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Thinking Time in Music Practice

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Implications for Music Teaching and Learning

- Aspiring musicians may benefit from developing a habit of focused thought in which each performance trial within a practice episode is clearly defined and preceded by a vivid image of the intended outcome.
- Effective music learning requires making immediate comparisons between intentions and outcomes in each performance trial during practice. Listening to a self-recording can aid in the confirmation, disconfirmation, or extension of one's initial judgments.
- Music teachers can promote thinking time (i.e., moments of silence to set intentions and make evaluations) in music practice through strategic assignments that lead students to clarify moment-to-moment goals.

Abstract

We asked school- and college-aged instrumentalists ($N = 32$) to imagine an ideal performance of a brief passage of music, record a performance of the passage, and describe discrepancies they noticed between their imagined and actual performances. The more experienced participants took at least as much time to imagine their idealized performances as it took to perform them; less experienced participants took less time to imagine what they were about to play. There were no differences among experience levels in the numbers or types of discrepancies identified. The differences between more and less experienced participants were also evident in a subsequent practice period. More experienced musicians' practice included more frequent moments of pause, whereas school-aged participants seldom paused and tended to address performance issues other than those identified in their commentaries.

Keywords

metacognition, music performance, music practice, self-regulation, skill learning

It seems axiomatic that skill development in every domain of human activity requires active practice and research findings have indicated that effective practice is characterized by sustained, focused, and purposeful effort applied strategically toward improving the various components of skilled behavior (e.g., Ericsson et al., 1993). The moment-to-moment activities that comprise practice sessions vary among domains and among levels of individual skill, yet all skill learning engages fundamental processes of procedural memory formation and refinement (Herzfeld & Shadmehr, 2014; Seidler et al., 2013; Wolpert et al., 1995; Wu et al., 2014).

The study of music practice includes a wide range of research approaches, including systematic observation (e.g., Duke et al., 2009; McPherson & Renwick, 2001; Miksza et al., 2012), surveys and other methods of self-report (Burwell & Shipton, 2011, 2013; Hallam et al., 2012, 2020; McPherson & McCormick, 1999, 2000; Miksza, 2011), experimental interventions that prescribe practice strategies (Barry, 1992; Duke & Simmons, 2006; Hewitt, 2001; Rosenthal, 1984; Rosenthal et al., 1988; Ross, 1985; Stambaugh, 2011), and mixed approaches (Miksza, 2007; Pike, 2017; Rohwer & Polk, 2006). Although the principles of procedural memory formation ultimately underlie all of these investigations, there has been little explicit attention paid to connecting the practices of aspiring musicians to the mechanisms

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through which skill memories are encoded, stored, refined, and retrieved.

The brain's initiation of every action generates not only a suite of motor commands but also an internal efference copy that generates a prediction of the movement's expected outcome. This predictive coding is the foundational process through which all organisms develop skills and refine procedural memories (i.e., memories for how to do things; Herzfeld & Shadmehr, 2014; Seidler et al., 2013; Wolpert et al., 1995; Wu et al., 2014). The perception of a given action's consequences informs subsequent action and decision-making through both conscious and subconscious processes and the iteration of motor sequences during practice often leads to the reduction and eventual elimination of discrepancies between intentions and outcomes (Wolpert & Ghahramani, 2000).

Thus, the research in motor learning suggests that musicians will derive the most from independent practice when they formulate clear proximal goals (intentions) regarding the physical and auditory components of music performance and recognize discrepancies between those goals and their actual performance (outcomes) in each practice trial. The clarity and precision of intentions or proximal goals necessarily define the granularity of potential discrepancies that an instrumental music learner may perceive. Goals of (a) producing a tone, (b) producing a tone characteristic of the instrument, (c) producing a tone characteristic of the instrument that is in tune and in tempo, and (d) producing a tone characteristic of the instrument that is in tune and in tempo and convincingly conveys an intended musical effect represent increasing levels of goal specificity and complexity. The extent to which repeated performance trials contribute to the updating and refinement of procedural memories necessarily depends on commensurate levels of both intentional and perceptual clarity.

