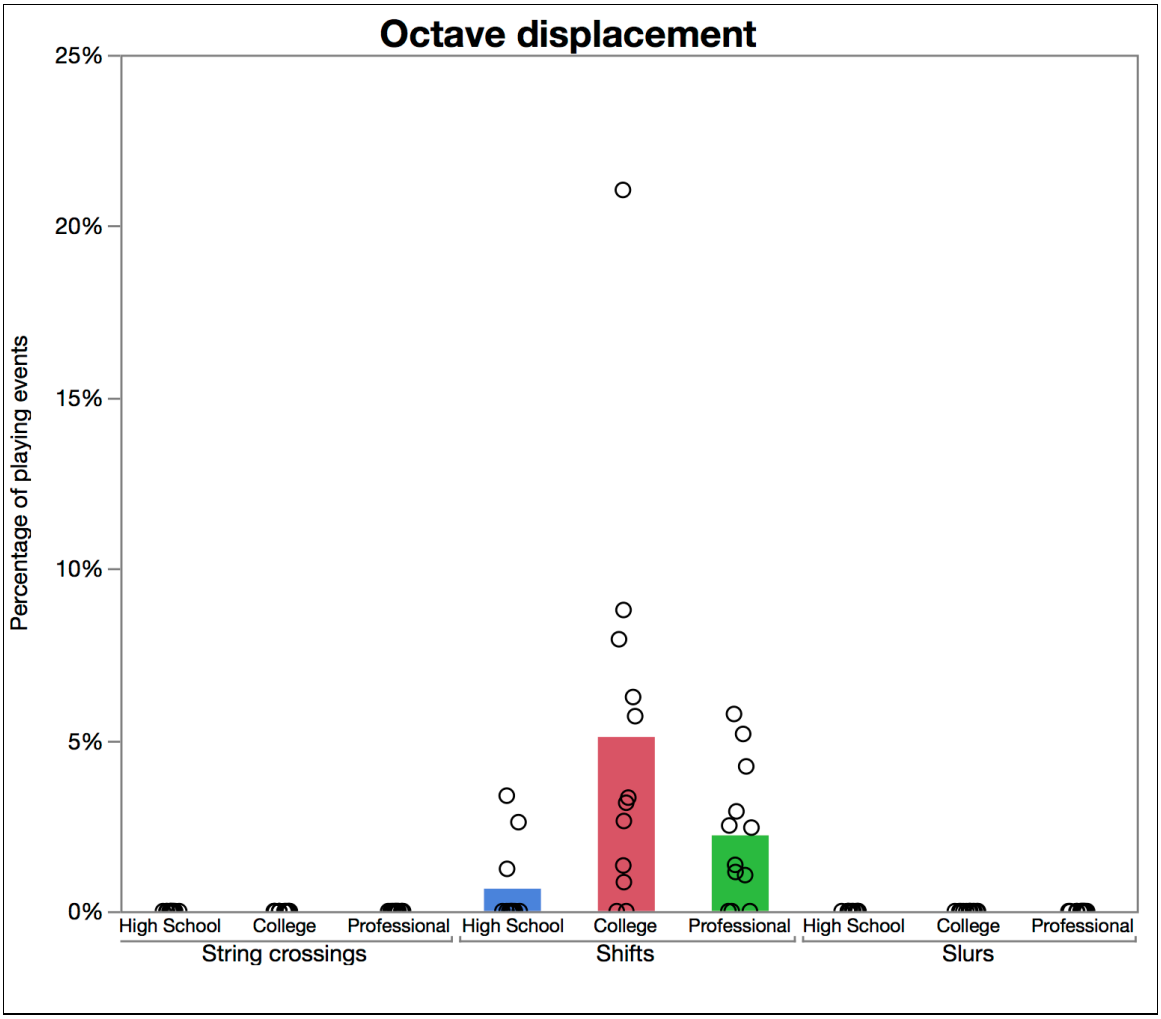

Figure 16: Percentage of playing events in which participants played in a different octave. Mean values shown are those for the entire group, not only the individuals who showed this behavior (i.e., the means include zero values for participants who never employed this strategy).

The data for octave displacement are also typical of results for overt practice strategies. This behavior helps separate the musical task of learning the material from the

technical challenge of playing it in a less-familiar and sometimes uncomfortable physical location on the instrument. As such, it is perhaps unsurprising that it appeared only in the context of practice sessions focusing on the shifting excerpt. 75% or more of professional and collegiate participants employed this technique at least once in this setting, but only 3 high school students did. At the same time, one individual used octave displacement far more than anyone else; no other participant in any group used it in even 10% of playing events, less than half of this individual's rate.

Pedagogues suggest that adding double stops to the printed material is useful for solving at least two types of problems (e.g., Fischer, 2004). Double stopping a note against an open string or against a neighboring note in the score (playing them simultaneously instead of sequentially) allows violinists to assess their pitch accuracy with greater precision than would playing each note alone. Double stopping also facilitates a player's planning of blocked fingerings, in which the left hand fingers are placed as a group rather than singly even though the notes are executed one at a time, a technique often useful in string crossings. Over 80% of participants in all groups used double stops when working on the string crossing excerpt, where both of pedagogues' suggested reasons to employ the technique may have been in play. In the shifting excerpt, where blocked fingerings were less of a concern but leaping to high positions may have increased individuals' pitch uncertainty, between 25% and 60% of group members added double stops, while in the slurring excerpt, 25% or fewer of participants in any group did so.

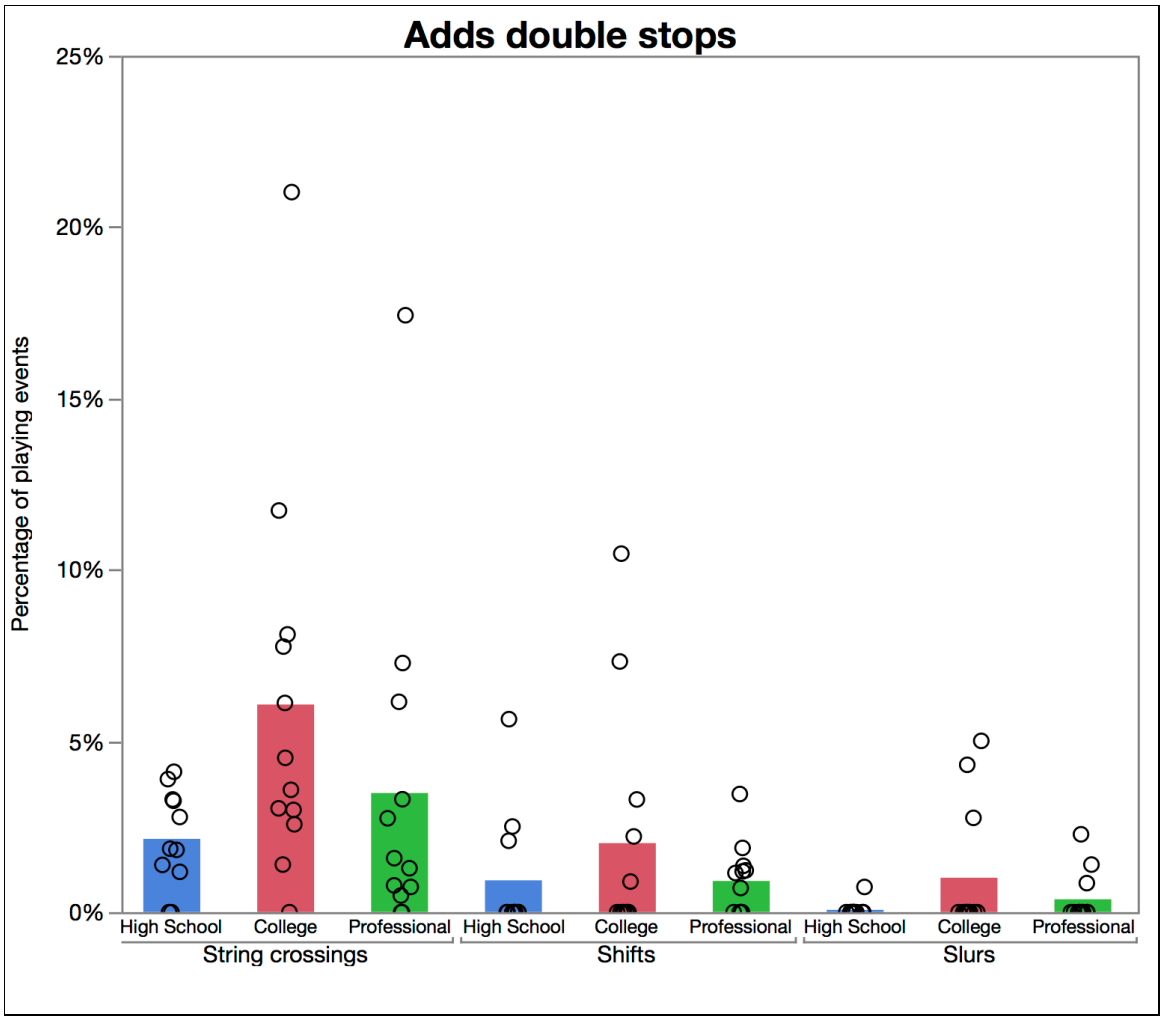

Figure 17: Percentage of playing events in which participants added double stops. Mean values shown are those for the entire group, not only the individuals who showed this behavior (i.e., the means include zero values for participants who never employed this strategy).

The rates at which participants used this technique again clearly illustrate three of the overall trends among the data for overt practice strategies. Double stops were used very sparingly; in no practice session did the average participant in any group employ this strategy in over 7% of the playing events. Moreover, Figure 17 illustrates why the standard deviations for this behavior in Table 1 are high relative to the mean value: a few individuals employed this practicing tool extensively, while most others used it on just a few occasions. The clear pattern across groups in the percentage of participants who used

double stops at all demonstrates consensus that it is most applicable to string crossing work, and also useful for checking high pitches, but there are a few individuals in each group who rely more on this strategy than their peers do. Finally, across all excerpts, high school students again exhibited this strategy the least frequently. It may be especially notable that only in the string crossing excerpt was there a similar number of high school participants who employed the technique at all compared to other groups. Perhaps the least experienced participants nearly exclusively use double stopping to check blocked fingerings, ignoring the technique's pitch-checking function.

Events in which participants played backwards (playing the notes in the reverse order seen in the printed score) occurred in only two individuals' slurring practice, and only there on a few events, suggesting that participants did not find this tool useful in that setting. More than half of professional participants and about a third of students, however, employed the technique when practicing the shifting excerpt. These numbers suggest that participants found this technique useful for isolating the very localized problems endemic to the shifting except. Although I did not extract numerical data about what specific problems participants were practicing when this behavior appeared, from watching the videos I am reasonably confident in confirming that the bulk of these instances occurred when individuals repeatedly played the notes surrounding a shift while alternating forward and backward directions in the score.

As shown in Figure 18, this technique too seems to be a favorite of a few individuals, even in contexts wherein many members of the group put it to use occasionally. Unlike some of the behaviors discussed above, one or a few members of each group also used this tool in most of the other practice contexts as well, but in all but one case this was limited to a very few playing events. In no practice session by any individual, in any context, was this behavior seen on more than 10% of playing events; it was used sparingly indeed, but fairly widely among professionals when practicing shifts.

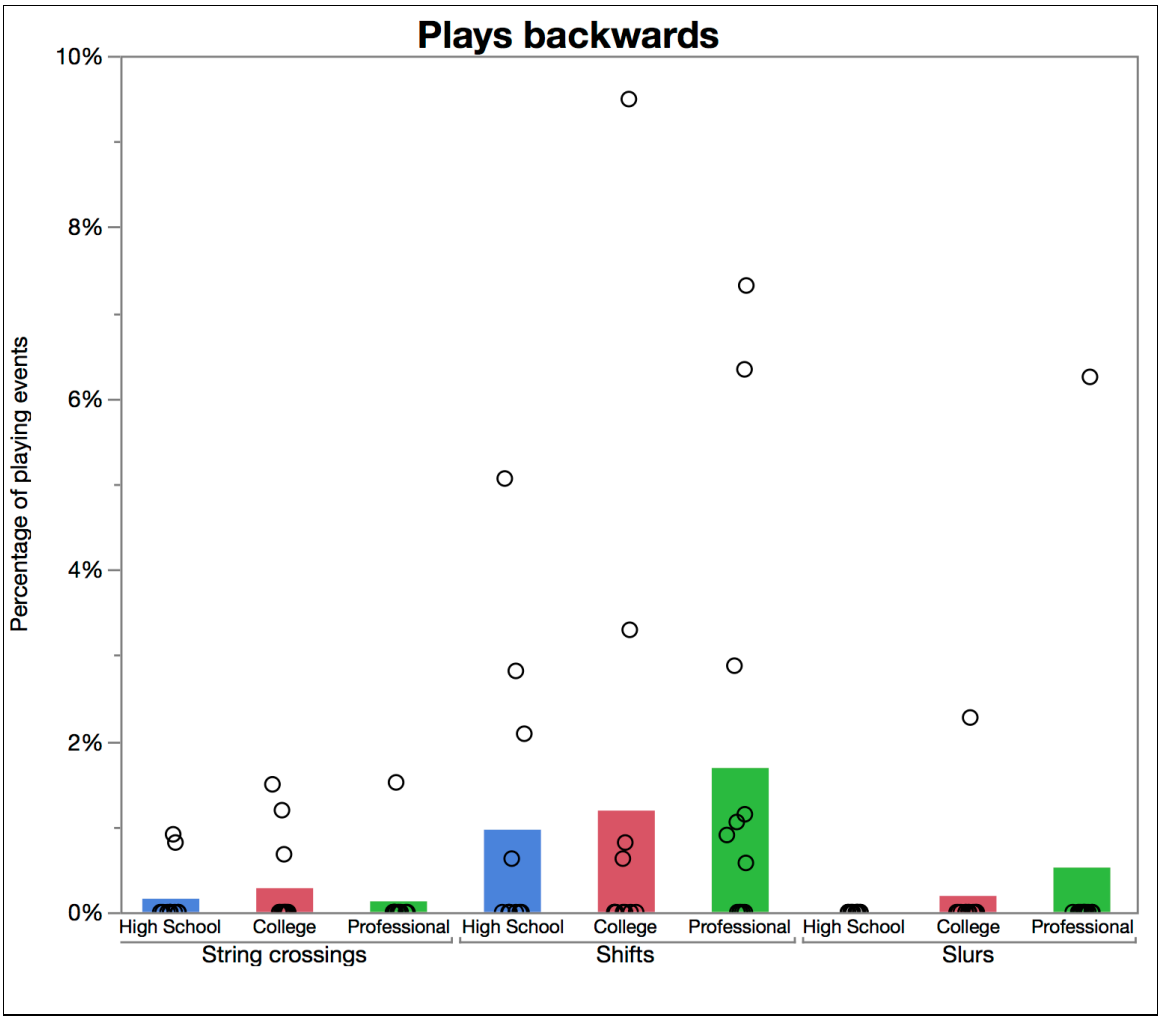

Figure 18: Percentage of playing events in which participants played backwards. Mean values shown are those for the entire group, not only the individuals who showed this behavior (i.e., the means include zero values for participants who never employed this strategy).

The data on how participants incorporated two seemingly similar strategies, altering the printed rhythms and bowings systematically, present slightly more complicated results. Altering bowings may involve removing all bowings from a slurred passage, breaking longer slurs into shorter sections, or adding slurs to material that does not actually call for them. Removing or shortening bowings may help simplify a passage when those bowings add complication; alternatively, adding bowings may simplify a passage if coordinating the two hands is a problem. My own teachers suggested employing altered rhythms of the form seen in Figure 7 (page 79) to practice complicated

"finger twister" passages. Another form of rhythmic alteration involves splitting a long printed note into its subdivisions (e.g., playing a single half note as four repeated eighth notes). Both of these behaviors as I have labeled them may therefore actually represent categories that include multiple related strategies, each of which may be applicable to subtly different problems. In both behaviors, the systematic, regular application of the alteration across sections of the material is a key feature; these are not single deviations from the score, but rather consistent changes made across the entirety of the material.

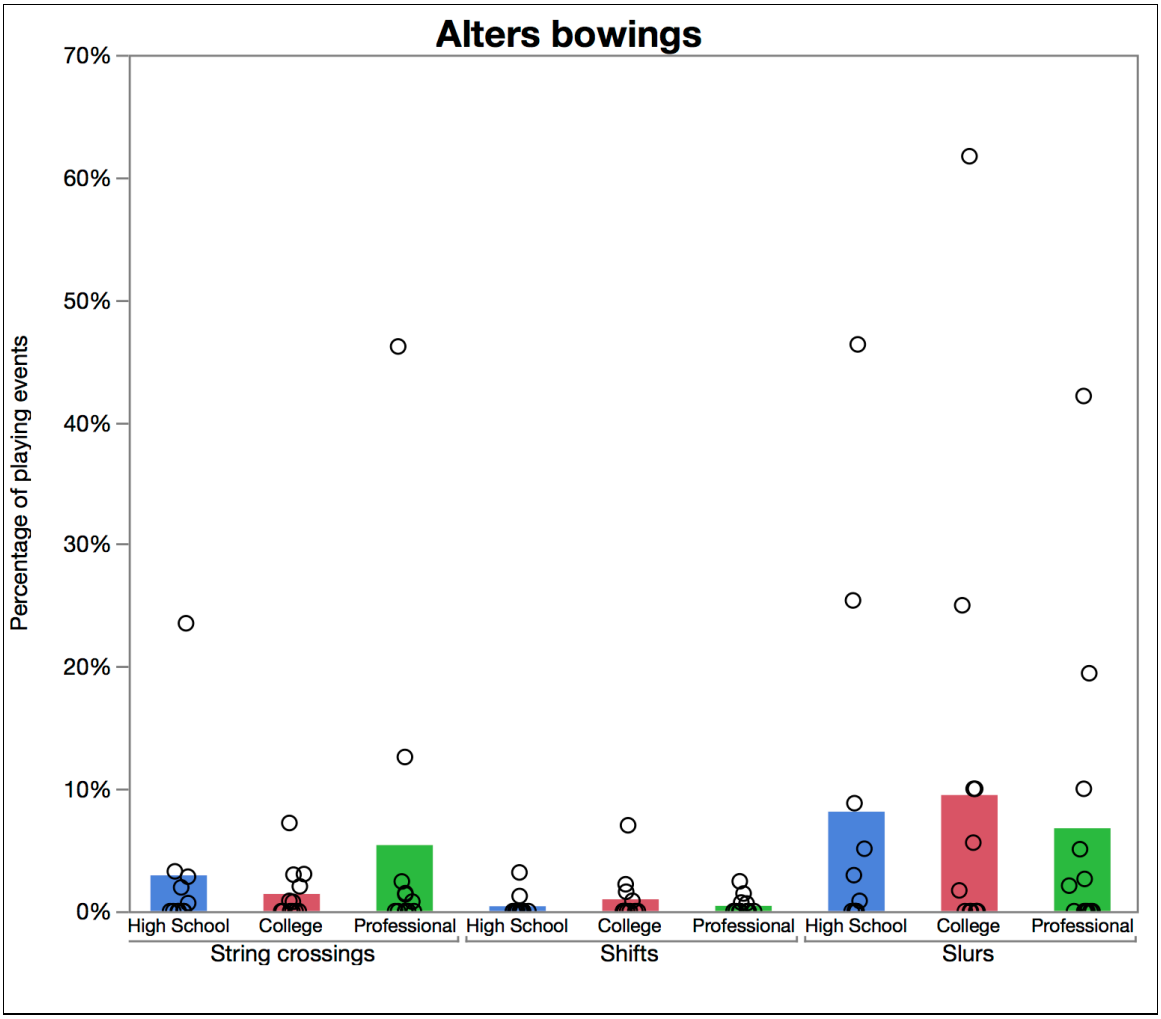

Figure 19: Percentage of playing events in which participants systematically altered the bowings. Mean values shown are those for the entire group, not only the individuals who showed this behavior (i.e., the means include zero values for participants who never employed this strategy).

Figures 19 and 20 show that, like other overt practice strategies, systematic bowing and rhythmic alterations show great individual variability. A few individuals use them extensively, but many use them rarely or not at all. The data presented in Table 1 clarifies what can be seen in the charts. About half of all participants in all groups employed both of these tools when practicing the string crossing excerpt, and half of participants in all groups also used altered bowings when practicing the slurring excerpt. In the context of the slurring excerpt, again, about half of high school students used altered rhythms at least once, while a higher percentage of professional participants (67%) did; conversely, only a quarter of college violinists did.

