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Implications of extrinsic cognitive load on three levels of adult woodwind players

Laura A. Stambaugh

Abstract
The purpose of this study was to examine the effects of two levels of extrinsic cognitive load when three levels of adult woodwind musicians practiced. Extrinsic load was manipulated through repetitive and random practice orders. Participants (N = 43) were novice, intermediate, and advanced university woodwind players who completed a three-day, repeated measures design. At the end of two days of practice, novices who had practiced in a blocked (repetitive) practice order played significantly faster than those who had practiced in a random order. However, this difference was eliminated at 24-hour retention testing. Intermediate players experienced no differential effects of extrinsic cognitive load at the end of practice or at retention. For the advanced players, a trend was found for speed increasing from the end of practice to 24-hour retention (p = .06). While the constructs of cognitive load theory are relevant to woodwind learning, further research is needed to determine effective paradigms for their implementation.

Keywords
cognitive load, contextual interference, practice, MIDI, woodwind

Expert skill is marked by the formation of cognitive schema, such as the ability to chunk pitches or rhythms together into meaningful units (Chase & Simon, 1973; Ericsson, Krampe, & Tesch-Romer, 1993; Gruson, 1988; Owens & Sweller, 2008). For example, a first-year violin student may not realize the pitch sequence G A B C D is the first five pitches of a G major scale, but a high school violinist can understand these individual pitches as a unit. As teachers and performers, we should select learning paradigms that support schema formation because these will promote learning. One such paradigm is cognitive load theory, an instructional theory proposed by Sweller (1988), based on the architecture of human cognition with a limited working memory and unlimited long-term memory. Through the lens of cognitive load theory, the current study

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examined how the structure of practice affected three levels of adult woodwind players. Instead of assuming a “one size fits all” approach to practice, there is a need to understand how factors such as experience level, cognitive development, and instrument interact with specific practice strategies. This study investigated three levels of adult learners practicing technical tasks in two different ways on one woodwind instrument.

Cognitive load is similar to the earlier constructs mental load and task difficulty, because cognitive load is the amount of executive processing required for a person to complete a task (Moreno & Park, 2010). Factors contributing to cognitive load are the characteristics of the task, the physical learning environment, and the learner, as well as all the interactions among those three contributors (Choi, Merrienboer, & Paas, 2014). When a task is being learned, it is routed through working memory, including partially separate processing for aural and visual information, and for pitch and rhythm (Jerde, Childs, Handy, Nagode, & Pardo, 2011), before being consolidated into long-term memory (Gog & Paas, 2008; Paas, Tuovinen, Tabbers, & Gerven, 2003). Since working memory has limited capacity (Miller, 1956) and duration (Peterson & Peterson, 1959), it is a limiting factor in learning. However, the use of schemas can overcome some of the limitations of working memory (Paas et al., 2003). Returning to the violin example of G A B C D, an experienced violinist could use her existing schema for the beginning of a G scale to occupy one “slot” in working memory. The novice violinist, who conceptualizes each note as an individual, would use five working memory “slots” for the same set of pitches. These differences in working memory load between experienced and novice instrumentalists are worthy of investigating.

Three categories of cognitive load have been identified (Paas & Merrienboer, 1994; Sweller, 1988, 2010). First, intrinsic load is the level of difficulty inherent in a task and it is the result of its number of interacting elements. Sweller (1988) suggested a number of ways to evaluate cognitive load, including the number of items in working memory, the number of possible “productions” at each given step in a behavior, the “number of cycles in the solution”, and the “total number of conditions [that need to be] matched [between the starting point and target]” (p. 272). Subsequent research (Joseph, 2013; Paas et al., 2003; Paas & Merrienboer, 1994) evaluated behavioral and physiological methods of measuring cognitive load. Self-report questions and EEG could indicate relative intrinsic cognitive load, while eye-tracking during the task, heart-rate variability, and spatial ability were not strongly related to intrinsic cognitive load.

In music, one could argue that playing a specific pitch on the piano demands less cognitive load than playing a specific pitch on the trombone because the piano task has fewer component elements. The pianist uses fine motor skills to find and press the piano key, but the trombonist must generate an aural image of the pitch while coordinating breathing, embouchure, and fine and gross motor skills to produce the pitch. Playing a pitch on the trombone requires many interrelating elements (higher intrinsic load), while playing a pitch on the piano has fewer elements (lower intrinsic load). An individual’s prior knowledge and experience will also impact intrinsic load (Paas et al., 2003). If the trombonist is a professional symphony player, then playing a single pitch has a lower intrinsic load than if the trombonist is an adolescent beginning student because the professional has existing schema for the component elements of tone production.