Conceptions of intentions may be as simple as a statement of a target behavior (e.g., play an accent, use the correct sticking, remember the key signature) or may take the form of visual, auditory, or kinesthetic imagery. In a multicase study of middle school instrumentalists' practice, Oare (2016) reported that students were motivated to choose, and to persist in practicing, music for which they possessed a clear auditory image. The ability to generate auditory and motor imagery appears to influence music learning during both encoding and retrieval (Brown & Palmer, 2013), although some research suggests that even among experienced musicians there is a wide variation in auditory and motor imagery abilities (Brown & Palmer, 2013; Highben & Palmer, 2004).

The process of imagining intended outcomes preceding a movement sequence is somewhat different from the notion of mental practice, which involves "cognitive rehearsal of a task in the absence of overt physical movement" (Driskell et al., 1994, p. 481). Magill and Anderson (2017) further specified that mental practice involves thinking "about the cognitive or procedural aspects of a motor skill or engaging in visual or kinesthetic imagery of the performance of a skill or part of a skill" (p. 452). Indeed, much has been written about the ability to vividly imagine music in the absence of sound and a number of studies have demonstrated benefits of mental practice in conjunction with physical practice (Cahn, 2008; Coffman, 1990; Highben & Palmer, 2004; Ross, 1985; Theiler & Lippman, 1995). Mental practice is typically construed as an iterative process that unfolds over time (i.e., a silent, imagined simulation of physical practice) during practice sessions that are quite apart from physical practice, but the inherent limitations of mental practice stem from the absence of feedback that derives from movements' consequences. In the current study, we focus on the imagining that may precede a given performance trial during physical practice episodes, which, although comprising many of the features of mental practice, involves only a single instance of an imagined performance trial followed by an actual performance trial.

The ability to recognize discrepancies between intentions and outcomes while in the midst of performing requires that musicians allocate attention to self-monitoring during motor action. As expertise develops, greater motor control permits skilled performers to reduce the attentional demands of motor production, as well-practiced movements become increasingly automatized and can operate without conscious control. Novices, however, devote considerable attention to the active control of movement to achieve initial success, often at the expense of their ability to attend to task-relevant feedback (Beilock et al., 2002, 2004).

To more carefully scrutinize their playing or singing, expert musicians often record and review their own practice sessions. Recordings allow learners to step outside their own internal perceptions and interpret outcomes from a different frame of reference. The information gathered from listening to recordings of one's own playing or singing can illuminate for the learner aspects of their performance they may choose to address in subsequent practice trials. But it is important to note again that feedback gained from listening to recorded practice cannot serve to update procedural memory directly, as doing so requires temporal contiguity between motor commands and outcomes (Wolpert et al., 1995).

Although previous researchers have found that listening to model recordings is advantageous (Fortney, 1992; Henley, 2001; Hewitt, 2001; Linklater, 1997; Rosenthal, 1984; Rosenthal et al., 1988), few studies of music practice have addressed learners' self-recording (Puopolo, 1971) or assessed the prevalence of listening to self-recordings during music practice (Hallam et al., 2012; Miksza, 2007). Hallam and colleagues (2012) administered a questionnaire to more than 3,000 young instrumentalists and found that participants overall *disagreed* with the statement, "I record myself playing and listen to the tapes." In a study of self-reported and observed practice behaviors, Miksza (2007) found that high school band students never or almost never recorded themselves practicing. Although many musicians and pedagogues are convinced of the utility of recording and listening to their own practice (Kageyama, n.d.; Klickstein, 2009), no systematic research study has been designed to determine whether, and to what extent, listening to recorded practice influences learners' perceptions of discrepancies between intentions and outcomes.

The tendency of novice musicians to avoid addressing performance errors (i.e., discrepancies) during practice is well documented (Lisboa, 2008; McPherson & Renwick, 2001; Miksza et al., 2012; Pike, 2017; Pitts et al., 2000). For example, Pike (2017) characterized one teenage pianist as a "surface rehearser" based on observation of the student's at-home practice. The student's practice included "several stumbles, incorrect notes, and incorrect fingerings" (Pike, 2017, p. 743) with no subsequent attempt to resolve discrepancies despite clear directives from his teacher to isolate the passage. Furthermore, Pike noted the student's tendency to transition between activities quickly without taking time for reflection. In contrast, Pike characterized another participant as a "somewhat-effective rehearser," noting moments where the student stopped to think about performances before isolating passages and applying effective strategies (Pike, 2017, pp. 742–743).