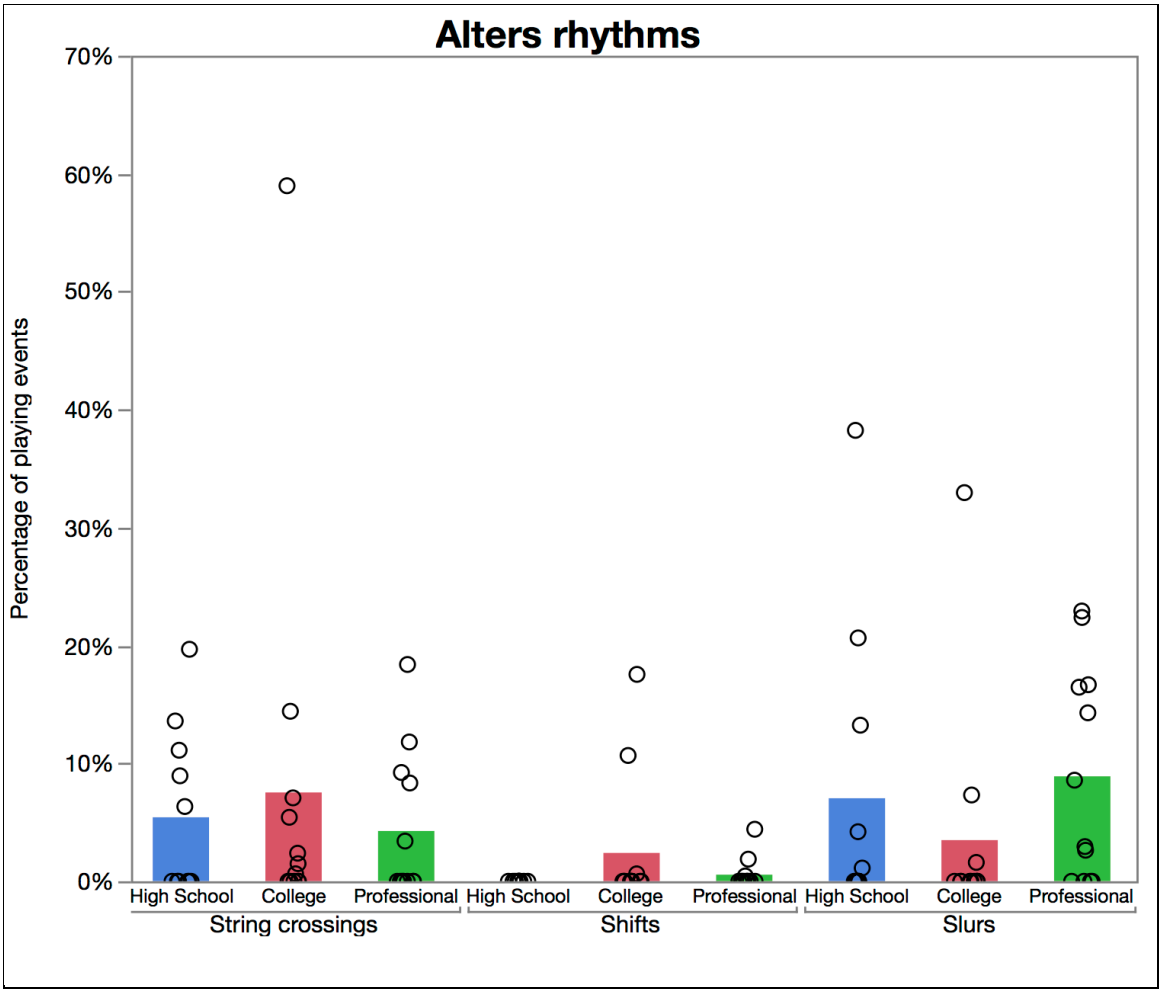

Figure 20: Percentage of playing events in which participants systematically altered the rhythms. Mean values are those for the entire group (i.e., the means include zero values for participants who never employed this strategy).

Both of these strategies were less popular when participants practiced the shifting excerpt. Among college students and professionals, only a third ever altered their bowings in this setting, and a quarter altered their rhythms. No high school students altered rhythms systematically in this context, and only two individuals altered bowings. To be sure, rhythmic and bowing irregularities, presumably errors, were present in shifting practice, but the regular, consistent alterations that defined these behaviors (and that I chose to define it because they demonstrate volitional control) were essentially absent from these practice sessions.

As mentioned above, for most practice strategies, a few individuals in each group tend to be responsible for most of the individual instances seen in the data. These two behaviors exemplify this trend. In all three practice contexts, 40% or more of the individuals in each group never displayed either behavior. Of participants who did use each behavior, most used it lightly, using altered bowings on less than about 10% of playing events, and altered rhythms on around 20% or less. Two or three individuals, however, raise the apparent means, employing the techniques at twice or three times the rate of other members of their groups, even after ignoring those who never displayed the behavior. As mentioned above, these individuals could be considered as outliers, but the same pattern occurs on all overt strategies, making it notable in its own right, and moreover two or three individuals represent as much as a quarter of any group. With these two behaviors, however, even most of those individuals seem to have mostly decided they were inappropriate tools for the shifting excerpt. Two individual college students altered rhythms more on more than 10% of their playing events when learning the shifting excerpt, but no other individual reached half that rate in any group. Notably, one of these two individuals' altered rhythms took the form of subdividing longer rhythmic values, whereas almost all other instances of rhythmic alteration in the present study were of the form seen in Figure 7 (page 79).

In general, it is safe to conclude that participants across groups found rhythmical alterations of the form seen in Figure 7 as well as systematically altered bowings inappropriate or unhelpful for practicing the shifting excerpt. Many participants from all groups, however, used these strategies in their slurring and string crossing practice, and perhaps not surprisingly those who used did employed altered bowings more extensively when working on the slurring excerpt. In contrast with previously discussed practice strategies, these two strategies did not seem to be any more prevalent among experienced participants than among less experienced ones.

Playing pizzicato seems to be a particularly unusual practice strategy. Around a quarter to a third of participants in all groups displayed this behavior in all practice sessions, with higher percentages among professional participants in practice sessions covering the shifting and slurring excerpt. However, two further observations are warranted here. First, there were two distinct behaviors that both could be described as plucking or playing pizzicato, and they were grouped into this category by the computer script that extracted numerical data from my transcriptions. The first was playing a section of the material while plucking rather than using the bow. The second was plucking a string, often at the end of a playing event that had otherwise been executed arco (with the bow); subjectively, this often seemed to be an indication of the participants' frustration with their efforts.

Second, more so than in any other behavior, single individuals contribute most of the playing events featuring pizzicato playing. As seen in Table 2, in the high school and college groups, a single individual was an outlier in all three practice contexts, showing high rates of the behavior. Among professionals, two individuals each displayed anomalous pizzicato behavior in a different practice context. The other individuals who displayed this behavior did so on very few occasions, and those occasions seemed to be expressions of frustration, rather than active modifications of the material being practiced. Playing pizzicato seems to truly be an individual practice idiosyncrasy.

That a few individuals in each group employ each strategy far more than others has been recurring theme thus far, but this tendency is exaggerated with pizzicato. Only four individuals across the entire study employed this behavior extensively. Those four individuals used pizzicato practice quite extensively. Among students, three or fewer participants played pizzicato in any practice session at all. Most of the instances of this behavior seen among individuals who were infrequent users appeared to be of the plucking the string in frustration variety. Only four individuals seem to have actually employed pizzicato as a proactive strategy at all.

		String crossings	Shifts	Slurs
High school	Who (% of events)	P#24 (17%) 2 others (<1.5%)	P#24 (49%) 3 others (<3%)	P#24 (11%) 2 others (<2%)
College	Who (% of events)	P#14 (24%) 2 others (<3%)	P#14 (6%) 2 others (<1%)	P#14 (26%) 1 other (1%)
Professional	Who (% of events)	P#19 (11%) 2 others (<2%)	P#18 (66%) 6 others (≤ 2%)	[no outliers] 5 others (≤ 2%)

Table 2: Outliers accounted for almost all instances of pizzicato. Four individuals—one in each student group and two among professionals—accounted for more instances of this behavior than all the other individuals in their groups combined. The percentages shown for "others" reflect maximum individual, not mean, rates (e.g., two others who each used pizzicato in fewer than 1.5% of playing events).

Other behaviors

Part marking represented the frequency of events wherein participants stopped playing and took up the pencil, expressed in Table 1 as a rate of marking events per playing event. Usually, participants proceeded to write on the page, though I also counted the few incidents when participants put the pencil back down without writing because these were clearly examples of part-marking behavior generally, even if they represented cases in which individuals decided against it. I made no attempt to analyze what participants wrote; any such an examination may be appropriate to future work. Among

participants who wrote in the score at all within each practice session, rates were fairly consistent. Among individuals who used the behavior (not the overall mean affected by non-users seen in Figure 21), professionals' marking rates were the highest, or tied for the highest, in any context, but the contrast between extremes for groups and contexts is of approximately the same magnitude as the standard deviations. In contrast to many other behaviors, outliers seem neither to have had a major role in shifting the mean values, nor to have been common enough to warrant examination in their own right. High school violinists were the only group to have had at least one participant in all three

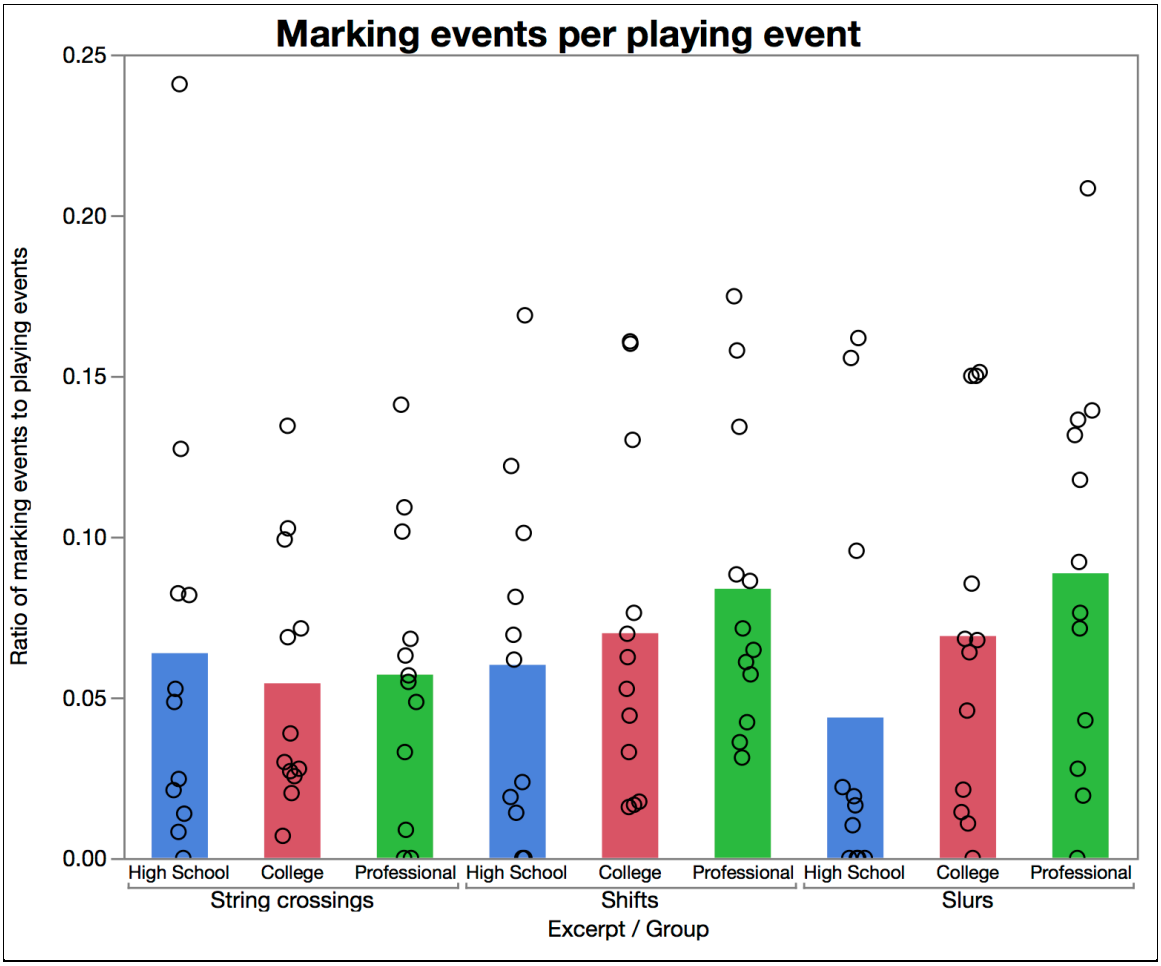

Figure 21: Marking events per playing event. Mean values are those for the entire group (i.e., the means include zero values for participants who never employed this strategy).

practice sessions refrain from marking at all; in fact, a single individual never picked up the pencil. Even excluding this one individual, the number of high school violinists who never decided to engage with the pencil may be a little high, but in light of the comparable rates among those who did with other groups, this seems to be weak evidence. In other words, participants in the present study do not appear to have marked their parts at different rates as a result of their experience levels or of the material they were learning.

Likewise, the percentage of time within the practice session that participants spent playing seems to be fairly stable across groups and practice contexts. Table 1 shows that with one exception, participants across groups and practice sessions spent between 80% and 89% of their practice sessions playing. The one exception was professionals practicing the shifting excerpt, who spent slightly less than 79% of their time playing. Standard deviations were comparable in magnitude to the variation between groups, suggesting again that meaningful trends are unlikely to be present. The high individual variability seen in Figure 22 may reflect the similar variability of rates of part marking; time not spent playing was recorded in my data as marking, adjusting the metronome, or other. Other events were very rare, and it seems unlikely that adjusting the metronome consumed a large amount of time.

As discussed when I defined each behavior in Chapter 3, I distinguished between three categories of playing event in which participants repeated notes based on whether they repeated the first note of the material they were about to play; repeated the last note of the material they had just played; or played, repeated a note, and then continued. I did not, however, make distinctions between different types of repetitions that may in fact be meaningfully different. Sometimes participants repeated a note just once, sometimes many times. Sometimes participants appeared to deliberately repeat the first pitch in tempo, as though preparing; at other times they changed the pitch slightly, apparently correcting themselves; and at other times they seemed to be stalling for time or displaying

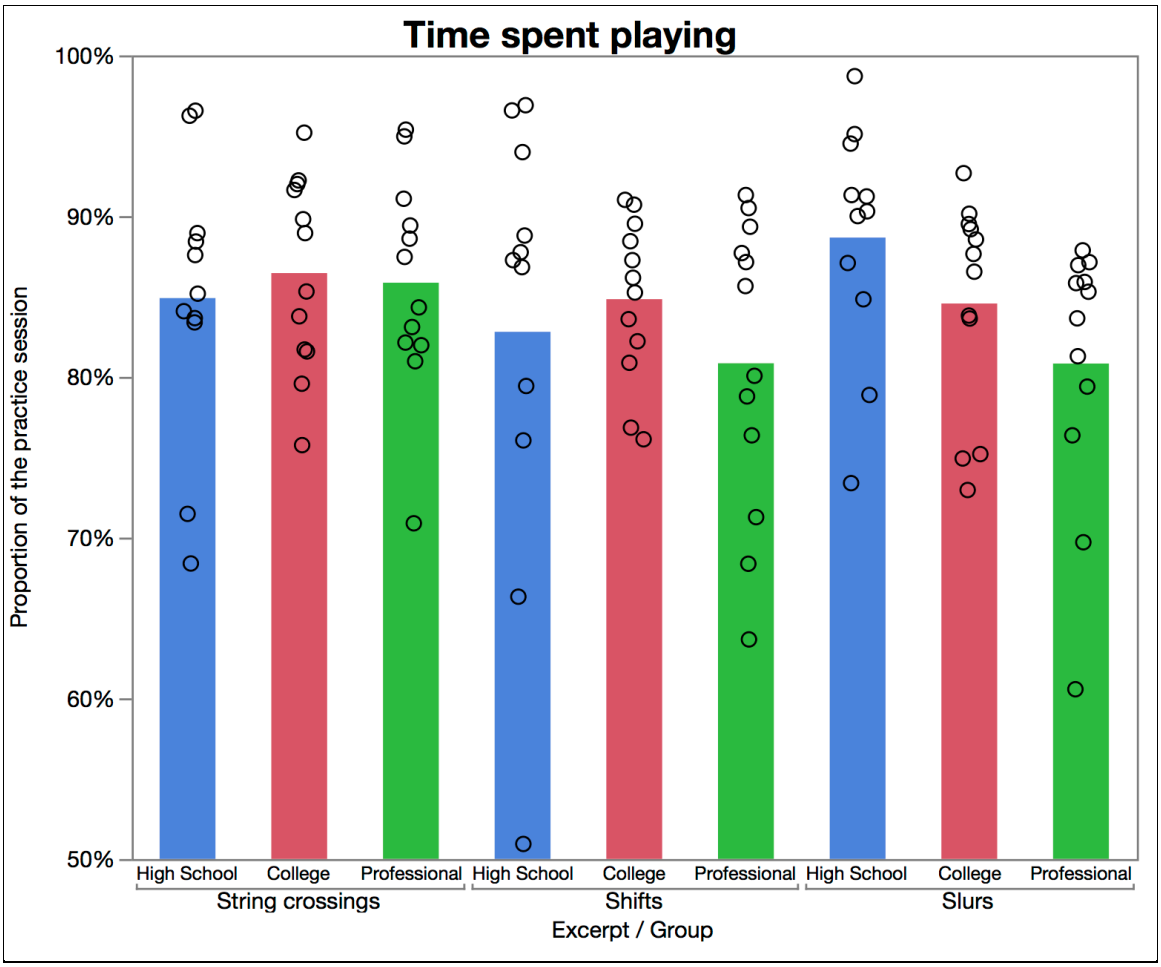

Figure 22: Percentage of time within the practice session spent playing.

a nervous tic. There did not seem to be any way to objectively determine which of these or other possible categories applied to any particular instance of repeating notes, and so I did not make any distinctions. However, the fact that any or all of these behaviors may be a catchall category, one that includes not only purposeful but also accidental or even unnoticed behaviors, may explain why they show some different trends than the other behaviors I examined.

As seen in Table 1 (page 116), a high percentage of participants displayed note repetitions. Two thirds or more of participants in all groups repeated events' first notes in every practice context; except for high school students playing the slurring excerpt, the same was true of final note repetitions. Repeating an internal note was slightly less

common; among professionals practicing the string crossing and slurring excerpts and among college students practicing slurs, only half showed this behavior. On the shifting excerpt, however, repeating notes in all three positions was present for every individual in the study, with the exception of one professional participant who avoided repeating any internal notes.

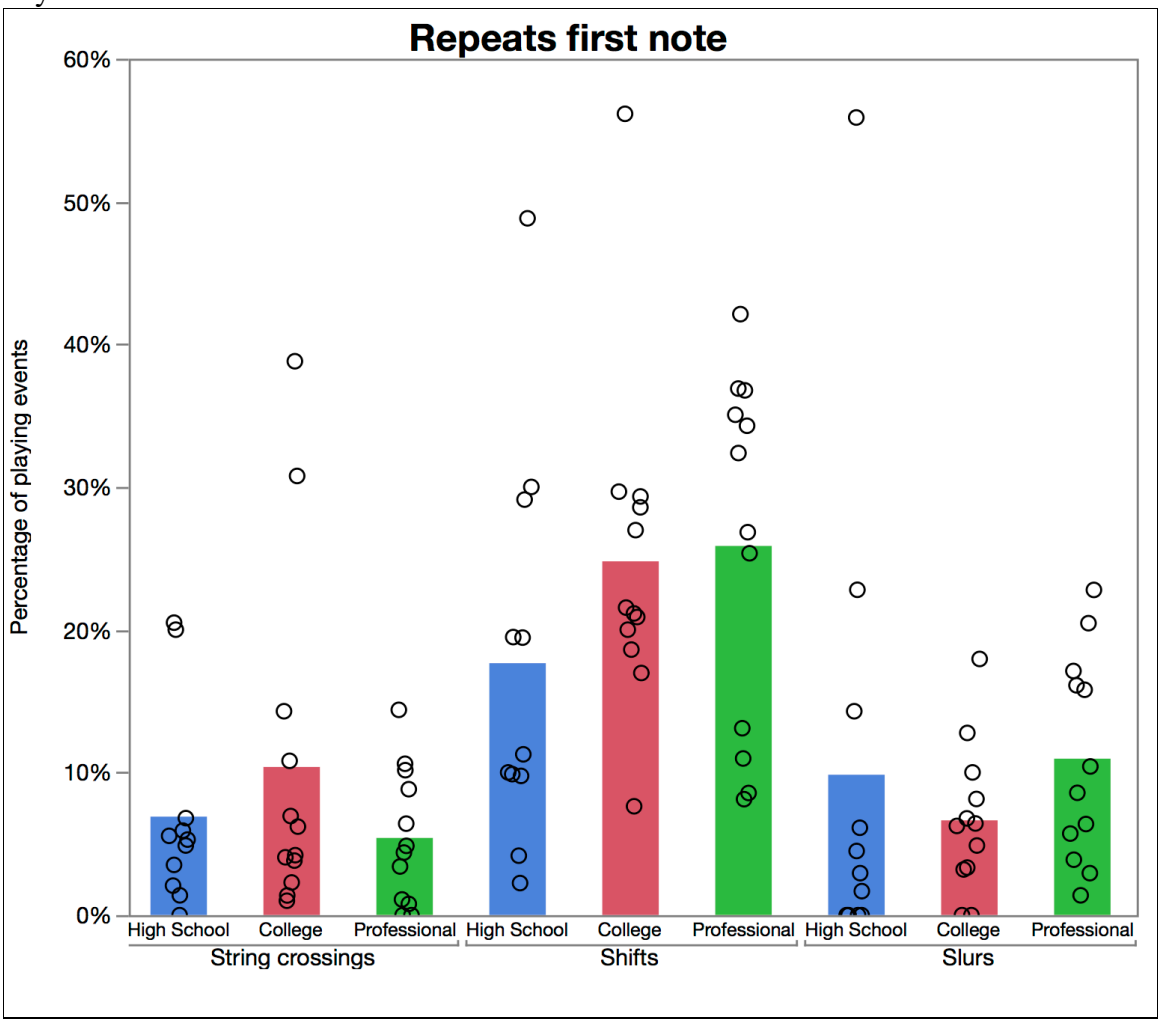

Figure 23: Percentage of playing events in which participants repeated the first note. Mean values are those for the entire group (i.e., the means include zero values for participants who never employed this strategy).