It is clear from the literature in motor learning that learners' accomplishment of movement goals, including sound production, depend upon (a) the clarity of intentions, (b) the accuracy of perceptions of outcomes, and (c) the capacity to make comparisons between the two. The purpose of the present study was to examine the extent to which practice behaviors of instrumentalists of different levels of experience and skill embody these features of effective skill learning.

We created a practice task in which participants were prompted to (a) imagine as clearly as possible the successful performance of a familiar passage they were about to play (intention), and following their performance of the passage, (b) describe how their actual performance (outcome) may have differed to what they had imagined. We designed the test procedures to create a thoughtful and deliberate practice sequence, which afforded participants an opportunity to choose material, formulate intentions, perceive discrepancies, and make assessments of their performances. Approximately half of the participants offered their assessment after hearing their recorded performances. The remaining participants offered their descriptions after a brief period of silence. At the end of each session, we invited participants to practice for three uninterrupted minutes, which we also recorded and analyzed post hoc.

We posed the following questions:

Research Question 1: When musicians with different levels of experience and skill are asked to imagine an idealized version of a brief passage of music that they are about to play, to what extent does the time required to imagine the passage match the time required to play the passage?

Research Question 2: When musicians with different levels of experience and skill are asked to make comparisons between their musical intentions and their actual performances, are there differences between the responses of those who first listen to a recording of their own performance and the responses of those who silently think about their own performance after playing?

Research Question 3: During an interval of undirected practice, to what extent do musicians at different levels of experience and skill incorporate intervals of thoughtful silence in their practicing?

Method

We recruited a convenience sample of 32 string, wind, and keyboard musicians (19 self-identified females and 13 self-identified males) between the ages of 11 and 28 years old who at the time of the study were upper elementary/middle school[1] musicians ($n = 8$), high school musicians ($n = 8$), and undergraduate ($n = 8$) or graduate ($n = 8$) music majors (further details are provided in Supplementary Tables S1–S3). The school-aged students were participants in the University of Texas String Project and the college-aged participants were enrolled in various music degree programs in the Sarah and Ernest Butler School of Music at the University of Texas at Austin. All of the school-aged students were also enrolled in regular music instruction through their school orchestra programs and took weekly private lessons from String Project faculty.

All participants were recruited via an email announcement that included a description of the study and consent documents or via in-class recruitment visits by the first author. All musicians volunteered to participate and received no compensation for their involvement. We obtained parental consent for the younger musicians, all of whom gave their assent. All procedures were approved by the university's institutional review board for human subjects research.

Test sessions were conducted in a quiet office or classroom and we made both video and audio recordings of the sessions.[2] We asked participants to bring to the test session a piece of printed music that was "in progress"; that is, a piece that was not new to them but required additional practice before it would be ready to perform in public. When they arrived at the test location, participants completed a brief questionnaire about their practice experiences (see Supplementary Tables S1–S3), after which they assembled their instruments, warmed up, and tuned in keeping with their typical practice routine, activities that ranged in duration from less than a minute to several minutes. The proctor (the first author) then explained the procedures for the study and invited questions for clarification (see Supplementary Figure S4 for an outline of test procedures).

After explaining the test procedures, we asked participants to "choose a relatively short phrase or passage that you can easily sing in your head" and then to "picture in your mind an ideal performance of the passage you select, imagining what you wish to convey to a listener through the music." We told participants before they played that we would ask them to compare their imagined versions of the passage with their actual performance and reminded them that, as the music they selected was not yet polished, their performance may not match exactly what they imagined. We allowed participants to move at their own pace; they chose how much time to devote to imagining before beginning to play.

We were interested in assessing the extent to which participants would identify discrepancies between their imagined and actual performances either (a) after a defined period of silent thought (think-describe, TD) or (b) after listening to a recording of their performance (listen-describe, LD). Half of the participants in each experience-level group were randomly assigned the TD condition: $N = 16$; $n = 4$ graduate, $n = 4$ undergraduate, $n = 4$ high school, $n = 4$ middle school. The remaining and same number of participants ($N = 16$) in each experience level were assigned the LD condition.

Participants in the LD condition, after playing their selected excerpt, immediately listened to a recording of their performance using AKG K99 Perception studio quality headphones and then described differences between what they had imagined and what they had actually played. Their descriptions were prompted by a series of scripted, open-ended questions (with follow-up questions determined ad hoc) about their comparisons of their imagined and actual renditions (see Supplemental Material).

Participants in the TD condition, after playing their selected excerpt, were asked to pause for 30 s and think silently about what they had just played and then answered the same scripted questions about their comparisons of their imagined and actual performances. After all questions had been answered, participants in this condition then listened to the recording of their performance (LD) and answered a second series of interview questions, beginning with questions about what they noticed on the recording that they had not mentioned earlier. In other words, the TD participants, after describing their comparisons, then listened to a recording of their performance and commented a second time (TDLD).

After answering the final interview questions, we invited participants in both conditions to practice for 3 min, working on anything that they wished; that is, they could continue practicing what they had just performed, work on something else, sit silently for 3 min, or simply put away their instrument. We refrained from explicitly directing participants to address the discrepancies they had identified. Providing participants with autonomy for approaching free practice allowed us to observe how participants approached refining performances, if at all, and more fully answer our third research question. The test proctor left the room during practice and participants were told that video recording equipment would remain on.

Analysis Procedures

We defined the imagining duration as the period of time between the end of the proctor's verbal prompt and the onset of tone marking the beginning of the participant's performance. We recognize that participants may have started to imagine their performance prior to the verbal prompt, as early as during the segment selection process. Also, for some participants, the moments just prior to the onset of tone may have comprised physical preparation for performance rather than a focus on mental imagery.

We analyzed participants' responses to interview questions by first generating written transcripts and grouping statements about comparisons into one of six categories. We adapted a statement classification procedure developed by Hamilton and Duke (2020): *intonation* (e.g., playing in tune, shifting in tune, or statements pertaining to precise finger or hand placement), *tone* (e.g., quality of sound, unintended nonmusical sounds, physical aspects of tone production such as bow or breath control), *expression* (e.g., phrasing, inflection, vibrato, dynamics, voicing, or overall character), *style* (e.g., articulation, duration of notes such as staccato and tenuto, and separation or connection of notes expressed in technical terms; statements about stylistic aspects in terms of expressive intent were regarded as statements about inflection), *notes* (e.g., playing the correct notes, or fluency of technical facility), and *timing* (e.g., tempo, fitting rhythms to a tempo, or bimanual coordination).

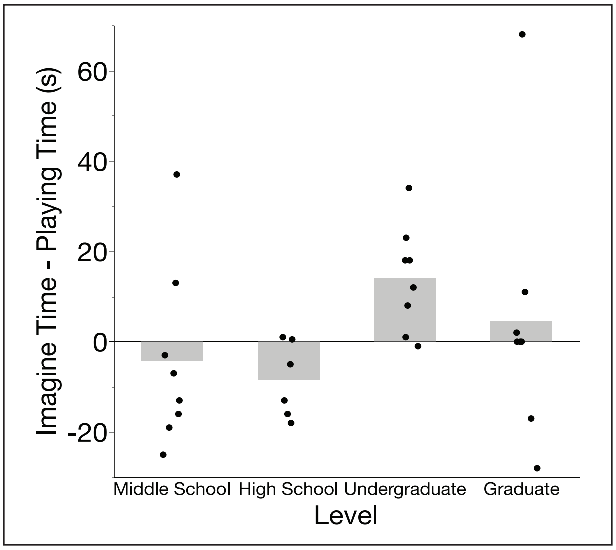

Figure 1. Differences in Duration Between Imagined and Actual Performances by Participant

Note. Positive values indicate more time spent imagining than was required to play the target passage; negative values indicate less time spent imagining than was required to play the target passage. Points indicate the difference in duration between imagined and actual performances for each participant. Gray bars indicate group means. Time is reported in seconds.