The distributions of individual data points in Figures 23, 24, and 25 suggest that in contrast to the practice strategies discussed above, repetition behaviors are fairly evenly distributed among participants. In this respect, these behaviors seem less like overt strategies and more like the other measures of practicing behavior discussed earlier in the

chapter. The rates for all three repetition types, or positions within the event, in the shifting practice session are much higher than in the other two contexts.

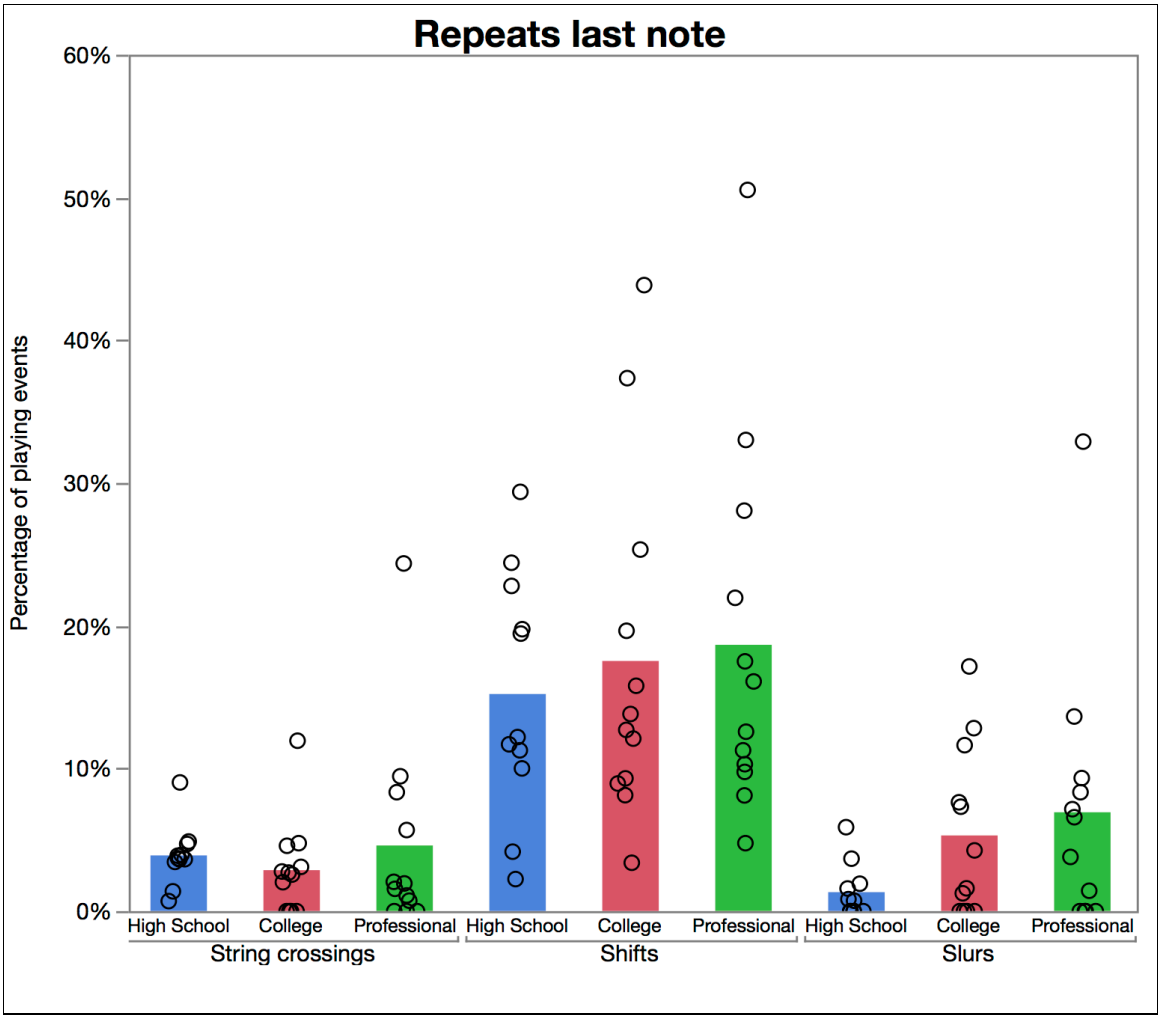

Figure 24: Percentage of playing events in which participants repeated the last note. Mean values are those for the entire group (i.e., the means include zero values for participants who never employed this strategy).

To the extent that repetitions, particularly those in which participants adjusted the repeated note's pitch, reflect errors or confusion, the higher rates seen in the shifting excerpt may be due at least in part to its difficulty. Particularly when considering internal repetitions (in which a participant began playing, repeated a note, and then continued) there is at least one reason to think this might be the case. Recall that I defined ratcheted practice as series of events that appeared to represent an attempt at a single longer

playing trial, but instead appeared as multiple events separated by a short backtrack of no more than a beat in the score. That definition itself was built upon how I defined each playing event: if a participant backtracked by even a single note in the score, I considered the forward motion to have stopped, and I began a new playing event at the location to which the individual backtracked. However, if that participant simply paused or repeated a note before continuing, I recorded a single playing event. The distinction between one event and a series of two or more ratcheted events thus could be as little as a one-note backtrack, but the presence of internal repetitions, especially those in which participants

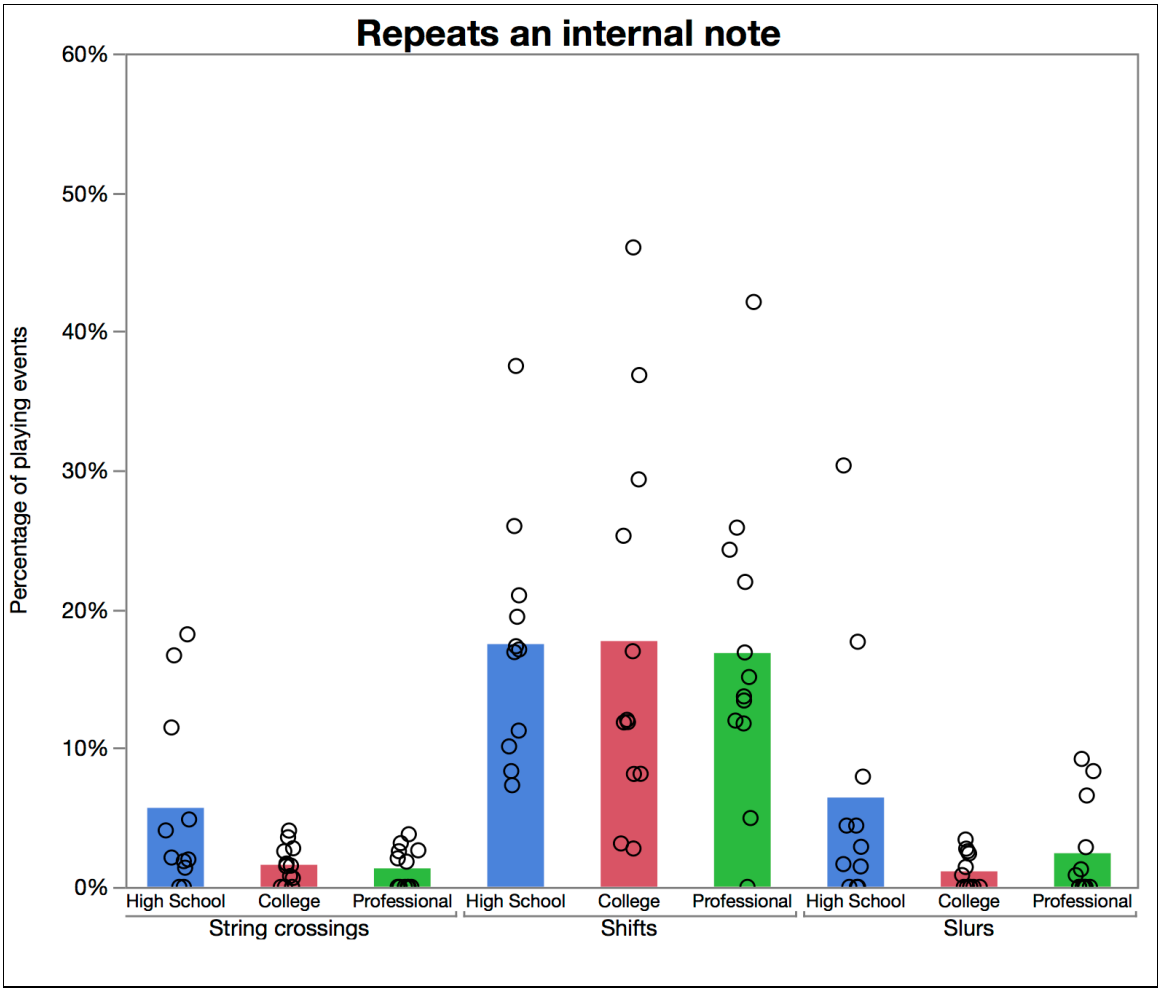

Figure 25: Percentage of playing events in which participants repeated an internal note (i.e., not the first or last note). Mean values shown are those for the entire group, not only the individuals who showed this behavior.

corrected a pitch, still represents a break in forward progress through the material. Internal repetitions, therefore, may be cousins to, or miniature versions of, ratcheted practice, which as I noted earlier seems to occur when participants encountered difficulty, when they tried but failed to execute longer sections of material. Internal repetitions, like ratcheted practice, may indicate that individuals are struggling with the material they are trying to learn.

I was hesitant to include the final behavior, including a note in the preceding slur, in my analysis at all. As discussed in Chapter 3, I intended to limit my analysis to those behaviors that seemed to reflect participants' choices regarding or approaches to practicing each excerpt; I did not intend to directly measure the accuracy of their efforts or their success in executing their plans. This behavior, however, seemed to represent a particular category of mistake. It did not seem to be a regular, systematic bowing alteration, or I would have included all instances within the behavior "alters bowings." However, as an objectively observable behavior, but one that could not objectively be dismissed as definitely reflecting a mistake, I recorded it in my transcriptions frequently enough for it to have made the .5% threshold for inclusion in the analysis.

The data seem to support the idea that this behavior reflects a particular mistake, and even if it is sometimes a decision, it is a highly idiosyncratic one. As might be expected, this behavior was never seen in the string crossing strong excerpt, which only included a few slurs to begin with. Only one professional participant and a third of college students showed this behavior in the shifting excerpt, and there they did so on a vanishingly small share of their playing attempts, less than 1.5%. Two thirds of high school students did exhibit this bowing pattern on the shifting excerpt, but most of them also did so at low rates. One individual high school student, however, displayed the behavior on greater than 60% of playing events.

In the context of practicing the slurring excerpt, where opportunities for such an error were ubiquitous, many participants included a note in the preceding slur. It was still

rare among professional players; only a third ever displayed this behavior, and then in fewer than 2% of their playing attempts on average. Two thirds of college students showed the behavior in this context, and over 80% of high school students, and percentages of playing events in which it appeared were higher for these groups, too. However, I must again emphasize that when I recorded this behavior being present, that specifically means that it was not part of a systematic pattern of bowing alterations, in which case I would have recorded it as such. Instead, these represent single slurs extended by one note, in the context of a passage with a signature challenge—syncopated slurs—that made an error of this form likely. As a probable error, one that is predictable from the practice context, it seems imprudent to discuss including a note in the preceding slur any further at this point; readers who suspect this behavior represents a more salient feature of practice may wish to investigate further.

CLOSING REMARKS

The data from this study seem to answer both research questions in the affirmative. Yes, violinists do change their approaches in response to the challenges presented in the material. That is, when they work on different kinds of music, they use different overt strategies, and they also change their overall approach to target specific trouble spots or to work on sustaining continuous behaviors across broad stretches of the material as appropriate. Yes, the specific behaviors violinists exhibit in each situation do vary as a function of experience in two ways. Individuals with more experience tend to make more use of explicit practice strategies, including regulating their work with the metronome as well as those behaviors that involve altering how the music is performed, than other participants. Also, behaviors that seem to reflect the interaction between participants' intents and their ability levels (e.g., ratcheted practice or complete playing events) show differences as a function of group. Disentangling experience, playing

expertise, and expertise specifically within the arena of effective, efficient practice must be a topic for future research.

The purpose of this study was not to compile an exhaustive list of the things people do in response to each challenge, nor to assess how effective each type of behavior was in addressing that problem. I did not attempt to choose the three most salient or characteristic challenges present within violin playing. As such, I will not present a final list of which behaviors appeared in each practice session. The more important finding is that, as a rule, violinists tailor their behavior to the challenges of the music they are working to master. They treat behaviors and behavioral patterns as tools used to solve a particular kind of problem. Behaviors that seem to indicate self-regulation without requiring musicians to actually alter the music seem to indicate that participants focused on continuity across the slurring excerpt, but focused their work on more exact points when learning material characterized by shifts; their work on the string crossing excerpt seems to have struck a balance between the two. Behaviors that may have reflected a degree of intentionality but that also likely included responses to feedback, reactions to participants' perceptions of prior or ongoing activity (e.g., making a complete performance rather than stopping) seem to reflect the same intentions as the self-regulatory behaviors, but with limitations imposed by differing ability levels.

Overt practice behaviors involving modifications to the printed material do not appear to be tools used by inexperienced players to help them identify or cope with problems that more experienced individuals solve through less-intrusive means. Rather, professionals (and for some behaviors college students) tended to employ such tools more frequently than did high school students, not less. Participants in all groups identified similar problematic locations within each excerpt to practice. It is possible that because they needed to be comfortable reading and playing in high positions, the high school participants recruited for the present study represented a particularly savvy group of students.

The findings suggest that what distinguishes musicians' practice by experience level is not their overall identification of problems or their ability to manage their behavior. Instead, the metronome use data suggest that as musicians gain experience, they use at least this one tool in a more sophisticated manner, though the trends may also simply be indicative of the probable correlation of experience with ability level. The data for modified practice behaviors suggest that with experience, musicians use more rather than fewer different approaches to the music. And the data for behaviors that depend not only on participants' intentions but also on their ability to successfully execute reveal, unsurprisingly, that particularly when working for continuity, less experienced violinists' attempts to practice like their more experienced peers are modulated by their abilities.

Interestingly, when I asked participants whether they used the same method to practice the three excerpts or whether they worked differently, many answered that had indeed used essentially the same approach (see Appendix C, page 207). They typically described that approach as identifying particular problems and then resolving them. Some participants described their work on the shifting excerpt as different from the other two, in that they had to formulate a plan before proceeding to find and fix problems. However, very few discussed deliberately working for continuity on the slurring excerpt, or the specifics of how one practices shifts differently than other material, apart from having to form a conscious plan. Participants did, however, offer up more exact descriptions of the technical aspects of the string crossing excerpt, describing not only different bowing patterns but also the blocking patterns demanded of the left hand.

Even more interestingly, when I asked them to identify the signature challenge of each excerpt, a surprisingly high percentage of participants did not accurately identify either string crossings or the slurring pattern, referring instead to something vaguely related (see Table 5 on page 214). This near-identification was most common among high school students, but even professionals sometimes identified different salient features in the excerpt than expected. This apparent contradiction—quite a few participants verbally

identifying different kinds of challenges even while their behaviors suggest that they worked similarly—is intriguing. Perhaps subtler behavioral measures in future studies will distinguish finer modes of work that do reflect these different perceptions. The differences between what musicians said about their work and what was evident from observing their practice highlight the need for further research.

Chapter 5: Discussion

Individual practice is an important part of musicians' lives. Some pedagogues have written entire books on the topic, while others have given practice chapters or subchapters of more general texts (Auer, 1980; Bruser, 1999; Carney, 1980; Farkas, 1956; Fischer, 2004; Galamian, 1985; B. Kaplan, 2004; Klickstein, 2009; Morganstern, 2002; Nardolillo, 2015; Westney, 2003; Wye, 2000). Many state and national teachers' associations publish journals that regularly feature practice advice, and independent magazines such as *The Strad* or *Strings* publish articles written specifically for musicians at a variety of experience levels. Additionally, in the last generation, the emergence of the blog medium and the popularity of YouTube© have enabled a proliferation of articles, posts, and videos with suggestions and advice about how to practice (e.g., Blackerby, n.d.; Deverich, n.d.; Hahn, 2004; Niles, 2011; Thomsen, 2011).

As discussed extensively in Chapter 2, the research community is beginning to study musical practice systematically, but there is a surprisingly small body of literature considering the central role that practice plays in musicians' lives. Some studies have explored students' knowledge of practice strategies, others have examined the relationships between aggregate practice quantity and performance accomplishment, others have examined the influence of a number of variables on individuals' acquisition of the motor skills related to musical sequences of just a few notes, and case studies have explored a few individuals' practice habits in great detail. However, one of the central ideas of the pedagogical literature has yet to be assessed: the assertion that when musicians work on music with fundamentally different kinds of challenges, they do or should alter their approach, that is, that they should choose different tools for different kinds of jobs.

The present study was designed to address the above question, as well as exploring whether its answer varies as musicians gain experience. The formal of this study were:

1. Do musicians use different behaviors to practice material presenting qualitatively different challenges?
2. If so, do musicians' approaches to the same type of challenge vary as a function of their experience level?

Participants in this study were high school violinists, college music majors with violin as their primary instrument, and professional violinists. All participants practiced three difficult musical excerpts for 10 minutes each, and each passage featured a different technical challenge (string crossings, shifts, and a syncopated slurring pattern). After each practice session, participants performed the passage three times. I transcribed their practice behaviors, then compared the extent with which a variety of practice behaviors (1) tended to occur during practice of on one excerpt or another, (2) characterized the practice of one group or another, or (3) varied between groups, but only when participants were working on a specific excerpt.

RESULTS OF THE PRESENT STUDY

The data in the present study suggest that participants at different experience levels are more similar than different in the problems they identify and the methods by which they attempt to solve these problems. Participants did indeed appear to recognize different sorts of challenges in each of the three practice contexts and respond with different behaviors, even if their verbal reports sometimes suggested otherwise. What differences did exist between groups appear to lie in their ability to successfully effect change with their similar approaches, and perhaps in the range of tools at their disposal, rather than in their identification of problems or their selection of tools to address them.

Collectively, results suggest that participants in different groups employed similar approaches and that the approaches varied according to each excerpt's content. They also suggest that individuals with more experience use a wider variety of approaches, experience greater success using these approaches, and perhaps use their chosen strategies in a more sophisticated manner. Data from the present study also include hints that experienced participants may indeed vary in subtly in very detailed aspects of their problem identification, slight differences in analysis that may warrant further study.

The present study measured only practice behaviors and not performance outcomes, and thus cannot directly confirm pedagogical assertions that certain behaviors lead to improved playing and efficient learning. However, participants' pairing of certain specific behaviors to specific excerpts seems to confirm that they at least share pedagogues' belief that they should vary their choice of approach in response to different musical problems. Participants at all levels displayed similar pairings of approaches to problems; novice violinists do not appear to be less able than their experienced counterparts to identify what they need to work on or how to work on it. Though limited to practice activity rather than performance outcome data, there is evidence that younger participants are less able to employ these tools effectively, and my subjective impressions in watching participants' practice support this. Again, subtle differences in exactly how participants at varying levels defined the problems they identified may contribute to this differential ability to improve performance.

Responding to the characteristic problem of each excerpt

The shifting excerpt features many drastic leaps in register that, on a violin, can be accomplished either by shifting (moving the left hand up and down the instrument's fingerboard) or by changing strings while maintaining a high position. The specific melody of the excerpt was composed such that the second approach also necessitated

many, albeit smaller, shifts; thus, regardless of what fingering participants chose, they would need to execute many shifts. A shift is a problem that inherently exists at a point in time between two specific notes on the page. The violinist plays the note preceding the shift in one position, and must be in the new position for the following note. Although practicing the material before and after the shift may also be advisable (Fischer, 2004), shifts are by their nature localized. Although I intended this excerpt to challenge participants' left hand technique, those who opted for fingerings that kept them in high positions to some extent distributed the problems across both arms.

The string crossing excerpt's challenge is repeatedly moving the bow across string levels, either moving the left hand as well or else placing fingers across multiple strings, and coordinating the two hands. String crossings were present in all three excerpts and are common in all but the simplest of melodies, but this excerpt featured copious amounts of them, and it also frequently changed between different patterns of subsequent string crossings. Though each string crossing is also localized between two notes, the problem lies in the varying patterns and, in some cases, in blocking the left hand in a position common to multiple notes. Thus, while still somewhat localized, this excerpt's challenge only arose across sections of multiple beats or sections of the music containing different patterns.