We also categorized each statement from the first interview as describing either a *discrepancy* (i.e., mismatch between intention and outcome) or *consistency* (i.e., match between intention and outcome). In the second interview of the TDLD group, we included three other categories for classifying participants' responses: *positive change* (statements that expressed a more positive assessment—a closer match—after having listened to the recording), *negative change* (statements that expressed a more negative assessment after having listened to the recording), or *confirmation* (statements that expressed confirmation of the statements made in the first interview).

We analyzed the time allocated to playing and nonplaying episodes in each of the free practice sessions using Scribe 5 behavior analysis software (Duke, 2020). Systematic observation of the free practice sessions began after the test proctor left the room and ended when 3 min had elapsed and the test proctor reentered the room, or when the participant began to put away their instrument.

Results

Durations of Imagined and Actual Performances

We first compared the time participants used to imagine the passages they were about to perform with the time required to perform the passage. Figure 1 presents individual and mean differences in duration between imagined and actual performances. Positive values in Figure 1 indicate more time spent imagining an ideal performance of the passage than was spent playing the passage. The magnitude of the differences between the durations of participants' imagined and actual performances varied among groups.

An analysis of variance (ANOVA) with planned contrasts revealed that the difference scores between imagined and actual performances were significantly greater among college-aged participants (i.e., graduate and undergraduate) than among school-aged participants (i.e., high school and middle school), $F(1, 28) = 5.43, p = .03, \eta^2 = .19$. With only three exceptions, graduate and undergraduate participants took at least as much time to imagine the passage as was required to play it, whereas middle school and high school musicians tended to take less time to imagine the passage than was required to play it. Mean differences in duration between imagining and playing were positive for undergraduates (M = 14.1 s, SD = 11.6) and graduate students (M = 4.5 s, SD = 28.4) and negative for middle school (M = −4.1 s, SD = 20.1) and high school (M = −11.2 s, SD = 18.5) participants.

All but three of the college-aged participants devoted at least as much time to imagining as was required to perform the passages they had selected, which seems consistent with the notion that the college-aged participants created vivid mental images of their musical intentions. The rich descriptions of intention these musicians provided during interviews support this idea. As one graduate horn player explained,

> What I'm trying to portray is a cellist throughout this whole thing, and that's how I'm trying to portray this entire etude. I'm thinking about the bow motion that's happening. At the same time, it has to still be short and separated, because that's what it's asking. But in terms of the forward motion that has to go, I am thinking about the motion of how a cellist would do this. (Graduate participant)

Comparisons Between Imagined and Actual Performances

Following the performance of the selected passage, participants either listened to a recording of what they had just played (LD) or were invited to think silently for 30 s about what they had just played (TD). Statements made by those who heard the recording before commenting and those who thought silently before commenting were quite similar, both in number and in content: There were 73 total statements from those who heard the recording and 71 from those who did not (see Table 1). A chi-square test revealed no significant difference in the numbers of statements in each category between the group who listened to

Table 1. Numbers of Participant Interview Statements in Each Content Category and in Each Valence Category.

	LD	TDLD	
Interview Statements	Interview 1 Describe	Interview 1 Describe	Interview 2 Describe
Content category			
Intonation	11	7	4
Tone	13	8	13
Style	2	8	8
Expression	27	32	19
Notes	9	12	4
Timing	1	4	10
Total	73	71	58
Valence category			
Consistency	15	11	0
Discrepancy	58	60	31
Confirmed Interview 1			10
Positive change over Interview 1			5
Negative change over Interview 1			12
Total	73	71	58

Note. Frequency counts are reported for statements made in each content category and valence category. LD participants had only one interview, following their listening to the recording. TDLD participants had two interviews, one after a period of silent thought and a second after having heard the recording. Thus, comments that either confirmed or modified statements from the first interview appear only in the column labeled Interview 2 Describe. LD = listen-describe; TDLD = think-describe and listen-describe.

the recording and those who thought silently about their performance, $\chi^2(5, N = 144) = 10.18, p = .07$. The distributions of discrepancy and consistency statements were also similar in the two conditions.