The slurring excerpt's challenge was inherently non-local, spread across broad sections of the material. While the notes themselves displayed no syncopation, the slurs consistently crossed strong, metrically stressed points in the music, including most beats. While common in some styles of music, this pattern is unusual in the Western classical canon. Thus, while the other problems tended to emphasize different aspects of physical dexterity, this excerpt focused more on overcoming deeply learned (but not inherently physically difficult) habits and patterns. Because its signature challenge was based on a pattern of slurs, and slurs by definition themselves each span multiple notes, this problem more than the others is non-local, arising only as an emergent property of longer sections

of material. I intended this excerpt to challenge participants' right arm technique, although a few expressed greater concern with the left hand fingerings.

Across all groups, participants' behaviors suggest that they identified the nature of each excerpt's challenge relatively accurately. A range of practice behaviors suggests that participants at all experience levels accurately identified the intended challenge of each excerpt. At a basic level, when I asked them at the end of their participation to identify each excerpt's signature challenge, most participants across all groups were reasonably accurate, although some identified only related concerns (e.g., focusing on the left hand aspects of the string crossing excerpt). A minority verbally reported completely different problems or stated that they didn't know what problem I intended them to address, but their actions during practice suggest otherwise. A range of practice behaviors converge on the conclusion that all participants worked for continuity when practicing the slurring excerpt, a context in which the inherent problem emerged only when playing larger sections of material, but they focused on specific troublesome locations within the score on the shifting excerpt. Their behaviors suggest a balance between these approaches when working on the string crossing excerpt.

In Chapter 4, I first considered behaviors such as participants' choices of starting points within the material or their use of the metronome, behaviors that indicate intentional about what to practice and how to approach it. I then considered behaviors that not only demonstrate intent, but also share the common element of being defined by participants making overt, observable changes to the printed music. The evidence from these first two types of behavior suggests that participants focused on continuity when working on the slurring excerpt, specific troublesome locations when learning the shifting excerpt, and a balance of the two when working on string crossings. The data also suggest that they used different behavioral tools to solve each type of problem, and that the requiring overt modification to the material were (a) used sparingly, (b) applied only

to specific contexts, and (c) in some cases reflective of personal practice habits. Finally, I discussed other behaviors, including two (marking the part and the percentage of time spent playing) that did not show any clear patterns as functions of the variables of interest.

Among the last category of "other" measurements, too, were note repetitions and including a note in a previous slur. Although these behaviors did vary as a function of context, these results are somewhat ambiguous because measures of note repetition were catchall categories, included behaviors that subjectively appeared to represent differing degrees of intentionality. Moreover, all of the instances of including a note in a previous slur, as well as many of the instances of note repetitions, appear to represent execution errors, rather than practice decisions. These behaviors do seem to reflect where participants encountered difficulties, but they do not seem to reflect participants' decisions about how to work on different types of musical challenges as do the other measures included in this study.

Participants in all three groups started more of their performance trials (i.e., playing events) on the first note of the excerpt during their practice sessions on the slurring excerpt than on the string crossing excerpt, which in turn generated more performance trials starting from the beginning than did the shifting excerpt. Although some of these events may be explained by the first note being a convenient place to start when working on a localized challenge in the first measure, it is also by definition the only place to start a complete, beginning-to-end performance. The data on complete performance trials and the average length of each playing event also support the idea of a continuity spectrum. Participants started at the beginning more often, executed more complete performances, and played a higher percentage of the material in a typical playing event when they were practicing the slurring excerpt than the string crossing excerpt, and when practicing the string crossing excerpt than the shifting excerpt.

High school participants were the exception; they performed fewer beginning-to-end repetitions than other groups in all settings. Four high school participants, in fact, never executing a complete performance trial of the slurring excerpt in practice, and two of these individuals never accomplished a complete performance of any excerpt. By contrast, only one college student never practiced the slurring excerpt in its entirety, and all professional participants played this excerpt from beginning to end at least a few times. However, several pieces of evidence suggest that rather than approaching the material with different goals than members of other groups, student participants simply had a more difficult time accomplishing those goals. Like members of other groups, the average length of each playing event was long when high school students practiced the slurring excerpt, short when working on the shifting excerpt, and intermediate when working on the string crossing excerpt. High school students who managed to accomplish any complete performances did indeed accumulate more of them when practicing the slurring excerpt than the other two excerpts, although the same difference did not differentiate the string crossing from the slurring excerpt. In situations where members of other groups executed relatively high rates of complete performances, high school students yielded comparatively high rates of ratcheted practice, a behavior pattern which seems to represent attempts at extended performances interrupted by mistakes. And in these same situations, high school students in particular frequently repeated notes within a playing event; often, these internal repetitions featured pitch adjustments, and they seem to be very similar to ratcheted practice in that they may reveal instances in which execution errors interrupt attempts at long, continuous performances.

These data suggest that participants tried to play long sections of material when practicing the slurring excerpt, short spots when learning the shifting excerpt, and intermediate sections with the string crossing excerpt. This seems to support the suggestion that they identified continuity as a goal for slurring practice, isolated discrete spots within the shifting excerpt, and worked on difficult locations within the string

crossing excerpt, locations however that were more spread out than the comparable discrete challenges in the shifting excerpt. An alternative explanation might be that participants' practice sessions featured events of differing lengths because the excerpts varied in difficulty; the harder the excerpt, the more participants broke it into small pieces. Participants did indeed agree that the shifting excerpt was the most difficult of the three, and high school students reported that the slurring excerpt was the easiest.

However, additional evidence that participants set different goals in each context comes from overt practice strategies featuring modifications to the material. Participants in all three groups added double stops—played notes concurrently rather than successively, as they had been notated—more often when practicing the string crossing excerpt than in either of the other practice sessions. This strategy is useful for isolating the relationships of the left hand fingers across strings when blocking fingers in groups, rather than changing strings from the arm (Fischer, 2004). Participants systematically altered the rhythms of the printed material in the slurring and string crossing contexts, but not in the slurring excerpt. They employed octave displacement in only the shifting excerpt. They did not display these behaviors simply in response to the excerpts they reported were difficult; instead, they deployed them in response to particular kinds of challenges to be overcome and goals to be met, as pedagogues describe. That they chose different tools, in other words, demonstrates that they identified different problems in each excerpt, and supports the idea that each excerpt's tendency to elicit playing events of different characteristic lengths is at least partially a function of participants' choosing a context-appropriate balance between continuity and isolation of discrete problem spots.

Perhaps the clearest evidence that participants identified different problems in each excerpt, but that all three groups identified similar problems, comes from the data on aggregate practice totals for each note and choice of starting locations (see Figures 11 and 12 on pages 106 and 107). The broad trends are indeed clear; the similarity of the visual contours in each graph is striking. Whether measured by which notes participants chose

as starting points or by which notes garnered the most attention and repetitions across entire practice sessions, participants across groups focused on similar locations. Notes that received a great deal of attention or served as frequent starting points for professionals also received similar attention from college and high school students, although high school students may have devoted more attention than other groups to the beginning of each excerpt. In all three excerpts, the first note was the most common starting location, but this trend was far more pronounced for the slurring excerpt.

The tendency for all groups to start at the beginning more frequently when practicing the slurring excerpt yet again points to their common focus on practicing this material for continuity. Participants displayed greater diversity of starting locations in the string crossing excerpt, though they still tended to start at the beginnings of measures, suggesting that they were following structural units rather than isolating particular notes within these units. Also, professional participants actually started at the ninth measure of this excerpt more often than they did at the beginning. While the first note was the most common starting point for playing events in the shifting excerpt, this excerpt had many notes that served as starting points. The graphs for cumulative practice on each note also seem clear; there are many distinct spikes in the curves—notes that received more attention than their neighbors—in the shifting and string crossing excerpt, while the curves for all three groups are visibly flatter for the slurring excerpt.

The evidence suggests that participants focused on continuity when practicing the slurring excerpt, focused on specific challenging locations when working on the shifting excerpt, and struck a balance between longer, continuous performances and repetitions of local structural units when practicing the string crossing excerpt. Moreover, the evidence suggests that across groups, participants identified similar problematic locations in the string crossing and shifting excerpts, and with some exceptions engaged in similar self-regulation or control strategies to address these problems. The general similarity of responses across groups suggests that experience changes individuals' broad

understandings neither of the challenges they must overcome when learning a piece of music nor of the general strategies they should employ to successfully master these types of material.

Differences resulting from experience levels

If the one of the overall themes of the present study is the homogeneity among groups in terms of the problems they identify and their approaches to those problems, what behaviors differentiated groups? Perhaps the clearest difference is one that I touched on only briefly in Chapter 4. In the present study, I focused on the practice behaviors that participants displayed, on actions that reflected their decisions about how to work. I did not attempt to directly measure the outcomes of those efforts; I did not collect data on accuracy of pitch, rhythms, bowings, or any other aspects of execution except insofar as participants' perceptions of that accuracy influenced their subsequent actions.

However, in watching the videos, the clearest difference between groups was, unsurprisingly, that more experienced individuals played better and appeared to make progress more effectively than less experienced ones. Perhaps this is unsurprising; the variables of experience and expertise are no doubt intertwined. Indeed, as discussed extensively in Chapter 2, a vast amount of experience in the form of focused practice is essential to musicians and other skilled individuals developing expertise in their field, although the details of this process are a matter of continuing research. In this study, the high-experience group consisted of professional players, who were selected based on a demonstrated work history in competitive employment as violinists. It is unsurprising that individuals who have already proven themselves to be skilled violinists should make rapid, efficient progress while sounding good in the process, while less experienced individuals who have not yet built up comparable skill sets would have more difficulty.

Indeed, some of the data in the present study support the idea that the differences between groups are simply attributable to the degree of development of their skills. Professional participants adjusted their metronome settings on more occasions within each practice session, for instance, than other participants engaged in metronome work. At first, this seems to suggest that professionals may employ more sophisticated control over this tool, monitoring it more closely and controlling their interaction with the device more carefully. However, when the number of adjustments is adjusted to reflect the overall pace of participants' work, as measured by the number of playing events in a practice session, the differences between groups appear smaller. It could be simply that professionals, with their higher levels of expertise, simply accomplished more in the same amount of time by working faster and more accurately, without actually making many substantively different decisions about subsequent actions in practice. They might, in other words, just be better.

However, the data on how individuals in different groups employ overt practice strategies suggest that there may be more distinguishing groups than just differing ability levels on the instrument. In the absence of statistical significance testing, the data on any individual behavior must be examined cautiously, but the overall tendency is clear. In most practice contexts in which participants as a whole seemed to find a given practice strategy appropriate (e.g., isolating the open strings in the string crossing excerpt), the professional group either had or shared the highest percentage of group members who displayed that behavior. In many situations, though less ubiquitously, professionals also displayed the behavior in question on a high percentage of playing events compared with other groups. Professionals, it seems, use overt practice strategies somewhat more extensively than other groups.

Adding subtlety to this picture, when other groups use of overt strategies equaled or topped that of professionals, those tended to be among the most extensively used behaviors. For instance, participants applied altered rhythms and bowings to their

practice of the slurring excerpt relatively frequently, as compared to their rates of applying other strategies to the situations in which those other strategies were appropriate. For these behaviors in this context, professional participants were fairly comparable to those in other groups. But experience seemed to predict the appearance of less common strategies. Twice as many professionals isolated the open strings underlying string crossings as did college students, and they did so on nearly three times as many events in the practice session. High school students, on the other hand, never displayed this behavior, and they were also the group in which the fewest participants added double stops or practiced backwards in the shifting excerpt. Again, in the absence of statistical tests, each individual result must be treated as tentative, but the overall picture seems clear: Experienced individuals not only seem to make more extensive use of practice strategies, but also appear to apply a wider variety of them and to apply them in less common ways.

I had expected to see evidence of fundamental differences of problem identification among professional participants as compared to others. Chess grandmasters, for instance, perceive larger structural units on the board than less skilled players, allowing them to take in more information at a glance (Chase & Simon, 1973). I had expected to see evidence of similar mechanisms at work distinguishing professionals from student violinists. For instance, I had expected to see that overt practice strategies would be more common among student players than professionals, because I had assumed that at least some of these strategies operate by means of allowing violinists to better identify and isolate challenges in the music, and had further assumed that professionals simply would be in less need of such diagnostic tools.

Such evidence was actually scant in the data. As discussed above, the use of overt practice strategies actually seems to be more common among experienced individuals, not less. And as also previously discussed, one of the data's overarching themes was that experience groups were very similar in the problems they seemed to identify and the

general approaches they undertook to solve these problems. However, the exceptions to that general theme, as mentioned in relation to Figures 11 and 12 (pages 106 and 107), warrant some more inspection here.

Local maximums (spikes) in the data for cumulative repetitions around the first major register change at note 9 in the shifting excerpt were seen in all three groups. As with other locations in the material, when one group showed evidence of having paid attention to a particular location, so did the other groups. However, at this particular point, the spike in the data appears two notes earlier, at note 7 (that is, beat 2 of the first measure) and levels off or slightly decreases across the register change; the spike for the two student groups, however, appears on note 9, the note after the register change. The same trend appears in the data for event starting notes (Figure 11): Both student groups show evidence of having selected note 9 as a starting location, whereas the professional group appears to have instead preferred to start at note 7. These data suggest a qualitatively different way of perceiving the problem. Student participants appear to have identified the problem as playing the high material after the leap, which must be played in at least sixth position on the E string (or fourth position, for the high school variant of this excerpt). Professionals instead appear to have identified the problem as the shift, as physically getting from the lower material preceding the register change to the higher material following it. This represents a fundamentally different way of considering the problem at hand.

There are hints of other such differences in the data; for instance, high school students appear to have neglected the second beat of measure 7 in the same excerpt as a location worthy of attention, as compared to their more experienced colleagues. However, none is so clear as the example from the first measure, particularly insofar as (a) all groups paid attention to a specific location, but defined that location such that only professionals included the shift itself, and (b) the evidence is clear from both the cumulative practice data in Figure 12 and the event starting location data in Figure 11. It

is indeed possible that this single instance represents a chance event; maybe the particular professional individuals I recruited found starting on the beat to be more aesthetically pleasing than most people would. However, because this bit of data fits so well with what has been learned in other fields about expert perception, it seems hasty to dismiss it.

It may be that the very nature of the excerpts in the present study prevented such effects from appearing more often. To amplify differences in behavior arising from different practice contexts, I composed excerpts that were saturated in their characteristic problems. It would be difficult to spend more than a few seconds with the shifting excerpt before starting to think about everything one has learned about practicing material that leaps between registers. The very concentration of the problem, in other words, may have primed everything participants know about practicing shifts, including perhaps a professional-level understanding that shifts themselves are more salient than the high notes following. This might help explain the fact that this tantalizing hint of a between-group difference clearly appeared on only the very first major shift of the excerpt. Another factor related to the density of shifts in this excerpt is that they appear in such close proximity in the score. Perhaps in other places too, professionals chose to start before the shift they wanted to practice and other participants started on the material after the shift, but because the locations were so close together, the same note filled the dual roles of high material following shift A and launching point to practice shift B. Further research will be needed to determine if experienced or expert violinists do in fact identify certain problems in fundamentally different ways from less skilled individuals.

Practice is highly individualized

The mean values for each behavior presented in Table 1 (pages 116-117) allow for the identification of ways in which individuals change their approach in response to the material they are learning, as well as ways that those approaches vary among

experience levels. However, another notable feature of the table is the standard deviations. For many of the behaviors listed, these values are quite high relative to the mean value, indicating high variability among individuals. Moreover, the standard deviations presented in Table 1 only represent the variability among members of each group who actually employed the behavior at all. As also seen in Table 1, many behaviors were either neglected or rejected by a high percentage of participants, even in contexts where their colleagues employed the same techniques extensively. All occurrences of open string isolation, for instance, appeared in just six individuals' practice.

If using an omnibus statistical test, it might be appropriate to remove such outliers before proceeding. However, outliers are a notable feature of the data for almost every overt practice behavior. As mentioned in the previous paragraph, only six participants isolated open strings at all; playing pizzicato was extremely rare, but four individuals employed it extensively. One college student employed altered rhythms when practicing the string crossing excerpt at about three times the rate of any other individual in this context. In practicing the slurs, four student participants employed this technique in over 10% of their playing events even though 15 of the student participants never used it at all in this context. The same trend holds for nearly every practice technique. As such, these individuals cannot really be considered outliers from a population of violinists that actually displays all behaviors at near-zero rates. Instead, the persistent appearance of several atypical individuals in the data for every practice technique must be considered a notable phenomenon in itself.

The data in the present study say nothing about whether those individuals who never displayed a particular behavior have never learned about that practice tool, whether it simply did not occur to them to use it, or whether they considered it and rejected it. What can be said is that practice habits are highly individualized. Participants in all

groups seemed to have their favorite ways of working, leading them to preferentially employ certain tools while using others only minimally or abstaining from them entirely.

The examples above all come from the data on overt practice strategies, those requiring participants to volitionally alter the printed material. However, some of the data suggest that similar personal habits and idiosyncrasies influence other types of practicing behavior as well. Three professionals abstained from practicing string crossings with the metronome on, and four participants each in the professional and college groups opted not to use the metronome in the slurring practice session as well (even though two professionals turned it on and back off in this context, apparently checking the target tempo). In both these settings, however, experienced individuals who did use the metronome did so extensively; among users, collegiate and professional participants spent on average more than half of their time with the metronome on. Likewise, the data for repeated notes, catchall categories as they were, show great variability. For each of these behaviors, many individuals engaged in it rarely or not at all in a given practice session, but others displayed it on 40% or more of their playing events.

Pedagogical takeaways

The data I collected in this study pertain entirely to violinists' behaviors and decisions during practice; collecting data about the outcomes of those behaviors and decisions—performance improvements—was outside the study's scope, except insofar as these outcomes influenced subsequent actions. I chose not to expand that scope (a) to focus on participants' behaviors and (b) due to practical limitations relating to assessing note-by-note performance accuracy in nearly 18 hours of often intense practice sessions. While results leading to suggestions for concrete instructional approaches would be desirable, the lack of data on the effect of any of the measured data upon performance accuracy places severe constraints on any such recommendations. In other words, I can

say only what participants at each level did in response to each type of challenge with which I presented them, not whether any of these responses were actually good ideas.

That being said, teachers can take encouragement from the finding that participants across groups appear to have identified similar problems in each of the excerpts. Participants in all three groups identified continuity across the slurring excerpt as a goal, and they chose to work on more discrete, localized problems in the shifting and slurring excerpts. Moreover, they seem to have identified the same locations within each of the excerpts as being worthy of extra attention. Students, in other words, seem to recognize the same problems and set the same goals as their professional colleagues do. There are hints in the data for cumulative practice on the shifting excerpt that students may tend to focus on the high notes following a shift at the expense of practicing the shift itself, but more research is needed to assess whether this is a real phenomenon or whether that detail of this data set was a coincidence.

The cumulative practice data in Figure 12 (page 107) suggest that in all three practice sessions, high school participants devoted more attention to the beginning of all three excerpts than they did to the end. Participants in other groups appeared to spread their attention more evenly to problems throughout the excerpt. Younger musicians may have a relatively difficult time prioritizing problems by difficulty level, instead allowing these problems' order in the score to dictate a practicing agenda.

Again, the data in the present study do not speak to whether the practicing behaviors that professional participants displayed are in fact effective at solving problems, and there is considerable evidence that which behaviors participants use do reflect great levels of personal preference or habit. With that being said, it does not seem unreasonable to assume that professional practice should be a model for less experienced players to emulate. If we accept this assumption, two further pedagogical suggestions may be tentatively made.

The phenomenon that I called ratcheted practice, in which participants apparently attempted to play extended events, but these attempts were interrupted by minor backtracks often in response to errors, appeared to substitute for complete or otherwise extended performance trials in less experienced participants' practice. It was most common among high school students and least common among professionals, though rarely completely absent. Among experienced individuals, this behavior occurred most often in difficult contexts, when even they appeared to be having difficulty with execution. In my experience from both lessons and an earlier data collection not reported here that involved interviewing participants while they watched videos of their own recently completed practice sessions (see Chapter 1), musicians appear to sometimes be unaware that such ratcheted series of events were not in fact correct, uninterrupted performances. Many of the instances of ratcheting in the present data set feature such rapid backtracking and fluid, immediate continuation that it seems reasonable to assume that here, too, participants could have been unaware of the interruption. The backtrack seems to function as a mental eraser, leaving individuals aware only of the corrected version, and as such, may make it difficult for them to be aware of the existence or persistence of any such "erased and corrected" errors. Further research is needed, but this may be a behavior that teachers should bring to their students' attention and discourage.

Another trend among experienced participants that students may wish to emulate is the use of a diverse array of overt practice strategies. The existence of books such as Fischer (2004) and Nardolillo (2015), works that instruct the reader in such behavioral tools and appropriate contexts in which to use them, suggests that this finding will not surprise teachers. However, the present results confirm that even the most experienced players actually put these tools to use. Again, whether this is because they are truly effective problem-solving tools or merely habits cannot be addressed here. Together with the anecdotal evidence leading pedagogues to espouse their use, though, the present data certainly lend another bit of support to the claim that these behaviors are effective. The

finding that less experienced participants use fewer behavioral tools, and use them less often, than others do does not address whether students are unaware of them, or whether they are less familiar with them and thus these options simply come to mind more slowly. I was somewhat surprised to find that professionals used these tools more than others, since I had expected many to be diagnostic tools to draw the practicer's attention to an undetected problem or facet of a problem. They may instead be tools better put to use after the violinist has already discovered the problem and identified its nature.