Across all participants and at all time points in the test procedures, statements about expression were most frequent. In terms of valence, discrepancy statements were more frequent (LD = 58; TDLD = 60) than consistency statements (LD = 15; TDLD = 11) in both conditions. Observations by middle school participants tended to be vague and often made little reference to expressive intentions adopted before playing. A juxtaposition of responses from participants of different skill levels illustrates this point:

> Well, if I played it like I intended to play, I would have actually gotten the dynamics correct and I would not have done so much messing up with my fingers. My fingers just kind of tripped over each other and got confused. (Middle school participant)

> When I think of this section, the reason why I think it could always use more attention to detail is because of this really lyrical top line with this very clear accompaniment pattern. So, one of the main things I was trying to do is really separate and phrase the top line without letting the accompaniment get in the way, and I think it was relatively successful. It sounded good; directing those dotted notes through the melody notes, and I think it came across well. (Undergraduate participant)

After describing discrepancies following a period of silence, participants in the TD condition then heard a recording of their performance (LD) prior to the second interview. More than half of the statements made in the second interview pertained to discrepancies that had not been mentioned in the first interview. Approximately 30% of the statements reflected changes in perception between the first and second interviews, most often revising an earlier statement in a way that reflected a more negative assessment of their playing after having heard the recording (see Table 1).

When asked to consider why they noticed new discrepancies when listening to a recording, many participants commented on their ability to fully attend to their sound when the demands of performance were removed:

> I think because at the moment you've got to keep playing, you know, your focus is not 100% on what just happened. So, I think when you're listening, your brain is totally focused on what you're listening to. It's not like it's divided. (Undergraduate participant)

> I think it's because I wasn't playing it. I was listening to it, so because while I was playing it I was trying to think about, I was focusing on a lot of multiple things, so when I was listening, all I was doing was focusing on listening to it and picking up things that I didn't notice. So, it was definitely easier for me to figure out stuff that I didn't know was there. (High school participant)

Table 2. Time During 3-Min Self-Directed Practice Interval Devoted to Playing the Target Passage, Related Material, Unrelated Material, and Pausing.

	Target passage		Related exercise or elsewhere in the same piece		Different piece		Pause	
Skill level	*M* s (*SD*)	*n*	*M* s (*SD*)	*n*	*M* s (*SD*)	*n*	*M* s (*SD*)	*n*
GR	130.8 (59.2)	8	38.3 (43.2)	3	0 (—)	0	20.3 (17.5)	8
UG	86.3 (82.2)	8	85.4 (63.2)	5	0 (—)	0	35.6 (23.5)	7
HS[a]	91.0 (63.0)	5	92.8 (63.0)	5	116.3 (56.8)	2	16.4 (13.6)	6
MS	118.6 (61.5)	7	52.0 (53.9)	6	118.5 (—)	1	13.2 (9.6)	6
ALL	107.9 (66.8)	28	69.4 (57.2)	19	117.0 (40.2)	3	21.8 (18.4)	27

Note. Mean durations spent in each practice or pause activity for participants in each level; *n* = number of participants in each level who devoted any time to each practice activity (e.g., six of the eight MS students paused at any time during the 3-min practice interval). Means were calculated by dividing the total time in a given activity by the number of participants in each level who actually devoted time to that activity. *SDs* are reported in parenthesis below the means. GR = graduate; UG = undergraduate; HS = high school; MS = middle school.
[a]One HS participant elected not to practice during the allotted time and was excluded from the analysis.

Self-Directed Practice

We assessed the use of time during the 3-min self-directed practice periods, during which participants practiced the passage they had just performed (target passage), practiced a related exercise or some other passage in the same piece, practiced a different piece, or paused (silence). The results of this analysis are presented in Table 2. Nearly all participants played for a majority of the time allotted (*M* = 2 min 50 s). Only one participant, a high school student, elected to forgo practicing during the allotted time; we did not include his data in the practice analysis.

Graduate students spent the most time on the target passage, just over 2 min on average, followed by middle school participants. High school participants and undergraduates spent the least time on the target passage, 91 and 86 s on average, respectively. College-aged participants did not spend any time practicing another piece, although several high school and middle school participants chose to do so.