Teachers and student musicians should also bear in mind that it is not necessarily advisable to imitate every aspect of professionals' practice. Some professional behaviors may be the practice equivalent of power tools, most useful to those possessed of the advanced skills and knowledge necessary to use them properly. Other advanced musicians' habits may represent shortcuts, instances of experienced musicians skipping steps that students would be better advised to carry out in their entirety. Further research is needed to examine the proper use of the behaviors examined in this study as well as others that do not appear in the current data.

I began this section on pedagogical implications by mentioning the constraints arising from having no data pertaining to the accuracy of participants' execution. After all of my other suggestions, I either explicitly mentioned further study being needed or couched suggestions among words such as "perhaps" or "may be." The biggest pedagogical takeaway, thus, is the need for further research. Practice is a central activity in musicians' lives, and it is complex, involving the interplay of many variables. A tremendous amount of work needs to be done and data collected to understand how musicians acquire musical and technical expertise.

OVERALL SUMMARY AND FUTURE RESEARCH

Taken together, the evidence suggests that in answer to the research questions, (1) musicians work on different types of material using different approaches or strategies, and (2) these approaches change as musicians gain experience. However, between-group differences do not seem to reflect a shift from blunt practice tools featuring modified behaviors to more subtle practice tools as participants gain experience; rather, participants with greater experience actually employed certain excerpt-specific modification strategies that did not appear when less experienced violinists worked on the same material. And likewise, many behaviors that could have indicated differential problem identification or goal-setting, or otherwise could have pointed to differences in what participants identified as important to work on within each excerpt, instead showed great homogeneity across experience levels. Participants chose similar starting spots in each excerpt, and they appear to have devoted similar attention to each point in the material (although high school students may indeed have loitered near each excerpt's beginning). If we accept that multiple ratcheted practice events replaced single, more expansive performance trials executed by more experienced individuals, it would seem that all groups similarly modulated their focus on continuity or specific challenging details between excerpts, but those with more experience were more able to successfully complete these objectives. Those between-group differences that did arise suggest that violinists monitor and control their behavior while practicing more closely as they gain experience.

While this study yielded much data about the effects of context and experience upon individuals' practicing habits or behavior, it does not speak to whether young players can or should attempt to emulate the specific behavioral differences that distinguished them from their more experienced counterparts. The data suggest that somewhat more professional participants than others used the metronome, and they adjusted it somewhat more often, though this may have been a function of their overall

faster pace of work. It might be tempting to conclude that student participants should use the metronome more often, or even should increase their overall rate of activity to more closely resemble expert behavior. However, if the metronome is actually a tool best used at a certain stage of work on a piece, one that professionals were able to reach quickly and that some student participants took longer to achieve, using the metronome prematurely might actually prove detrimental to learning. An individual's longitudinal learning of a piece over time is one of many facets of musical context not covered in the present study. Further research exploring more of the variables covered by the umbrella term "context" will help students to more closely tailor their work to their own situations.

The pattern of behavior that I labeled as ratcheted practice seems to warrant further investigation. In this mode of behavior, participants engaged in behaviors that could be construed as single, extended performances. However, these extended performances also included small backtracks, repetitions of just a few notes usually in response to errors, followed by a continuation of the performance. Although I did not collect any data that speaks to whether participants perceived these backtracks as interruptions, my anecdotal experience as a teacher suggests that when students display this pattern, they are frequently unaware that they did not actually play from the beginning to the end without interruption. The backtrack seems to be the mental equivalent of an erasure, and they reach the end having perceived a single correct performance of the entire event despite having actually played two versions—one correct, but another incorrect—of a subset of the material. This seems to strengthen not only the incorrectly learned version of the material, but also students' perceptions that they have mastered the material, a conflict detrimental to their abilities to accurately assess their readiness for performance and to identify remaining problems to be resolved.

The data in the present study show that ratcheted practice, while not absent from professionals' practice, is more characteristic of inexperienced musicians. It seems to correspond to situations in which participants tried but failed to practice broad,

continuous events, appearing to substitute for complete playing events among less experienced players. Ratcheted practice also occurred among professional participants more frequently during the shifting excerpt, which all participants agreed was the most difficult. Even for experienced performers, then, this behavior may represent failed attempts at extended performances and simply have occurred less frequently in their work because, as more skilled players, they committed fewer errors. This study cannot address the extent to which individuals are aware of interrupted, ratcheted patterns in their practice, or whether experienced musicians actively avoid this mode of behavior by, for example, recognizing the errors and stopping rather than repeating and continuing. Is this way of working indicative of inexperienced players failing to perceive errors, and does it actually interfere with individuals' ability to identify, target, and fix problems? Does it instead represent individuals' active rejection of interruptions, choosing to ignore problems that either are fleeting and need no dedicated attention, or to which they will return later? Or is it instead a trivial surface feature that does not affect practice efficiency?

The present results show ways in which participants' behaviors vary with experience. However, they do not speak to whether, when novices differed from experienced players, these differences (1) indicate a lack of cognitive awareness of strategic responses to specific problems, (2) show a failure to perceive appropriate situations in which to employ these behaviors, (3) arose just because experienced individuals moved through stages of preparation more quickly and therefore encountered practicing situations that other participants did not reach in the limited time available, or (4) some combination of the above. Further research will be needed to disentangle the sources of practice differences that occur as musicians gain experience and develop expertise.

The present study grouped participants by experience level, and not necessarily by expertise. It is certainly safe to assume that professional participants were better violinists

than the high school students in the present study, and subjectively, the quality of their performances confirmed that. However, there was also great variation within groups, and some of the advanced college students may have been on par with some of the professional participants. As discussed extensively in Chapter 2, expertise is directly related to the magnitude of an individual's cumulative experience, but does not necessarily predict success in particular practice situations, while other factors including heritable, stable traits also affect varying skill levels between individuals with similar experience (Ericsson et al., 1993; Hambrick et al., 2008; Lehmann & Ericsson, 1997; Madsen, 2004; Meinz & Hambrick, 2010).

The present study did not separate the interrelated factors of experience and expertise. Some behaviors may have been shared by the best violinists in each group, differentiating skilled individuals from others within their own group, but would not have been recognized because I neither separately measured nor grouped individuals by expertise. Conversely, there may be behaviors that specifically reflect experience more than skill level. All young players may retain habits taught to novice musicians because they help mitigate common deficiencies (e.g., ear training), habits that inexperienced but musically aware students perhaps should jettison. Professionals may have used "gig skills" (i.e., ways of practicing that allow them to prepare music to be minimally presentable in the most efficient manner), obscuring differences that might have emerged had they been preparing for a public solo performance, in which efficiency is less important than a maximally artful and flawless final product. Performances with limited rehearsal and practice time are far more common in the professional than the student world, and so professionals may have displayed an exaggerated commonality in this study, while differences between how the most and least skilled individuals in this group work on each of the excerpt's signature challenges, given time to polish them to perfection, may have been minimized.

To some degree, the obstacles to entry at each level further confuse the two factors of experience and expertise—individuals must have auditioned and been accepted to a college degree program, or have demonstrated high levels of competitive professional experience, to have been included in each group respectively. Because the relationship between experience and stable personality traits in developing expertise is a topic of ongoing research (e.g., Hambrick & Meinz, 2011a; Hambrick et al., 2008; Meinz & Hambrick, 2010), it must be highlighted that the present study did not attempt to separate them. Rather, this study attempted to ascertain whether individuals' practice habits change as they gain expertise and/or experience, and the data answer in the affirmative; it is not only their output, their musical skill level, that develops with increased ability, but also the toolset which they deploy in the particular practice sessions that collectively add up to experience. Further research that measures both skill and experience more carefully, or that separates these factors through design, will be needed to make distinctions between them, which was beyond the scope of the present work.

Similarly, neither this study nor any other that I have encountered attempted to measure or group participants separately in their skill or experience as practicers separately from their skills as performers. That is, two individuals at a given experience level, with similar credentials and exhibiting comparable performance skills, may differ in how they reached that level. One may compensate for lower overall ability level with either efficient practice skills or by spending much more time and effort in each practice situation. The other individual may be able to play similar material in less time simply because their initial attempts are more immediately successful, not because she practiced more efficiently (perhaps contributing to the unclear relation between practice volume and accomplishment in specific tasks). Measuring not only what activities participants engaged in, but the outcomes—the changes in performance that occurred immediately and whether they persisted in later performance trials of the same material—would help differentiate between individual levels of practice efficiency.

As mentioned above, it is possible that inexperienced participants exhibited learned practice behaviors that are designed to mitigate common shortcomings in novice individuals and that are taught to young musicians, but that some skilled individuals may in fact not share these deficiencies. For those individuals, then, these behaviors may represent inefficient ways of working, even if they are beneficial to others. More generally, participants at all levels may exhibit behaviors that they learned at an earlier stage of their careers, that teachers found effective and taught to their students but that may actually vary in effectiveness between individuals, or that through some other means have become habitual without actually being effective. Prior research has shown that teachers and students alike believe that more teaching of practice skills happens in lessons than is actually the case (Koopman et al., 2007), and little if any research documents if any of the specific behaviors measured in this study actually correspond with the moments when musicians make progress. Moreover, Hallam (2001b) reports that several supposedly strategic practice behaviors are actually more closely associated with individual musicians' experience levels than they are with successful learning outcomes. It is possible that such behaviors are not so much potent practice tools as much as they are simply varied activities that help maintain attention and interest, though their continued presence in professionals' work would suggest that at least some of these behaviors are effective. Detailed measures of changes in performance accuracy throughout the practice session would help verify not only that these behaviors are context-specific and vary between groups, but also are associated with specific and lasting changes in subsequent performances.

Measuring event-by-event changes in performance details, and the extent to which such changes are retained in subsequent performances, will help more narrowly define the contexts to which specific behaviors are appropriate. For instance, not all shifts are equal; some participants in the present study chose to make leaping shifts up the E string as I expected when composing the excerpt, but others chose to make smaller shifts

in combination with string crossings while retaining high positions. Many experimented with both techniques before choosing one. Some differences in practice approach between these two varieties of shift may have been obscured because the data for both were aggregated. In transcribing many of the videos, I made an effort to distinguish what position participants were playing in at any given time, but as described in Chapter 3, I ultimately chose neither to continue this practice nor to include this data. I made this decision for two reasons. The present research questions are broad, reflecting the relative dearth of prior research in differences between performance contexts, and splitting hairs within one of the signature challenges did not seem appropriate. Also, the videos from which I was extracting descriptions and subsequently numerical behavior counts limited my ability to reliably make such distinctions; participants ducked behind the music stand at times, turned their backs to the camera, or chose other postures that made definite determinations of their exact shifting choices impossible.

In short, recording participants' exact technical and interpretive choices, as well as measuring their changes in performance accuracy on a performance to performance basis, seemed beyond the scope of the present study not only technically, but because the research questions I sought to address are more fundamental and had not yet been answered. However, drawing finer distinctions between and among practice contexts and challenges, as well as measuring the relative efficiencies of behaviors in subtly differing circumstances, would no doubt be of interest to pedagogues. The teaching community would certainly benefit from further research that makes finer distinctions between technical problems (e.g., large leaps as opposed to creeping shifts), and that measures when changes in performance occur, if these changes persist, and if such changes are indeed directly related to the times when individuals employ specific practice strategies. Such research may be particularly useful also to researchers seeking to understand human decision-making and skill development in general. As discussed in Chapter 2, the complex relationship between cumulative experience, individual variation in cognitive

traits, and domain-specific skills (in this case, applying practice strategies to appropriate musical and technical challenges) seems likely to be mediated by many small learning experiences. That is, individuals' aggregate practice histories are built up from specific applications of each behavior, their perceptions of success in each instance, and their subsequent decisions about whether to use that tool again, to try a different approach, or even their motivation to continue practicing at all. Understanding the process through which many complex series of activity add up to an individual's aggregate practice history, full of various reinforced behaviors but influenced by critical moments and stable individual traits, will require measuring the individual instances of learning within those series.

The results of the current study suggest that gaining such an understanding may be a difficult task, however. Several of the behaviors that I identified *a priori* as interesting, that I included as seeds in the Python script that extracted common behavioral categories from my verbal descriptions of participants' practice, occurred so infrequently that they were not included in the statistical analysis (e.g., systematically omitting one voice, which I had expected to characterize participants' practice of the shifting excerpt). Many of the behaviors that did occur frequently enough to be included for analysis were still rare, particularly modification strategies. Systematically altering the rhythms or bowings, adding double stops, and octave displacement all occurred in only around 5% of playing events even in the practice contexts in which they were reliably found at all. Others, such as isolating open strings in the string crossing excerpt, appeared at high frequencies in only a few participants' work. If these behaviors are indeed potent practice strategies as pedagogical authors suggest, we would indeed expect them to occur infrequently, since powerful tools should effect rapid change, obviating the need for their continued use. However, because these behaviors represent such a small amount of the activity seen in any practice session, developing a complete picture of how individuals use these behaviors in their practice will require examining a large amount of practice.

A finer measure of the relationships among challenges, behaviors, and performance improvements will also help generate future research on how individuals *should* practice differently as they gain experience, not only how they *do*. High school students appeared to struggle, particularly with the shifting excerpt. Were some of these struggles due in part precisely to the similarities between groups in the problems they identified and the similar tools they chose to employ? That is, should younger students have been identifying problems more precisely or analytically, but they instead used strategies that they were unprepared to handle? Did they use power tools when they were only ready for hand saws and sand paper?

To the extent that some or all of the behaviors seen in this study are indeed effective practice tools, this study does not address their mechanism of action. For instance, in my experience as a student, my teachers often assigned practicing with altered rhythms (see Figure 7 on page 79) as a method of evening out tempo fluctuations or sorting out "finger twisters"—passages of fast but rhythmically consistent material that for one reason or another sat awkwardly under the fingers. This technique was explained to me as preserving the challenging requirement of fast execution while also introducing time to think during the systematically introduced pauses. However, it is also possible that the mere number of repetitions required to complete the various rhythmic permutations is the true operative factor, while the rhythms themselves serve primarily to ensure that the musician continues to practice the material after attaining basic proficiency. Moreover, this behavior is not necessarily an efficient strategy for learning every type of fast passage; learning when to employ it seems to be mostly a matter of developing a "feel" for appropriate situations through trial and error, of trying it when nothing else seems to be working. Assuming that there are indeed kinds of technical passages that musicians can learn more efficiently by choosing this approach (and the results of this study suggest at least that musicians believe this to be the case), identifying

those passages' characteristics more precisely would help pedagogues to train student musicians to recognize when to select rhythmic variation as a practice strategy.

Subtle differences in the musical material may distinguish the situations in which rhythmic variations are best suited from those for which other strategies may be appropriate. Individual differences may be important, too; if one student's left hand technique is more stable and refined than their bow control, perhaps that student should employ a different approach than a peer, even while learning the same material. Furthermore, details of how any practice strategy is put to use seem likely to be important. To continue with the example of rhythmic variations, there are several questions a student might ask about putting this tool to use. Should I attempt to preserve the original tempo for the notes between the pauses or held notes? Exactly how long should I pause? Is one repetition of each variation enough? The answers to each of these questions may vary depending on the individual's strengths, and learning to apply the tool effectively will help to ensure that using it leads to improved performance, shaping this aspect of their practicing habits.

Assessing such detail while relying on methodologies employing subjective assessment and reliability judges may be too imprecise or too inefficient to analyze the vast amount of practice necessary to address research questions related to fine details or infrequently occurring behaviors. Prior research has indeed employed MIDI data measuring pianists' keystroke timing to assess rhythmic steadiness (Duke et al., 2011). However, even state of the art, commercial recording software cannot reliably transcribe live or recorded performances of acoustic instruments at present. To the extent that particular practice techniques may either be endemic to the culture or pedagogical tradition surrounding a particular instrument, or that those behaviors may be beneficial because of the specific physical techniques native to that medium, tools that facilitated gathering such data on non-keyboard instruments would be highly useful. In particular, keyboard instruments in general do not require performers to control intonation; the

player strikes either the correct key or another one. Practice techniques related to pitch control, whether related to ear training, accuracy of physical execution, or deliberate use of portamento, could best be assessed using tools that measure accuracy in this domain among musicians operating in their native medium.

I had expected to find data supporting the notion that experts' perception of each excerpts' endemic problems varied subtly but reliably from less experienced violinists. Studies in chess expertise, for instance, have shown that expert players in that domain literally perceive structures in a single glance that other, more novice players do not see (Chase & Simon, 1973; Chase et al., 1988). I saw relatively few such differences; as discussed earlier, behaviors indicative of musicians' strategic approach to perceived problems (e.g., the relative amount of attention, in the form of repetitions, devoted to each location in the music) were remarkably similar between groups. Experienced musicians displayed certain contextually-specific practice behaviors (e.g., playing only the open strings required for passages in the string crossing excerpt) more frequently than inexperienced players. To the extent that overt practice strategies are intended to isolate underlying facets of each type of problem from their superficial details or from other aspects of execution, this tendency may show that with experience comes increased ability to recognize those root problems. However, it is also possible that less experienced students merely were unfamiliar with the particular practice strategies, a more mundane explanation than that they actually perceived the nature of the material's challenge differently.

In the preceding discussion of differences between professional and other participants, I highlighted one example in the present study in which professional participants seemed to perceive a technical challenge in a fundamentally different light than did students, in a manner reminiscent of chess experts' different perception of the board. They seemed to identify the shift as being the problem, focusing on the notes

surrounding it, while less experienced participants directed their attention to the high notes afterward. With only one clear example and so much noise present in the cumulative data for repetitions and performance trial starts, clearly no conclusion should be drawn. However, future research is needed to explore the possibility that differences in how individuals perceive musical and technical structures and problems either influence their practice behaviors or lead to varying performance outcomes even in the absence of differential behavior.

The present study involved only a small selection of practice contexts, and these contexts were defined by the type of music that participants were practicing at the time. Pedagogues will no doubt have questions about other specific types of material beyond slurs, shifts, and string crossings. They also will benefit from information about how musicians work differently in response to finer subdivisions of these categories (e.g., when learning material with big leaps up and down the fingerboard as opposed to smaller, creeping shifts), or when working on material that contains these challenges interspersed with one another. Participants themselves frequently mentioned another way in which practice contexts vary, but that I did not explore in this study: time. All the data in the present study reflect speeded practice, because participants had only 10 minutes to learn material that was laden with technical challenges. Participants frequently asserted that they would have worked differently if they had had more time, or described subsequent practice steps they might have taken if allotted a few extra minutes. Case studies suggest that at least some musicians' practice approaches change as they gain familiarity with the material and approach the time of public performance (Chaffin & Imreh, 2001, 2002, Chaffin et al., 2003, 2009). Future research expanding the range of contexts in which practice behaviors have been systematically examined will help researchers understand how musicians work and adapt their approaches to material and to their own prior learning, and will help pedagogues identify situations in which

developing musicians (or even experienced ones) respond sub-optimally to the changing demands of the challenges they encounter.

Participants' comments on their thought processes provide an interesting window into human problem perception and goal-directed behavior. As part of the follow-up questions following their final practice session, I asked participants whether they believed they had practiced the three excerpts differently, and their responses generally fell into three non-mutually exclusive categories. Some immediately began identifying the technical problems endemic to each excerpt, apparently regarding the problems themselves as inseparable from the approaches. Some replied no, they had employed the same approach of finding and fixing problems, and seemed to consider this mission as an overall theme that united work on problems of a disparate nature. The third category of response viewed the work on the slurring and string crossing excerpt as similar (in one of the previous two categories) but recognized that forming a plan or orienting oneself was a discrete first step when dealing with the shifting excerpt.

These self-reports generally fall in line both with the standard model of Action Identification Theory (see Chapter 1) and with the idea that people fundamentally perceive structural units in domains in which they have expertise. The interchangeability of the first two categories is striking—they are distinct not in their content, but in their ordering. Participants who spoke of a common theme of finding and fixing problems nearly always went on to identify the individual problems of each excerpt (even before being prompted in the next question). Those who instead began with analyzing each excerpt's challenges sometimes later identified the find-and-fix model as a unifying element. The difference seems to reflect individual tendencies to view their process first at the micro or macro level—what the action identification literature would call their level of personal agency, the personal tendency to focus on details or the big picture—rather than observable behavioral differences. Interestingly, I did not identify any patterns

between groups (experience levels) in whether participants started with the overall approach and then analyzed details or vise versa.

However, the distinct third category, in which participants felt that a discrete initial step of figuring out how to attack the problem was required for the shifting excerpt alone, seems to explicitly reflect one of the main proposals of Action Identification Theory. Proceeding directly to action was possible for the other two excerpts, but at least some individuals required a dedicated phase of problem analysis before engaging in remediating practice behaviors when working on the shifting excerpt. The challenges presented in this excerpt were too substantial to be addressed by merely "fixing it," and individuals needed to devote actual attention to identifying specific problems and potential courses of action before resuming the work of simply practicing.

Whether they talked about problems or the process of finding them when describing their work, participants discussed the unifying nature of the problems in each excerpt. They did not discuss superficial details, aspects of the material that were trivial to execute, or aspects such as the harmonic progressions involved that may have been interesting but that did not impact their ability to perform the material. Instead, participants in all groups rapidly identified problems worthy of their attention. Between this question and the next (in which I asked participants to identify each excerpt's intended challenge), professionals and some college students seemed to explicitly describe more facets of the same challenges described by less experienced individuals, or to break down the material in more sophisticated ways. However, participants in all groups talked specifically about germane problems of execution, the types of things they would need to practice. Although the high school students were relative novices within this group of participants, they were preselected as students able to play materials in high positions. Any student capable of participating in this study was, therefore, already a considerable way down the path to expertise, and their responses were to a degree reflective of expert structural perception. As in their behaviors, however, experienced

individuals displayed a greater sophistication in their problem analysis. This seems to be akin to prior findings wherein chess grandmasters, for instance, are able to reconstruct meaningful board configurations with fewer glances at the original setups than others. Experts perceive more meaningful, relevant structure from each glance or experience than others do, and that ability increases with expertise.

Final comments

The present study represents only a step toward understanding the intricate interplay of perceptions, decisions, actions, and feedback that constitute music practice. The data confirm that musicians practice differently depending on the material they are learning. The data also suggest that although experienced musicians employ a few more discrete, recognizable practice strategies than their less experienced counterparts do, and although they may apply these practice tools in a more sophisticated manner do, participants across all levels were surprisingly similar in what challenges they identified and how they chose to work on them. However, the practice challenges involved in the present study represent only a tiny fraction of sorts of musical and technical challenges that musicians encounter. While the speeded practice situation that participants experienced is not unknown, extending this way of examining the detailed chains of behaviors into observations of self-determined practice pace could be beneficial. The enormous quantity of variables involved—specific behaviors, kinds of musical and technical challenges, stages of development both on the instrument and on a specific piece of repertoire—suggest that a large amount of research remains to be done. What we learn from such fine-grained analysis of musical behavior, however, will contribute substantially to our understanding of musical and motor skill acquisition, and of human decision-making in complex situations. It will also help supplement the revered body of pedagogical literature, helping teachers and teacher educators better understand the

challenges their students encounter, how students perceive those challenges, and how to improve students' abilities in problem diagnosis and behavior selection.

Appendices

APPENDIX A: IRB-APPROVED CONSENT FORMS AND PROTOCOLS

IRB USE ONLY
Study Number: 2014-06-0002
Approval Date: 11/04/2014
Expires: 11/03/2015

Consent for Participation in Research

Title: Content-dependent behavior in musical practice

Introduction

The purpose of this form is to provide you information that may affect your decision as to whether or not to participate in this research study. The person performing the research will answer any of your questions. Read the information below and ask any questions you might have before deciding whether or not to take part. If you decide to be involved in this study, this form will be used to record your consent.

Purpose of the study

You have been asked to participate in a research study about musical practice. This study will investigate how musicians of different ability levels practice differently depending on the specific challenges presented by the music.

What will you be asked to do?

While participating in this study, you will practice several different excerpts on your instrument. After practicing each excerpt, you will perform it three times. Between each excerpt, I will ask you several background questions. Participating in this study will take approximately 45 minutes of your time. I will make a video recording of your entire participation.

What are the risks involved with this study?

I will do my best to keep your video file secure (see confidentiality and privacy below), but as with any digital data, there is chance it could be accessed by others. If the risk of your video file being seen by others is unacceptable to you, you should not participate in this study.

What are the benefits of this study?

You will receive no direct benefit from participating in this study; however, I and other music researchers will gain information about how musicians work on different types of material, and how their approaches change as they gain experience.

Do I have to participate?

No, participation is voluntary. You may decide not to participate at all or, if you start the study, you may withdraw your participation at any time without penalty or loss of benefit. Withdrawal or refusing to participate will not affect your relationship with The University of Texas at Austin (University) in any way.

If you would like to participate, simply complete this form. There is an optional, extra question in which I ask you to allow me to use your video in conferences and

presentations. If you choose not to complete this extra session, I will not share the video, and your decision will not affect participation in the study.

You will receive a copy of this form so that you can look at it later if you want to.

Will there be any compensation?

You will receive a $10 iTunes gift card for participating in this study.

How will your privacy and confidentiality be protected if you participate in this research study?

The records of this study will be kept private. Audiovisual files (recordings), and any data I extract from them, will be labeled only with your participant number, not your name. Any other names you may mention while answering questions will likewise be identified only by a number. The data resulting from your participation may be made available to other researchers in the future for research purposes not detailed within this consent form. In these cases, the data will contain no identifying information that could associate it with you, or with your participation in any study.

If it becomes necessary for the Institutional Review Board to review the study records, information that can be linked to you will be protected to the extent permitted by law. Your research records will not be released without your consent unless required by law or a court order.

To protect your privacy, if you are a student of the Principal Investigator (Andy Strietelmeier), you should not participate in this study. If you choose to participate in this study, I will make an audiovisual recording of your practice and performance. Any recordings will be stored securely, and only the research personal associated with this project will have access to the recordings. Recordings will be kept for approximately seven years, or until the storage medium fails. If, and only if, you give me explicit, written permission, I will keep your recording permanently and include video of your participation when I talk about my work at conferences and presentations.

Whom should I contact with questions about the study?

If you have any questions or if you feel that you have been harmed prior to, during, or after your participation, please contact the researcher Andrew Strietelmeier at andystrietelmeier@gmail.com or 512.762.6354, or his advisor Bob Duke at bobduke@austin.utexas.edu or 512.471.0972.

This study has been reviewed and approved by The University Institutional Review Board and the study number is 2014-06-0002**.**

Whom should I contact with questions concerning your rights as a research participant?

For questions about your rights or any dissatisfaction with any part of this study, you can contact, anonymously if you wish, the Institutional Review Board by phone at (512) 471-8871 or email at orsc@uts.cc.utexas.edu.

Participation

If you agree to participate simply sign and return this form. Complete the optional video consent only if you are willing.

Signature

You have been informed about this study's purpose, procedures, possible benefits and risks, and you have received a copy of this form. You have been given the opportunity to ask questions before you sign, and you have been told that you can ask other questions at any time. You voluntarily agree to participate in this study. By signing this form, you are not waiving any of your legal rights.

_____ I agree to allow audiovisual recordings of my participation to be stored permanently and to be used in conferences and/or presentations.

_____ I **do not** agree to allow audiovisual recordings of my participation to be stored permanently and to be used in conferences and/or presentations.

_____
Printed Name

_____ _____
Signature Date

As a representative of this study, I have explained the purpose, procedures, benefits, and the risks involved in this research study.

_____
Print Name of Person obtaining consent

_____ _____
Signature of Person obtaining consent Date

IRB USE ONLY
Study Number: 2014-06-0002
Approval Date: 11/04/2014
Expires: 11/03/2015

Assent for Participation in Research

Title: Content-dependent behavior in musical practice

Purpose of the study

You have been asked to participate in a research study about musical practice. This study was explained to your parent or guardian, and they have given their permission for you to participate if you want to. This study will investigate how musicians of different ability levels practice differently depending on the specific challenges presented by the music.

What will you be asked to do?

If you agree to be in this study, you will:

- Practice several different excerpts on your violin or viola. After practicing each excerpt, you will perform it three times.
- Between each excerpt, I will ask you several background questions.

Participating in this study will take approximately 45 minutes of your time.
I will make a video recording of your entire participation.
There will be 35 other people in this study, including 11 other high school students.

What are the risks involved with this study?

Although I will do my best to keep your data secure, as with any digital information, there is a risk that your video could be accessed by others. If you are not willing to take that risk, you should not participate in this study.

What are the benefits of this study?

You will receive no direct benefit from participating in this study. However, I and other music researchers will gain information about how musicians work on different types of material, and how their approaches change as they gain experience.

Will I get anything to participate?

You will get a $10 iTunes gift card for participating in this study. I and other music researchers will gain information about how musicians work on different types of material, and how their approaches change as they gain experience.

Do I have to participate?

No, participation is voluntary. You may decide not to participate at all or, if you start the study, you may withdraw your participation at any time without any penalty or loss of benefit. Withdrawal or refusing to participate will not affect your relationship with The University of Texas at Austin (University) in any way.

If you would like to participate, simply complete this form. There is an optional, extra question in which I ask you to allow me to use your video in conferences and presentations. If you choose not to complete this extra session, I will not share the video, and your decision will not affect participation in the study.

You and your parent or guardian will receive a copy of this form so that you can look at it later if you want to.

Who will know about my participation in this research study?

The records of this study will be kept private. Audiovisual files (recordings), and any data I extract from them, will be labeled only with your participant number, not your name. Any other names you may mention while answering questions will likewise be identified only by a number. The data resulting from your participation may be made available to other researchers in the future for research purposes not detailed within this consent form. In these cases, the data will contain no identifying information that could associate it with you, or with your participation in any study.

If it becomes necessary for the Institutional Review Board to review the study records, information that can be linked to you will be protected to the extent permitted by law. Your research records will not be released without your consent unless required by law or a court order.

If you are my student, to protect your privacy, you should not participate in this study. If you choose to participate in this study, I will make an audiovisual recording of your practice and performance. Any recordings will be stored securely, and only the research personal associated with this project will have access to the recordings. Recordings will be kept for approximately seven years or until the storage medium fails. If, and only if, you give me explicit, written permission, I will keep your recording permanently and may include video of your participation when I talk about my work at conferences and presentations.

Whom should I contact with questions about the study?

Prior, during or after your participation, please contact the researcher Andrew Strietelmeier at andystrietelmeier@gmail.com or 512.762.6354, or his advisor Bob Duke at bobduke@austin.utexas.edu or 512.471.0972 for any questions or if you feel that you have been harmed. For questions about your rights or any dissatisfaction with any part of this study, you can contact, anonymously if you wish, the Institutional Review Board by phone at (512) 471-8871 or email at orsc@uts.cc.utexas.edu.

Signature

Writing your name on this page means that the page was read by or to you and that you agree to be in the study. If you have any questions before, after or during the study, ask the person in charge. If you decide to quit the study, all you have to do is tell the person in charge.

_____ _____
Signature of Participant Date

_____ I agree to allow audiovisual recordings of my participation to be stored permanently, and to be used in conferences and/or presentations.

_____ I **do not** agree to allow audiovisual recordings of my participation to be stored permanently and to be used in conferences and/or presentations.

_____
Printed Name

_____ _____
Signature Date

As a representative of this study, I have explained the purpose, procedures, benefits, and the risks involved in this research study.

_____
Print Name of Person obtaining consent

_____ _____
Signature of Person obtaining consent Date

IRB USE ONLY
Study Number: 2014-06-0002
Approval Date: 11/04/2014
Expires: 11/03/2015
Name of Funding Agency (if applicable):

Parental Permission for Children Participation in Research

Title: Content-dependent behavior in musical practice

Introduction

The purpose of this form is to provide you (as the parent of a prospective research study participant) information that may affect your decision as to whether or not to let your child participate in this research study. The person performing the research will describe the study to you and answer all your questions. Read the information below and ask any questions you might have before deciding whether or not to give your permission for your child to take part. If you decide to let your child be involved in this study, this form will be used to record your permission.

Purpose of the Study

If you agree, your child will be asked to participate in a research study about musical practice. This study will investigate how musicians of different ability levels practice differently depending on the specific challenges presented by the music.

What is my child going to be asked to do?

If you allow your child to participate in this study, they will be asked to:

- Practice several different excerpts on his or her instrument.
- After practicing each excerpt, he or she will perform it three times.
- Between each excerpt, I will ask your child several questions pertaining to his or her prior musical experiences and experiences in the study.

Participating in this study will take approximately 45 minutes of your child's time. There will be approximately 35 other people in this study, including 11 other high school musicians.

Your child's entire participation will be recorded, both audio and visual.

What are the risks involved in this study?

Possible risks associated with this study relate to the potential loss of confidentiality of video recordings. I will do my best to keep your child's video file secure (see confidentiality and privacy below), but as with any digital data, there is chance it could be accessed by others. If the risk of your child's video file being seen by others is unacceptable to you, your child should not participate in this study.

What are the possible benefits of this study?

Your child will receive no direct benefit from participating in this study. However, I and other music researchers will gain information about how musicians work on different types of material, and how their approaches change as they gain experience.

Does my child have to participate?

No, your child's participation in this study is voluntary. Your child may decline to participate or to withdraw from participation at any time. Withdrawal or refusing to participate will not affect their relationship with The University of Texas at Austin (University) in anyway. You can agree to allow your child to be in the study now and change your mind later without any penalty.

What if my child does not want to participate?

In addition to your permission, your child must agree to participate in the study. If you child does not want to participate they will not be included in the study and there will be no penalty. If your child initially agrees to be in the study they can change their mind later without any penalty.

Will there be any compensation?

Your child will receive a $10 iTunes gift card for participating in this study.

How will your child's privacy and confidentiality be protected if s/he participates in this research study?

The records of this study will be kept private. Audiovisual files (recordings), and any data I extract from them, will be labeled only with your child's participant number, not his or her name. Any other names your child may mention while answering questions will likewise be identified only by a number. The data from your child's participation may be made available to other researchers in the future for research purposes not detailed within this consent form. In these cases, the data will contain no identifying information that could associate it with you, or with your participation in any study.

If it becomes necessary for the Institutional Review Board to review the study records, information that can be linked to your child will be protected to the extent permitted by law. Your child's research records will not be released without your consent unless required by law or a court order. The data resulting from your child's participation may be made available to other researchers in the future for research purposes not detailed within this consent form. In these cases, the data will contain no identifying information that could associate it with your child, or with your child's participation in any study.

To protect your child's privacy, if he or she is a student of the Principal Investigator (Andy Strietelmeier), he or she should not participate in this study. If you choose to participate in this study, your child will be audio and video recorded. Any **audio and video** recordings will be stored securely and only the research team will have access to the recordings. Recordings will be kept for **approximately seven years** or until the storage medium fails. If, and only if, both you and your child give me explicit, written permission, I will keep the recording permanently and may include video of your child's participation when I talk about my work at conferences and presentations.

Whom to contact with questions about the study?

If you have any questions or if you feel that you or your child have been harmed prior to, during, or after your participation, please contact the researcher Andrew Strietelmeier at andystrietelmeier@gmail.com or 512.762.6354, or his advisor Bob Duke at bobduke@austin.utexas.edu or 512.471.0972.

This study has been reviewed and approved by The University Institutional Review Board and the study number is 2014-06-0002**.**

Whom to contact with questions concerning your rights as a research participant?

For questions about your rights or any dissatisfaction with any part of this study, you can contact, anonymously if you wish, the Institutional Review Board by phone at (512) 471-8871 or email at orsc@uts.cc.utexas.edu.

Signature

You are making a decision about allowing your child to participate in this study. Your signature below indicates that you have read the information provided above and have decided to allow them to participate in the study. If you later decide that you wish to withdraw your permission for your child to participate in the study you may discontinue his or her participation at any time. You will be given a copy of this document.

NOTE: Your child **WILL** be recorded if he or she participates in this study. The material inside this box applies only to my using the recordings from his or her participation in presentations of my work.

_____ I agree to allow audiovisual recordings of my participation to be stored permanently and to be used in conferences and/or presentations.

_____ I **do not** agree to allow audiovisual recordings of my participation to be stored permanently and to be used in conferences and/or presentations.

_____
Printed Name of Child

_____ _____
Signature of Parent(s) or Legal Guardian Date

_____ _____
Signature of Investigator Date

Recruitment letter text for high schools students and their parents:

My name is Andy Strietelmeier. I am conducting a research study investigating decision making in musical practice. My study investigates how musicians of different ability levels practice differently depending on the specific challenges in the music. [Child's name]'s music teacher suggested that your child would be a good potential candidate for my study, and I am writing to ask for your permission to include your child in my research.

I have attached/enclosed copies of the Parental Permission for Children Participation in Research form so that you can see exactly what your child would be asked to do. In summary, your child will practice and perform several excerpts, each of which features a different technical or musical challenge. I will video and audio record your child's participation so that I can analyze how they responded to each type of challenge. I will keep all records of your child's participation, including the video recording, confidential unless you explicitly grant me additional, written permission to include it in educational or presentation settings.

If you are amenable to your child participating in this research project, please contact me at andystrietelmeier@gmail.com or 512.762.6354 to set up an appointment; you can return the attached permission form at that time or in advance, or I can provide you with a duplicate form to sign at your appointment.

Thank you for your time.

Andy Strietelmeier
Ph.D. Candidate, Division of Music and Human Learning, The Butler School of Music, The University of Texas at Austin

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Recruitment letter for collegiate and artist-level potential participants:

My name is Andy Strietelmeier. I am conducting a research study investigating decision making in musical practice. My study investigates how musicians of different ability levels practice differently depending on the specific challenges in the music. As a [working artist/university music student], I hope that you would be interested in participating in my study.

I have attached/enclosed a copy of this study's consent form, which includes a description of exactly what I would ask you to do. In summary, you will practice and perform several excerpts, each of which features a different technical or musical challenge. I will video and audio record your participation so that I can analyze how you responded to each type of challenge. I will keep all records of your participation, including the video recording, confidential unless you explicitly grant me additional, written permission to include it in educational or presentation settings.

If you are amenable to participating in this research project, please contact me at andystrietelmeier@gmail.com or 512.762.6354 to set up an appointment; you can return the attached permission form at that time, or I can provide you with a duplicate form to sign at your appointment.

Thank you for your time.

Andy Strietelmeier
Ph.D. Candidate, Division of Music and Human Learning, The Butler School of Music, The University of Texas at Austin

Research Proposal

1. Title
   Content-dependent behavior in musical practice

2. Principal Investigator
   Andrew Strietelmeier, aas355, Department of Music (Division of Music and Human Learning)

3. Purpose

Individual practice is one of the defining elements in musicians' lives; some studies suggest that in music and other skilled fields, accumulating 10,000 hours or more of focused practice is a prerequisite for expertise (Ericsson, 2008). During practice, a musician goes through a complex series of interdependent decisions that involve identifying problems and selecting goals, taking action toward pursuing each goal, and monitoring the results of each step. Both common sense and the pedagogical literature suggest that identifying what to practice and choosing responses appropriate to the qualitatively different types of challenges that arise are vital skills for musicians to develop as they learn to practice (Fischer, 2004; Kreitman, 1998; Morganstern, 2002; Rolland & Mutschler, 1974; Westney, 2003). Just as a mechanic cannot fix a car without identifying what is wrong with it, then choosing appropriate tools and parts, musicians cannot improve their performances without identifying what aspect of the music they want to change, then selecting a course of action that will help them effect that change.

Because individual practice is such a complex series of activities, researchers exploring the activity have thus far employed a few common strategies to simplify the data they collect. Some measure aspects of practice behaviors as aggregate quantities, such as total amount of practice over periods of hours, months, years (Ericsson, 2008; Hallam, 2001a; Madsen, 2004). Some have attempted to profile the development of musicians' self-regulation skills using cognitive awareness of different methods of practicing to indirectly measure how many of these methods musicians actually use (Austin & Berg, 2006; Hallam, 2001a, 2001b). Others studies examined in detail the specific behaviors musicians employ when learning a single musical excerpt, or prescribed methods of working to different experimental groups and measured performance outcomes (Duke, Simmons, & Cash, 2009; Fine, Berry, & Rosner, 2006).

All of these strategies allow researchers to examine a particular aspect of learning music. However, because they either measure practice activities aggregated across time, rely on self-report, or examine activity in detail on a single piece of music, they cannot address a fundamental premise of the pedagogical literature. Specifically, they cannot address the idea that how one practices makes a difference, that work on one type of material or toward one goal should be different than other types of work (for instance, that one should behave differently when trying to learn a passage laden with difficult technical material than when trying to gain fluency across a lyrical passage). Other possibilities include (1) that the specific approach to any challenge is unimportant so long as individuals engage in a specific manner, (2) that the specific approach is a matter of personal preference, or (3) that specific do have real effects, but that these effects are vanishingly small compared to other factors such as the sheer amount of time spent on a problem. In this study, I propose an experimental paradigm to answer (1) whether musicians display qualitatively different practice behaviors in response to different types of material (that is, whether musicians practice material containing different types of challenges using different practice activities), and (2) whether

the set of practice behaviors used in response to different types of material varies as a function of musical experience. Although hearing what participants play and when they play it would be possible using only audio recordings, I will also make videos recordings to (1) determine what they were doing during any moments of silence and (2) record overt signs of decision making that do not create sounds (e.g., preparing to play, but then marking on the music instead). Because I will be drawing participants primarily from the Austin area, among the background data I collect will be the names of participants' teachers, allowing me to determine the extent to which my participants represent the community of violinists or perhaps instead reflect the pedagogy of one or two particular teachers.

4. Procedures

Participants (n=36 in three groups: high school = 12, collegiate music majors = 12, professionals = 12 as described below) will be violinists and violists. Each participant will practice three different excerpts for 10 minutes, and will perform each excerpt three times following the respective practice session. The three stimuli (examples) will vary in their primary challenge, but will be similar in difficulty level, speed, length, and other relevant factors. Prior to each practice session, I will play a MIDI-generated example of each excerpt to mitigate the effects of sight-reading expertise on subsequent practice behaviors. Participants will also answer a number of background questions. The entire procedure should take approximately 45 minutes.