We were particularly interested in instances during the practice sessions when participants paused and seemed to be thinking about what they were doing. Nearly all participants did so, but one undergraduate, one high school student, and two middle school students did not pause at all during the 3-min practice interval. Of the participants who did pause, the college-aged participants devoted approximately twice as much time to pausing as did the school-aged participants. Pause durations were longer, on average, for more experienced participants; however, there was considerable variability in all groups. An ANOVA with planned contrasts revealed that the average amount of free practice time spent in pause was significantly greater among college-aged participants than among school-aged participants $F(1, 27) = 4.66, p = .04, \eta^2 = .14$.

Discussion

We set out to observe musicians' thinking time in two different music practice contexts. In one context—imagining and performing a brief passage from one's own repertoire—we were particularly interested in the extent to which participants took time to imagine what they were about to play. We also examined the extent to which listening to a recording of their performance influenced participants' descriptions of discrepancies between their imagined and actual performances. In a second context—a brief period of self-directed practice—we recorded the presence of silent pauses among intervals of playing time. Our findings are based on a convenience sample of 32 instrumentalists and thus should be interpreted with due circumspection. Further research with larger samples should explore thinking time in these contexts.

We found consistent, significant differences between more and less experienced musicians in the time they took to imagine a musical passage that they were about to perform. Among nearly all of the more experienced musicians (i.e., undergraduate and graduate students) in our sample (13 of 16), the time they devoted to imagining an idealized performance of their selected passage was equal to or greater than the time required to play it. The opposite was true for the 16 school-aged musicians (i.e., middle and high school students), only four of whom took as much or more time to imagine their selected passages than was required to play it. This may reflect an inability (or an unpracticed ability) to think vividly through the act of performing on their instruments and to form a clear intention regarding upcoming actions. If this is true, then the potential to refine procedural memories through iterative practice is greatly diminished. This result is consistent with other observations of young musicians' practice, in which little time and attention was devoted to systematically addressing errors (Lisboa, 2008; McPherson & Renwick, 2001; Miksza et al., 2012; Pike, 2017; Pitts et al., 2000).

It is possible that some school-aged participants did not picture an ideal auditory image at all and instead relied on performing from notation to provide a template for comparison, which comports with Oare's (2016) observation that students tend to rely on their instrument as an "auditory crutch." It may also be the case that the younger participants simply anticipated making mistakes similar to those they had made in the past. Responses to interview questions support these notions. One high school participant, for example, offered clarification regarding her experience forming an ideal image:

> Whenever I have to think about myself playing something, the problem is I always think about how I play it now, so I was having trouble getting over that I already play it sort of out of tune. So, I was trying to get over that when I was picturing it. So, it was a little harder for me to do that. Whenever I do have to imagine something, it's like a copy and paste from what I've already heard. The most recent thing I had heard was me playing that or the most recent version was me, so that was how I remember it, so then it was hard to adjust it in my head. (High school participant)

The added dimension of the present data is the observation that many younger musicians did not seem to have developed the capacity to clearly imagine what they are about to do *immediately in advance of their doing it*, an aspect of goal setting for each practice trial that has important implications for music teaching and learning. In contrast, imagining an idealized version of an upcoming performance trial seemed much in keeping with what most of our college-aged participants do routinely during individual practice.

We compared assessments made by participants who had listened immediately to recordings of their performances (LD) with assessments made by participants who only thought silently about their performances (TDLD, first interview). Participants in these two conditions gave similar descriptions of discrepancies they observed between their intentions and what they actually played. It seems unsurprising that all participants made more *discrepancy* observations than *consistency* observations. One implication of this finding is that attending to performance with the explicit goal of making comparisons between intentions and outcomes and allowing space for reflection after playing yield evaluations that can potentially form the basis for subsequent planning. It is interesting to note that Hamilton and Duke (2020) found that musicians across a range of experience levels, on average, identified similar numbers and types of discrepancies between intentions and outcomes. We found that all participants in the present study were also capable of identifying discrepancies, irrespective of whether they heard a recording of what they had just played, although the depth of descriptions and their level of detail differed with experience.

The TDLD condition allowed us to compare the same participants' descriptions of discrepancies, first after a period of silent thought and then after listening to a recording. Although the number and content of discrepancies were similar among those who listened to a recording of what they had just played and those who only thought about what they had just played, supplying the recording to the TDLD participants led to their identification of more discrepancies in the second interview than they had identified after silent reflection. This may suggest a benefit in first formulating assessments about one's performance and then listening to a recording to confirm, disconfirm, or extend one's initial judgments.

The observations of self-directed practice during the 3-min practice interval were particularly notable. The most experienced participants tended to choose passages of a length and complexity that allowed them to focus on a limited set of potential discrepancies and they took time to pause and reflect throughout the practice interval, a finding consistent with related research (Duke et al., 2009). Most of the less experienced musicians appeared unfamiliar with setting a clear intention and they chose to work on more material than could be improved in a single, brief session.

Each participant entered the self-directed practice session with at least a few problems to address. High school and middle school participants, on average, spent little time practicing the target passage and little time pausing. All participants proved quite capable of making discriminations about their playing, but when given an opportunity to practice, middle and high school students did not create time and space to do so. Our results are consistent with the observed tendency of novice musicians to avoid addressing discrepancies in performance (Lisboa, 2008; Miksza et al., 2012; Pike, 2017; Pitts et al., 2000; Renwick & McPherson, 2002), yet the fact that all of the discrepancies in this study were identified by participants raises additional questions. Researchers should examine reasons why novice musicians would choose not to engage in focused practice once their awareness of discrepancies is brought into sharp relief.

Taken together, these data illustrate that the skilled musicians in our limited sample had a qualitatively different and integrated approach to performance and practice than did the less skilled musicians in our sample. The graduate students seemed most capable of breaking down their chosen passages into manageable practice units. When asked to imagine an ideal performance, the time they took to do so more closely matched the time it took for them to perform the target passage, in some cases a near-exact match. When asked to describe the comparisons they noticed, they spoke in detail. They often referenced expressive intentions in terms of character, spoke of attempting to imitate another instrument, and at times would sing to illustrate their intent. Their practice was focused and thoughtful with clear evidence of opportunities for comparison between intention and outcome.

Creating moments of quiet reflection was not a part of most younger participants' practice. They were able to make comparisons and identify discrepancies during the test procedures, but during self-directed practice, many did not address the very issues that they themselves had brought to light. This may be indicative of the participants in our sample having had little experience planning practice time systematically or it may simply reflect their tendency to play material that is more enjoyable to perform rather than work to resolve challenging problems.

If in fact our data are representative of developing musicians in general, our results highlight the need for music teachers to provide practice supports for younger students that emphasize thinking time over playing time. For example, a module that guides students through procedures similar to those presented in this study may serve as a useful practice assignment. Perhaps a worksheet or journal prompt that requires students to describe and reflect on thinking surrounding the practice of a single passage would assist in developing desirable behaviors.

Individual practice is the primary mechanism through which all musicians acquire and refine the skills of music performance. Although many aspects of practice have been well documented and prescriptions for effective practice abound, there remain aspects of *thinking* during music practice that have yet to be fully elucidated. The research in motor skill development makes clear that the refinement of procedural memories depends upon the conscious or subconscious identification of discrepancies between intentions and outcomes and the usefulness of such comparisons depends not only on accurate perceptions of performance outcomes but also on the clarity of movement intentions (proximal goals).

Making time during independent music practice to formulate clear intentions in anticipation of each performance trial seems to be a part of highly skilled musicians' repertoire of practice behavior (Hallam, 2001). Aspiring musicians may benefit from guided practice that is devoted to developing a similar way of thinking, one in which each iteration of a given passage is preceded by a vivid image of the intended outcome.

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Supplemental Material

Supplemental material for this article is available online.

Notes

1. For brevity, we will refer to this group of musicians using the term *middle school* throughout the remainder of the article.
2. Participants were video recorded using an HD digital camera with an external Bluetooth microphone clipped to the music stand holding the participants' music. Audio recordings of the participants' musical performances were made using an Apogee MiC 96K studio quality USB Condenser Microphone, connected via USB to a MacBook Pro (Retina, 13-inch, Early 2015) running Audacity® (Mazzoni, 2020) software.

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