I will make a video recording of participants' practice sessions. Musical practice involves too many activities for data to be hand-recorded live, and unlike piano, MIDI software cannot capture all relevant variables in producing sound on a violin. Additionally, as described above, I anticipate that participants' silent behaviors, such as marking their music and silently fingering (playing using only the pitch-determining left hand, omitting the sound-producing bow) will be among the notable practice behaviors I will document. Additionally, some practice and playing decisions lead to different behaviors that produce indistinguishable or near-indistinguishable aural results, the most notable example being playing the same material using different combinations of fingerings. The additional information gained with a video recording will be essential to identifying these and other types of decision-making behaviors. Because the violin is held immediately under the player's head, any camera angle allowing a clear view of the bow, instrument, and music stand will necessarily show the player's face, and so faces will be included in the video. I will make this clear in recruiting and giving instructions to participants; individuals who object to being recorded will not be enrolled for participation.

After completing informed consent, I will give participants any time they need to unpack their instruments, tune, and warm up. When they are ready, I will read to them the following instructions:

> This is a study exploring how musicians practice. I will ask you to practice three short excerpts for 10 minutes each; after you have practiced each excerpt, you will perform it three times. I will record your work so that I can examine it in detail later. You are allowed to withdraw your participation—that is, stop participating in the study—at any time.
>
> Before each practice session, I will play a recording of the excerpt at its target tempo. The target tempos are very fast. With only 10 minutes to practice, I understand that you will

> probably not get the material up to the same speed as the recordings, but your goal is to get each excerpt as close to the target tempo as possible while playing well. If you feel ready to perform at the target tempo before your 10 minutes are over, just let me know.
>
> I have provided a pencil and a metronome; you may use them as much or as little as you need.
>
> Do you have any questions?

After I have answered any questions that participants have, I will start the video recording. Participants will then complete three practice blocks. During each block, (1) I will read them instructions, which will include playing a model recording, (2) the participant will practice the material for up to ten minutes, and (3), the participant will perform the material three times. At the beginning of each practice block, I will read participants the following instructions:

> Here is the [first/second/third] excerpt. You may look at the music while listening to the recording if you think that would be helpful. [Play model three times.
>
> As a reminder, the target tempo is very fast; prepare to play the excerpt as close to the tempo as you can while playing well. Whenever you are ready, you may begin practicing. I will give you about 10 minutes to work.

I will tell participants when they have used five of their ten minutes in each practice block. After ten minutes have passed, I will direct participants to complete their performances using the following instructions, which also introduce the questions that I will ask during a rest period between each practice block.

> You have had about 10 minutes to practice. Please perform the excerpt for me now. [Performance]
>
> Please play the excerpt again. [Performance]
>
> And a third time. [Performance]
>
> Before we move to the [next/last] excerpt, I have a few [more] questions. [Insert one question set.]

The three practice blocks will be distinguished by the content of the musical material being practiced (see attached document). These three stimuli will vary in the nature of the primary challenge each excerpt presents—that is, each excerpt will be hard for a different reason. The three different types of challenges presented in the stimuli in the attached document (string crossings, large shifts of position, and slurs that run against the beat pattern) are all challenges endemic to violin playing. The specific order in which participants encounter each excerpt will be counterbalanced.

Between blocks, I will ask participants the following sets of questions:

Question set 1

Let's take a short break.

How long have you been playing [violin]?

Is this your first instrument? If not, when did you begin studying music?

Do you play any other instruments?

Students: Who is your violin teacher? Who have been your main teachers before now?

Professionals: Who were your primary violin teachers?

Question set 2

Let's take another short break.

Students: What grade are you in?/What year and degree program are you in?

Professionals: How long have you been playing professionally?

Were you already familiar with any of the excerpts I have asked you to practice today?

What repertoire are you currently working on?

After the third block, I will briefly summarize the aim of the study, and ask participants if they have any final questions:

Thank you for participating in this study. The goal of this study is to determine how musicians practice material with different technical challenges.

Do you feel like you practiced the three excerpts differently from one another? If so, in what ways?

I'd like you to tell me how difficult each excerpt was. On a scale of one to six, where six is the most difficult, how difficult was the first excerpt? The second one? The third one? [I will show participants the music if they have difficulty remembering.]

Do you have any questions or comments about your experiences here?

Following these final questions, I will end the video recording.

a. Location

I will record high school university participants' practice in space provided at UT's Butler School of Music. I will record artist-level participants either at UT or in their regular practice space, at their discretion.

b. Resources

Resources required for this research are minimal. I will provide my own metronome and video recorder to record all participation sessions.

c. Study Timeline
I plan to collect data in the winter of 2014/15, ending no later than February 2015. I plan to analyze data as I acquire it, continuing through spring of 2015 and to publish the results as my dissertation in the following school year.

5. Measures

I will make audiovisual recordings of all practice sessions and performances. I will analyze participants' observable activities during their work on each of the excerpts, looking specifically for (1) the variables studied in Duke, et al. (2009), (2) sequences of practice episodes as described in Maynard (2006), (3) specific locations within each excerpt on which participants spend time; and (4) other behaviors that deviate from explicit, unaltered repetition of the music specified in the stimuli. Specific examples include but may not be limited to marking the score, repetitions of incorrect material, and rhythms that differ systematically from those indicated in the score. I will use descriptive statistics to compare any observed differences between practice of the different stimuli and between the practice behaviors displayed by musicians at different experience levels.

6. Participants
   a. Target Population
   Participants will be violinists and violists (n=36) recruited from into three experience groups: high school musicians (n=12), collegiate music majors (n=12), and professional musicians (n=12).
   b. Inclusion/Exclusion
   As described in the previous section, participants will be selected by musical experience level on a particular instrument. Beyond that, there will be no further criteria.
   c. Benefits
   There are no foreseeable benefits to participants for participating in this study. The research and musical community will gain a greater understanding of whether and how musicians work on differently in response to different types of challenges—a fundamental assumption of the pedagogical community, as discussed in Section 3 above, but one that has barely been explored through systematic research—as well as whether and how these responses vary with experience.
   d. Risks
   Because I will make audiovisual recordings of participants' practice and performances, there is a risk of loss of confidentiality. However, because I will only record participants as they (1) practice violin and (2) answer minimally invasive questions about their prior musical experience and their impressions of the study itself, and since they will be informed that I will make audiovisual recordings before ever agreeing to participate in the study, the magnitude of the harm done in the event that their identities are revealed without their consent would be minimal.
   e. Recruitment
   My advisors and I personally know sufficient collegiate music majors and professional musicians to meet this study's needs; we know enough violin, viola, and orchestra teachers whose students

would be capable of learning the material. I will email potential collegiate and professional participants directly, and will email teachers with material to disseminate to their students. Recruitment letters may be found in the supporting material. None of the participants in this study will be students of the Principal Investigator (i.e., none of my students will be involved).

f. Obtaining Informed Consent

Before each participant's session, I will review with them the attached informed consent form. I will only proceed with the protocol after they have reviewed and signed the consent form. I have included an additional, optional section on the consent form covering usage of the video data in research conferences and presentations; individuals who prefer not to complete this additional section will still be able to participate in the study.

In the case of minor individuals, I will send their parent or guardian a Parental Permission for Children Participation in Research. Minors will only be allowed to participate if they give me a copy of this consent form completed by their parent or guardian and have completed an assent form themselves.

7. Privacy and Confidentiality

Participants' data will be stored in password-protected files on my laptop and on a hard drive in my office. I will not collect any sensitive data, only videos of their practice, performance, and answers to the experience-related questions described above. All files, including extracted data, will be labeled with assigned numbers rather than names or other personally identifiable information.

Confidentiality of the Data or Samples

a. I will record video and audio of their participation in the paradigm described above.
b. I will store video data in password-protected files on my computer. They will be backed up on a hard drive in my office.
c. Video files will be kept at least seven years, or until the storage medium fails after completion of the study. If and only if participants complete the optional consent agreeing to waive the confidentiality of their video data, I will keep the videos indefinitely.
d. Data extracted from the video will be stored only with participant number. To extract data, I will watch the videos, transcribing the dialog and describing non-verbal activity. (E.g., "Participant 3: activity 14: Marks part with pencil.") I will de-identify data by identifying participants by number only. Because I am not interested in identifying participants' teachers themselves, but only in identifying whether clusters of students from the same teacher are present, I will assign named teachers a numerical identifier and will destroy the key to this code after extracting data from all transcripts.
e. I will assign each participant a number, which will be the name of their video file and the file of their transcription/description file. I will also note their participant number on their copies of the musical stimuli. I will store transcription/description files on the same computer and backup drive as the video file. I will store paper consent forms in a file in my office. I will not create an explicit key file linking participants' names to their data files; because of the small group of participants drawn from known colleagues and their students (see section 6(e) Recruitment), I will visually identify participants in their video file if I need to connect an individual's name to their video and transcript data (e.g., to locate files to destroy in the event of delayed withdrawal from the study).

f. De-identified data in transcription/description form may be shared with other researchers and reported in publication. Video data including faces will be shared only with my UT Austin advisors, Bob Duke and Laurie Scott, unless participants give explicit, written permission in the appropriate line on the Inform Consent Form (and Assent Form, when applicable). Even when participants grant permission, I will only show, present, or copy renamed clips.
g. Because I will not collect sensitive information, I do not intend to deliberately destroy the de-identified forms of the data listed above, nor will I destroy video files (including faces) for participants who have given me explicit, written permission to share their audiovisual files. After approximately seven years, or the failure of the storage medium after completion of the study, I will destroy the video files—including participants' recorded faces and the names of their teachers, the only identifying information I will collect—of participants who do not give such explicit, written permission.

8. Compensation
Participants will receive a $10 iTunes gift card for participating in this study.

APPENDIX B: RELIABILITY

The instructions below were given to the reliability judge at our training session. At several points, the instructions use wordings such as "As a reminder. . . " because these directions were intended as a reference manual for the judge to refer back to, not as a stand-alone packet. A more complete discussion of the reliability procedure is found on page 94.

Reliability procedure

Please watch each video given to you, and while doing so, record what you see. The instructions below describe how to record what you see according to the established system.

Before you watch each segment, it will help you to know what the material sounds like. I have included copies of the sheet music and the audio examples that participants heard.

SCRIBE

I have supplied a Scribe file for each participant. As a reminder, you need to open Scribe with Firefox using File > Open. (The manual says it works in Safari and Chrome as well, but we'll be training on Firefox because that's what I know.) Once Scribe is open, treat it like Facebook: you do everything within the browser window, and the application has its own commands and menus. Inside Scribe, open the Scribe XML file for a participant in the Open Screen. The movie should load automatically; if it doesn't, change to the Setup tab, click the "Load Movie" button, and choose the movie for that participant.

Then switch to the Review tab. (Skip the Observe tab; that's where the tools used to record events live, but in this case I've supplied you that info.) On the Review tab, you will see each event displayed on a line of its own. Watch each clip in order by clicking that line's "Play" entry. You may watch a clip more than once if you need to. In places, the participants may make several rapid repetitions, such that the end of one appears again at the beginning of the next clip. In these situations, it may help to move earlier in the sequence (by playing an earlier event), then hitting the "Play" button at the top of the screen, which will keep playing until you pause it.

As you watch each event (each line in the Scribe file), you will mark the score sheet for each behavior you see. There are three basic things you will be recording: Non-playing events, playing events, and whether the metronome is on or not.

- **Non-playing events** include marking in the music, any sort of tinkering with the metronome, and other non-playing behaviors.
    - **Note.** These are simply artifacts of notes I made to myself when I originally recorded the data. Please write "note" in the left margin and cross out the line. Proceeding to the next line on the score sheet and the next event in the video.
    - **Marks part.** If a participant marks in the part, grabs the pencil but does not actually write, erases, or otherwise appears to mark or decide against marking the part, check this box.
      ★ This is exclusive; no other activity should occur during this event.
    - **Adjusts metronome.** If a participant turns the metronome on, turns the metronome off, or changes the metronome's tempo, please check this box. If the participant makes multiple changes to the tempo, it may be contained within a single event; likewise, selecting an initial tempo is considered part of turning the metronome on. However, if the participant turns the metronome on then turns it back off without playing anything, I will have recorded two subsequent events.
      ★ This is exclusive; no other activity should occur during this event.
    - **Other.** Other events naturally include anything that is not playing but is not covered in the other two events. For example, the first events in many practice sessions are me giving the participant instructions. Silent staring, tuning, and air-bowing also count as other events.
      ★ This is exclusive; no other activity should occur during this event.
      ★ Please count tuning as "other" rather than as a playing event.
- **Metronome is on**. Please check this box if the metronome is on. Use metronome setting at the end of the event. On events in which the participant turns the metronome on, check this box. On events in which the participant turns the metronome off, do not check this box.
- **Playing events.**
  In each playing event, the participant will of course play on the instrument. They will usually play material that is a section of the excerpt. If they play other material (e.g., a scale), check the "Plays other material" box, then continue to the next event. If the event seems to consist of a single note, consider it "other material" unless something indicates to you that it can be clearly labeled at a specific point: a single G could be any G in the excerpt, unless the participant, for instance executes the shift that follows a specific G even without playing the next note. *Please count tuning the instrument as an "Other" event, not a playing event.*

  If the playing event involves a portion of the excerpt, please bracket the material played. Place an open bracket ([ ) before the first note played, and a ending bracket ( ]) after the last note played. So for example, if you see a participant begin at the pickup to the second measure and continue playing up to and including the third sixteenth note of the fourth measure, you would mark:

I have segmented behaviors such that one playing event ends and another one starts when participants reach the end of the material, backtrack and start again (even by a single note), stop playing for too long to maintain coherence, or engage in non-playing behaviors.

Some playing events simply consist of the musician playing from point A to point B, but in other cases additional detail is needed to describe what's going on. I have watched the videos in my entire data set and extracted a set of interesting behaviors that occur reasonably frequently. These will be defined below. They include both "practice strategies" and other behaviors that may not be as clearly intentional.

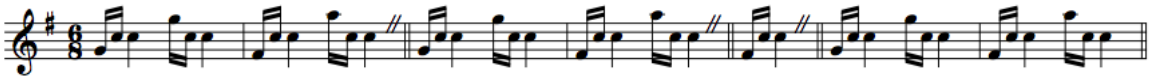
I have also decided *not* to take data on a number of behaviors. In some cases this is because a behavior occurs too rarely to draw conclusions from, or because only one or two people ever used it. In other cases, I am not gathering data on a behavior because it does not measure what I am trying to study right now. Most importantly, I am **not** taking data on pitch or rhythmic errors and accuracy. Don't worry about marking wrong notes.

If a playing event ends on one or more wrong notes (for instance, if the playing event in the above example ended with an A-G-F#-E slur all transposed down a step), use your judgment to record what they thought they played, regardless of mistaken execution. In this hypothetical example, the rhythm, slurring, and pitch contour would suggest that the participant played the first three notes of the third measure incorrectly; the alternative description (skipping the last note of measure 2, then playing an extra E at the end) is literally accurate, but doesn't seem to match what the participant actually did. You were chosen because you are an experienced violinist; use your judgment.

Those behaviors that I am taking data on are defined in the following list. If you see one or more of these behaviors in any event, please check the appropriate box. You may check as many boxes as you need to complete your description of each playing event.

- **Repeats first note.** Repeats only the first note once, twice, or many times, then continues on to play the indicated material.
- **Repeats last note.** Plays the indicated material, then repeats the last note once, twice, or many times.
- **Repeats another note.** Plays the first note (with or without repetition), then continues. At some point within the passage, repeats a single note one or more times, then continues in the music.
- **Plays with systematically altered rhythms.** Changes the rhythm of a passage in a purposeful manner, consistently elongating the same subdivision of the beat. Note: playing everything at ½ tempo is a tempo change, not a rhythmic alteration, even if the metronome is on. The following illustration demonstrates several events with systematically

altered rhythms. In the original notation, each pitch was played equally, as an eighth note in 6/8 time.



- **Plays with altered bowings.** Systematically, or regularly, altered bowings. This does not mean a bowing mistake: this means regularly changing the bowings in an apparently purposeful manner, including omitting them entirely.
- **Systematically adds double stops.** Purposefully plays the notated pitches against each other or against a drone. Does not include accidentally hitting other strings on a few notes.
- **Pizzicato.** Plays pizzicato. Since none of the material is marked as such, this should be apparent.
- **Another octave.** Plays the material with octave displacement.
- **Open strings only.** Plays only the open strings corresponding with the notated pitch. Because the left hand is omitted, the pitches will not correspond to those printed.
- **Plays backwards.** Exactly as it sounds. Plays the first note, then the penultimate note, then the antepenultimate note, etc., concluding with the first notated pitch of the material. If this definition seems wordy, it's probably because "plays backwards" means what it sounds like.
- **Includes a note in the preceding slur.** If a slur somewhere within the material lasts one note longer than notated, please check this box.
- **Ignores metronome.** If a participant plays with the metronome on, but plays at a tempo that does not seem to correspond with the metronome's current setting, tick this box.

In addition to errors, you may see instances of playing events in which a participant plays something other than the first note before starting or after ending. You may also see pauses and hesitations within a playing event. I have examined these and other behaviors and have ruled out analyzing them now, so please do not include them in your records.

I suggest using pencil. If you make a mistake in pen, please scribble out the entire box on your sheet and grade it properly in the next box. Write the Scribe ID of the event in the margin to the left. If the participant plays right up to the end of the clip, you may also want to watch the beginning of the next event before you mark the last note.

You may use your expert judgment. In the Altered Rhythms example above, the third event if played on its own without surrounding events for context, would simply look like it was played as usual, and the participant held out the last note a little. In context, it is clearly another instance of the altered rhythm in surrounding events. Use your professional judgment in deciding when this or other behavior labels apply. Likewise, if the same material appears at two locations within an excerpt and subsequent events make clear that you marked point A while the participant was actually playing point B, you may revise your markings.

Scribe makes a brief rewind when playing back an event. You will see the last second or two of the previous event each time you hit "play." In the event this becomes confusing (among lots of fast repetitions), it may help to watch the entire sequence before assessing them. Try your best.

Please write your initials, the label of the Scribe file and video, the page number of your record sheet, and the Scribe file ID for the first event on the page (the first column) as indicated at the top of each page. You only need to do one side if you print double-sided.

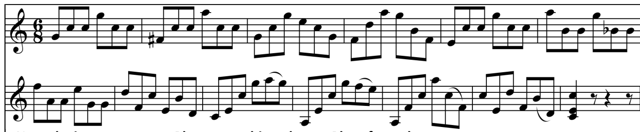
When you are done, you may give me your hard copy sheets if convenient. If not, please scan your results (including both sides, if double-sided) and email them to me. File size may necessitate splitting your sheets into multiple documents.

Thank you!

Data sheet examples

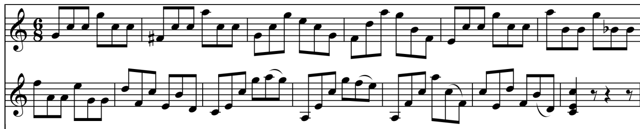
The following four pages show one full page of the reliability judge's score sheet for each of the excerpts (including the alternate version of the shifting excerpt for high school students). As with the IRB forms in Appendix A, each page has been somewhat reduced, which makes the musical material appear somewhat more cramped than when the sheets are printed.

Judge: **Participant:** **Page:** **First event Scribe ID:**



- Sys. alters rhythms
- Octave displacement
- Ignores metronome

Non-playing events	Plays something else	Plays from the excerpt		
Marks part	Plays other material	Repeats first note	Sys. alters bowings	Open strings only
Adjusts metronome	Metronome is on	Repeats last note	Adds double stops	Plays backwards
Other		Repeats other note	Plays pizzicato	Includes note in previous slur



- Sys. alters rhythms
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Non-playing events	Plays something else	Plays from the excerpt		
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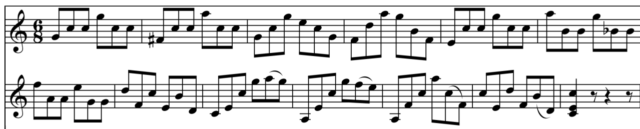
Other		Repeats other note	Plays pizzicato	Includes note in previous slur



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- Octave displacement
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Non-playing events	Plays something else	Plays from the excerpt		
Marks part	Plays other material	Repeats first note	Sys. alters bowings	Open strings only
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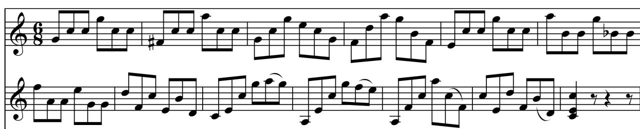
Other		Repeats other note	Plays pizzicato	Includes note in previous slur



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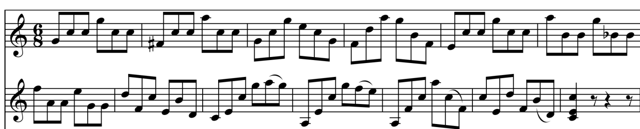

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- Octave displacement
- Ignores metronome

Non-playing events	Plays something else	Plays from the excerpt		
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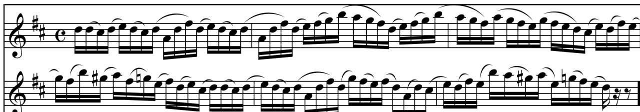
Adjusts metronome	Metronome is on	Repeats last note	Adds double stops	Plays backwards
Other		Repeats other note	Plays pizzicato	Includes note in previous slur

Judge: **Participant:** **Page:** **First event Scribe ID:**



Non-playing events
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- ☐ Other

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- ☐ Plays pizzicato
- ☐ Sys. alters rhythms
- ☐ Octave displacement
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- ☐ Plays backwards
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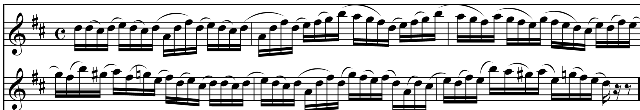

Non-playing events
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- ☐ Adjusts metronome
- ☐ Other

Plays something else
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- ☐ Metronome is on

Plays from the excerpt
- ☐ Repeats first note
- ☐ Repeats last note
- ☐ Repeats other note
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- ☐ Plays pizzicato
- ☐ Sys. alters rhythms
- ☐ Octave displacement
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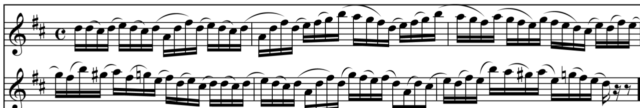
- ☐ Open strings only
- ☐ Plays backwards
- ☐ Includes note in previous slur



Non-playing events
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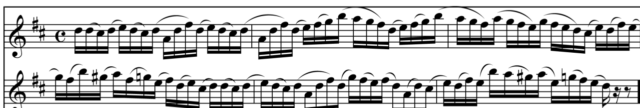

Non-playing events
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- ☐ Adjusts metronome
- ☐ Other

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Plays from the excerpt
- ☐ Repeats first note
- ☐ Repeats last note
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- ☐ Sys. alters bowings
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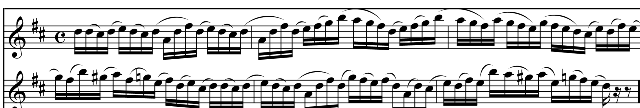

Non-playing events
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- ☐ Plays other material
- ☐ Metronome is on

Plays from the excerpt
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- ☐ Repeats last note
- ☐ Repeats other note
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- ☐ Octave displacement
- ☐ Ignores metronome
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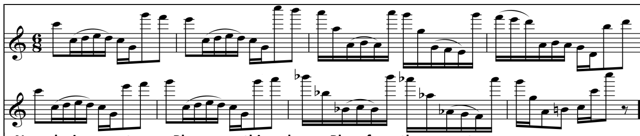

- ☐ Sys. alters rhythms
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Non-playing events	**Plays something else**	**Plays from the excerpt**		
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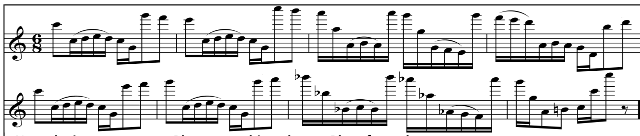
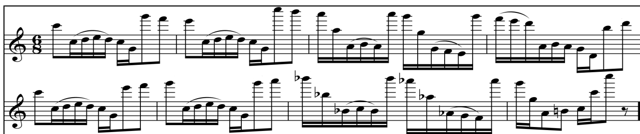
☐ Adjusts metronome	☐ Metronome is on	☐ Repeats last note	☐ Adds double stops	☐ Plays backwards
☐ Other		☐ Repeats other note	☐ Plays pizzicato	☐ Includes note in previous slur



- ☐ Sys. alters rhythms
- ☐ Octave displacement
- ☐ Ignores metronome

Non-playing events	**Plays something else**	**Plays from the excerpt**		
☐ Marks part	☐ Plays other material	☐ Repeats first note	☐ Sys. alters bowings	☐ Open strings only
☐ Adjusts metronome	☐ Metronome is on	☐ Repeats last note	☐ Adds double stops	☐ Plays backwards
☐ Other		☐ Repeats other note	☐ Plays pizzicato	☐ Includes note in previous slur



- ☐ Sys. alters rhythms
- ☐ Octave displacement
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Non-playing events	**Plays something else**	**Plays from the excerpt**		
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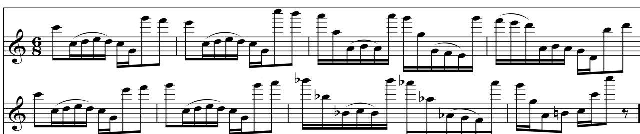

- ☐ Sys. alters rhythms
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Non-playing events	**Plays something else**	**Plays from the excerpt**		
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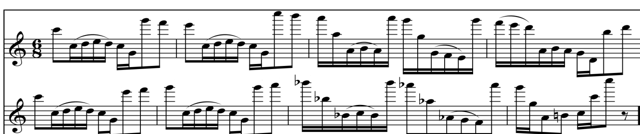

- ☐ Sys. alters rhythms
- ☐ Octave displacement
- ☐ Ignores metronome

Non-playing events	**Plays something else**	**Plays from the excerpt**		
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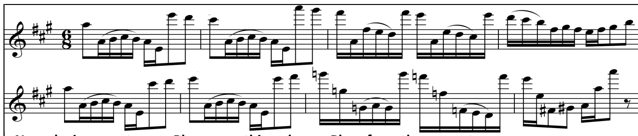

- Sys. alters rhythms
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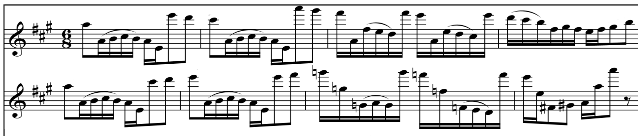

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Non-playing events	Plays something else	Plays from the excerpt		
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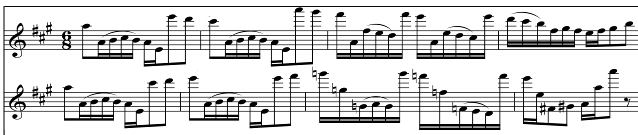

- Sys. alters rhythms
- Octave displacement
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Non-playing events	Plays something else	Plays from the excerpt		
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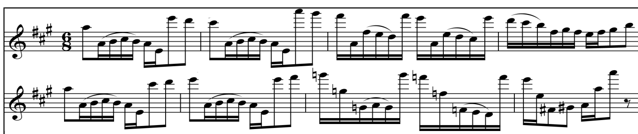

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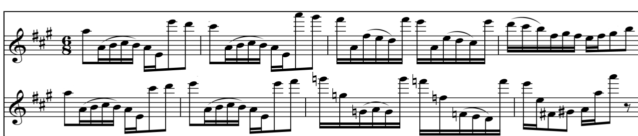

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APPENDIX C: PARTICIPANTS' VERBAL RESPONSES

In order to gain a profile of my participants' experiences and backgrounds prior to the study, as well as to learn about their impressions of the tasks they completed while participating, I asked them three blocks of questions. The first two blocks of questions were placed between practice sessions, and as such they also provided a mental break between participants' work on different excerpts. Because I did not perform a detailed analysis of the responses, I did not include most of these data in Chapter 3, except where it proved particularly relevant to another topic already under consideration, such as identifying that participants found the shifting excerpt to be noticeably more difficult than the other two. Their responses, however, do provide some additional perspective on the participants and their experiences, and so I provide them here.

Because of the conversational format in which these questions were presented, participants' answers to some of the questions overlapped. For example, many individuals preemptively identified each excerpt's signature challenge in the course of explaining whether they did or did not feel that they had practiced each one differently. Likewise, because most questions were open-ended (as opposed to multiple choice), participants often gave responses that still exhibited a great variety of detail even if they fell into broad categories. In the summaries below, I attempt to organize their responses according to the questions' intended order and format, and to distill common themes or differences, rather than trying to extract meaning from individual word choices or semantics.

Questions after the first practice session

Question 1: How long have you been playing violin?

High school violinists reported a mean experience level of 10.3 years (SD = 2.15 years), collegiate violinists 14.4 years (SD = 3.08 years), and professionals 37.2 years (SD = 7.48 years). While professionals displayed greater variability than the other two groups, these responses validate participants' group as a measure of their experience levels. Especially interesting is that the high school participants had almost exactly four fewer years' of violin experience. I had been somewhat concerned that college students in the present study might represent students who began at an extremely young age, while high school students might include individuals who started study later (such as in middle school orchestra), but that does not appear to have been the case.

Question 2: Is violin your first instrument? If not, when did you begin studying music?

All 11 high school participants reported that violin was their first instrument. Four of the 12 (33.3%) college participants reported playing another instrument before violin. These four participants averaged 5.75 years of musical training before beginning violin; all four had begun on piano, and one had some vocal training as well. Four of the 12 professional participants also began their musical studies on piano, an average of 3.34 years before beginning violin.

Question 3: Do you play any other instruments?

Participants in all groups reported playing a wide variety of instruments, with six high school students (54.6%), eight college students (66.7%), and 11 professional violinists (91.7%) reporting playing at least one other instrument. Details are shown in Table 3.

	piano	guitar	viola	cello	bass	percussion	voice	mandolin	lap steel	dobro	trumpet
High School	3		3	1		1		1			1
College	9		2	1	1	2	1				
Professional	6	2	9	1	1			1	1	1	

Table 3: Other instruments that participants reported playing.

Question 4: Who is your violin teacher? Who have been your main teachers before now? [For professionals: Who were your primary violin teachers?]

Teacher	High School	College	Professional
A		5	
B	1	2	1
C		4	
D	2	1	
E	1	1	1
F	1	1	1
G	3		
H			2
I			2
J		1	1
K			2
L		1	1
M			2
N			2
O			2
P			2
Other	24	22	36

Table 4: Participants' violin teachers.
Only those with two or more students among participants are listed.

I asked this question primarily to assess whether participants represented the studios of a wide range of teachers, or instead clustered with just a few instructors. Particularly because I recruited student participants with teachers' aid and recommendations, I wanted to be sure that my results reflected a sampling of many teachers' influence. If many participants all studied under the same teachers, I was concerned that my results for one or more groups might be more reflective of a few teachers' personal styles rather than violinists' standard practices.

Table 4 shows that while quite a few college students did study with two particular teachers, and several other teachers were represented by three or four students across multiple groups, participants also reported a wide enough variety of other teachers over time to assuage any concerns that their practice habits represent just one or two teachers' idiosyncrasies. In Table 4, only teachers with two or more students or former students in the present study are listed individually; to protect the identities of both teachers and participants, they are listed only by their initials. High school students averaged 2.9 teachers per student, college students 3.2, and professionals 4.6. In addition, two of the named teachers in this table were themselves participants in the study.

Questions after the second practice session

Question 5: [For high school students:] What grade are you in? [For college students:] What year and degree program are you in? [For professionals:] How long have you been playing professionally?

In the high school group were four sophomores, one junior, and three each of freshmen and seniors. College students' year in school was somewhat more difficult to categorize because in addition to traditional four-year students, the group included transfer students, graduate students, and students who had changed majors. The college group, however, included two masters students and 10 undergraduates. Two were music education students (including one of the masters students), one was a general music major (B.A.) but had been accepted to begin a masters degree in violin performance, and the remaining nine were violin performance majors, one with a double major in psychology.

More than half of the professional participants pointed out that this was a complicated answer, because it wasn't clear to them exactly when their professional careers began. As one participant put it, "I've been playing recitals, and being paid to play

recitals, since I was maybe sixteen. But, I mean, that certainly wasn't a source of income. Actually making money, that I can live and eat and pay rent? And all that stuff?" Because I did not ask college or even high school participants about professional engagements, I cannot say whether these groups appear to be on a career trajectory similar to the professional participants in this regard.

When I either waited for an answer or asked for an estimate, most professional participants provided some approximate number, averaging 20.5 years. One participant avoided answering the question at all.

Question 6: Have you been familiar with either of the excerpts you've practiced so far? And if the third one looks familiar, can you tell me that, too?

None of the participants reported familiarity with the excerpts. This was expected since I composed them for the study, but I wanted to make sure that none of them bore a strong resemblance to an etude or preexisting excerpt of which I was unaware.

Question 7: What repertoire are you currently working on?

A complete list here would be prohibitive. I wanted to find out if any of my participants—especially those in the high school or college groups—were working on unusually difficult repertoire, or else music that was substantially easier than others in their group. All the participants seemed to be working on music typical of their level. The most noticeable differences from this overall trend were among professionals. Many listed a much larger body of active repertoire than participants in other groups, including several dozen solo, chamber, and orchestral works that they were preparing for scheduled performances. A few professionals, on the other hand, only mentioned one or two orchestral parts and little if any solo repertoire. It was entirely unclear whether such discrepancies represent different levels of involvement, quirks of individuals'

performance calendars in the time surrounding their participation, or the depth to which they chose to delve in answering the question.

Questions after all three practice sessions were completed

Question 8: Do you feel like you practiced the three excerpts differently from one another? If so, in what ways?

Across all groups, participants' answers broadly reflected three ideas. These were not mutually exclusive: often, participants' initial answer would fall into one of these categories, and their explanation would fall into one of the other categories. Some participants also seemed to shift as they talked, initially reflecting one of these ideas before discussing elements more characteristic of one of the others. This flexibility suggests that by thinking about one or another aspect of their work as they explained, they would see or remember both differences and similarities between the excerpts and their work on them. Also, many participants' comments related to the next question as well, in which I asked them to identify each excerpt's signature challenge, because identifying exactly what was to be solved was often part of their explanation of how they had worked.

(1) One reaction could be summarized as, "No, I practiced all of the excerpts using the same approach. Namely, I tried to identify the problems and solve them." In a broad sense, this could be considered a definition of musical practice, and often in clarifying, participants would describe details that at first seemed to contradict their response. But the common idea seemed to be that, as opposed to polishing long sections or working on memory, in this context many participants viewed their job as finding specific things to fix and then fixing them, and in that sense they could be viewed as applying the same approach to all three excerpts.

(2) Another common reaction was to say that no, they did not use the same approach; then when explaining, these participants would describe the nature of the excerpts rather than any specific behaviors, strategies, or thought processes of their own. In a sense this is the same description as the previous one, except that participants who responded that their approaches were the same clearly viewed the process of identifying problems as a unifying theme, whereas participants in this group identified the problems themselves as distinguishing features. I will discuss details of these responses in the next question, which I intended to more directly address the excerpts' specific challenges.

(3) Many described their work on the slurring and string crossing excerpts similarly, whether their initial response reflected first idea (one process, identifying problems) or the second (distinct problems to solve). However, in this response pattern, participants described their work on the shifting excerpt as different than the other two excerpts in that they just had to figure out what was going on first, to find a fingering. One might expect that this response would be more common in the student participants, but professionals also appeared to express this reaction frequently.

Question 9: I chose each excerpt to feature one particular technical problem. Can you go through each excerpt and quickly tell me what its signature challenge is?

As mentioned above, many participants addressed this question more or less completely when answering the previous question. In these cases, I acknowledged that they had to some degree already discussed this, but asked them to summarize their earlier comments. In the analysis presented below, I include the details of their answers from the previous question.

Because reporting answers to this question required a certain amount of assessment on my part, a bit of explanation is needed. In assessing whether an exact match to the intended technical target was present, I looked for phrases that included either the exact wording I used to describe the challenge, or for synonyms. For example, in describing the slurring excerpt, I considered "slurs," "bowings," "syncopated slurs," "bow coordination," and "active bowings" all to be accurate descriptions of the intended target of the piece. If I labeled a description as containing only related challenges, the participant's response lacked a description of the technical challenge, but included other accurate details about the excerpt. Note that this does not necessarily mean that the participant failed to perceive my intended challenge; it may be that for these participants, the most problematic aspect of the excerpt was something other than I intended, either because the signature challenge was one of their strengths, or because another element was a personal weakness. I did not count descriptions consisting solely of the speed at which the excerpt was to be performed as extra detail simply because the instructions for the entire protocol identified this as a blanket goal; participants could reach this conclusion without having practiced anything. Likewise, "Not screwing up" and similar descriptions were not counted.

		High school	College	Professional
Crossings	Accurate	5 (45%)	10 (91%)	8 (67%)
	Related only	4 (36%)	1 (9%)	2 (17%)
	No relevant guess	2 (18%)	0 (0%)	2 (17%)
Shifts	Accurate	11 (100%)	9 (82%)	12 (100%)
	Related only	0 (0%)	2 (18%)	0 (0%)
	No relevant guess	0 (0%)	0 (0%)	0 (0%)
Slurs	Accurate	6 (55%)	10 (91%)	8 (67%)
	Related only	4 (36%)	1 (9%)	3 (25%)
	No relevant guess	1 (9%)	0 (0%)	1 (8%)

Table 5: Participants' guesses at each excerpt's primary challenge. Note that one collegiate participant was not asked this question, so percentages are determined from n=11.

Table 5 reports each group's accuracy in identifying the primary target of the excerpt. Note that while most participants were accurate, the collegiate rather than the professionals appear to have been the most consistent, and identified the shifting excerpt most accurately. Professionals seem to have almost overlooked the signature challenge in a few instances. For example, in discussing the string crossing excerpt, one mentioned the need to emphasize the downbeats rhythmically by exaggerating the bow direction, while demonstrating the relevant notes on the instrument (which necessarily includes crossing strings) without mentioning the crossings as complicating the issue. It seems that professionals in some cases may have mastered the skills to such a degree that, at times, they consider them merely facets of other problems.

High schoolers, in contrast, were more likely to name entirely different challenges. For instance, one identified the problem with the string crossing excerpt as being accidentals, while another said the string crossing excerpt was "a tongue twister for your fingers." Whereas when professionals neglected to mention the signature challenge, they seem to have absorbed it into a larger perceived problem, high school students simply perceived different aspects of the music as the most challenging features.

Out of the 34 participants who answered the question, only two (both college students) failed to identify the shifting excerpt's signature challenge. Of these two, one simply talked about the high notes; it is unclear whether this participant did not consider that getting to them was problematic or thought that this was implied and therefore did not mention it. The other, having elected to use fingerings that resulted in more string crossings and smaller shifts, focused on the string crossings as the primary problem. Although participants were less consistent in identifying the other two excerpts' challenges, they were still fairly successful.

Several participants mentioned both left hand and right hand problems of the string crossing excerpt—not only does the bow need to change strings, but a blocked, chordal fingering pattern is useful. Professional and high school participants mentioned

this left hand aspect of string crossings explicitly, while several participants in the college group alluded to it, mentioning intervals and "changing fingerings" (which, taken at face value, refers to any music with differing pitches, but here seems to refer to the massed, block movements between chords). One high school participant mentioned a contrast between melody and harmony in the string crossings.

In addition to identifying the slurring excerpt's primary challenge, participants noted many of its minor details. Although the melody was much more linear than the other two excerpts, featuring vastly fewer leaps, many participants elected to shift to avoid the string crossing to the F# on measure 1, beat 3, subdivision 3 (and in subsequent similar situations). In their answers to this question, participants frequently either brought up this shift or, if they chose not to shift, the string crossing. They mentioned finger dexterity and coordination. Though this was often identified as the easiest excerpt, participants certainly identified a wide variety of challenges when describing it.

Question 10: I'd like you to tell me how difficult each excerpt was. On a scale of one to six, where six is hard, how hard was the first excerpt? The second? The third?

As seen in Figure 10 in Chapter 4 (page 102), participants clearly considered the shifting excerpt to be the most difficult. However, though the slurring excerpt garnered the most low-difficulty ratings, it also displayed a wider variety of rankings with more than one vote than did the string crossing excerpt. That is, the participants as a group seemed to consider the string crossing and the slurring excerpts to be approximately equally difficult, but individuals' assessments of the slurring excerpt seemed more variable than the string crossing excerpt. There did not seem to be identifiable patterns by group. A more rigorous statistical analysis of the data did not seem to be warranted in this situation.

Question 11: Do you have any other questions or comments about your experiences here today?

Most participants did not have questions or comments. However, the three most common responses (other than "no") that I received were (1) inquiries regarding the excerpts, what compositions they were from or whether I wrote them, (2) requests to see the results when they were ready, and (3) caveats related to the ways in which they would have practiced differently had they had more time. Unfortunately, many participants who made these caveats waited to do so until after I had turned off the camera, so I cannot refer to many of their actual descriptions. However, as discussed in Chapter 5, their concerns point to one of the limitations of the current study. This was an extremely specific practice situation, using three difficult exercises, with instructions to play as fast as possible in a very short period of time.

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Vita

Andrew Strietelmeier was born in Valparaiso, Indiana in 1979. He began Suzuki violin lessons there at age four, studying with Betty Gehring. Raised a Lutheran, he participated in choral programs throughout childhood and continuing into his college years. Instrumental music programs in the typical American school system begins in late elementary or middle school years; encountering the choice in fifth and sixth grade, Andy displayed an early form of musical snobbery, opting to begin horn in band rather than join beginner orchestra. Andy received the Bachelor of Music Education degree from Valparaiso University in 2002, where he continued to study both violin under June DeForest and horn under Lee Shirer, performing in orchestras and bands while singing in the Kantorei. He received the Master of Music degree in violin performance from The University of Texas at Austin in 2004, where he studied with Vincent Frittelli. While completing his masters degree, Andy joined the University of Texas String Project, sealing his fate as a future doctoral student in music education. He currently teaches orchestra and violin at Denison University in Granville, Ohio. Andy has appeared in recitals, festivals, concerts, and master classes in North and South America as well as Europe. He has performed, presented research, and given pedagogical talks at the American String Teachers Association, Music Educators National Convention (now know as the National Association for Music Education), the Greek Society for Music Education, the International Double Reed Society, and the Texas Music Educators Association.

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