Extrinsic load is imposed by the instructional context and it either hinders (extraneous load) or promotes (germane load) schema formation. If the adolescent trombone student is practicing in the living room with the television on and siblings running around, those forms of extrinsic cognitive load are extraneous because they are likely to limit learning. In a rehearsal setting, key signatures impose a higher level of extraneous load for a beginning player because the player must hold the relevant sharp or flat in working memory while also attending to all the
other requirements of playing in an ensemble. Because the effects of cognitive load are additive, it is quite possible to overburden working memory (Owens & Sweller, 2008; Paas, Gog, & Sweller, 2010). Therefore, teachers can limit extraneous load and enhance germane load by recommending practice strategies that are appropriate for the demands of the specific musical task and the student’s current ability.

Musicians manage cognitive load on a daily basis as they practice. Although previous music research rarely used the theoretical construct of cognitive load (an exception is Owens & Sweller, 2008), it has frequently provided evidence of learners manipulating cognitive load to enhance learning. For example, beginning instrumentalists primarily use repetition (Hallam, 1997; Leon-Guerrero, 2004; McPherson & Renwick, 2001; Rohwer & Polk, 2006), which is low in extraneous load. The high demands of simply learning to play the instrument (intrinsic load) require lower levels of extrinsic load to prevent overload. As a player progresses, certain behaviors like posture, hand position, fingerings, embouchure adjustments, and notation literacy become schema based (less intrinsic load). Then, the player must adopt more complex practice strategies to create germane load, such as using a metronome (Brittin, 2006; Miksza, 2007), isolating passages (Maynard, 2006), increasing tempo (Brittin, 2006; Hallam, 1997), or combining mental with physical practice (Coffman, 1990; Ross, 1985; Rubin-Rabson, 1943).

Chaffin (2011) referred to aspects of cognitive load theory in his examination of cognitive workload of instrumental conducting, specifically in regards to a conductor’s ability to manage multiple tasks simultaneously. Del Mar Galera, Tejada, and Trigo (2013) situated a small solfège study in cognitive load theory, with inconsistent results. Owens and Sweller (2008) applied cognitive load theory to an academic music class with 11–12 year old boys who were experienced instrumentalists (no further information about their musical experience was indicated in the study). The students learned about time signatures and rhythm values using three different visual presentations and four different audio-visual presentations, each designed to have high intrinsic cognitive load. The presentation formats with the highest levels of extraneous cognitive load were found to be least effective for learning. Therefore, the authors recommended cognitive load theory was a viable framework for structuring music learning. The current study addressed this recommendation by applying cognitive load theory to a music performance context.

Two other areas of previous research are relevant to this study of cognitive load in woodwind instrument practice. First, instrumental music practice is a topic with a long history of anecdotal and empirical interest, including deliberate practice (e.g., Ericsson et al., 1993; Meinz & Hambrick, 2010), self-regulated practice (e.g., McPherson & McCormick, 1999), use of models (e.g., Anderson, 1981), mental practice (e.g., Coffman, 1990), work and rest periods (Davis, 2009; Duke & Davis, 2006; Simmons & Duke, 2006), varied practice (Donald, 1997; Duke & Pierce, 1991), the role of auditory feedback (e.g. Finney, 1997), novice and expert approaches (e.g., Hallam, 1997), motor skill perspectives (e.g., Norton et al., 2005), and organizing practice (Abushanab & Bishara, 2013; Rose, 2006; Stambaugh, 2011, 2013; Stambaugh & Demorest, 2010). The way practice is organized, both within and across sessions, impacts extraneous and germane cognitive loads.

The second area of related literature concerns contextual interference, which considers the amount of processing required when practicing multiple tasks (Battig, 1966; Shea & Morgan, 1979). Contextual interference predates cognitive load theory by over 30 years, but studies of contextual interference are essentially manipulating extrinsic cognitive load. A low level of extrinsic load is imparted when all trials of one task (e.g., a D Major scale) are completed before moving on to practice the next task (Eb Major scale). Blocked practice is the name generally
assigned to this repetitive order, with only one task active in working memory. A high level of extrinsic load is transmitted when mixing up the order of several scales (D, Eb, A, Eb, A, D ...). This order is generally referred to as random practice (also, interleaved), and it allows multiple tasks to be active in working memory. Blocked practice usually supports better learning immediately after practice, while random practice often enables better performance at retention testing (for a review, see Merbah & Meulemans, 2011). This finding was consistent for beginning clarinet and experienced university woodwind players practicing 7-note technical tasks (Stambaugh, 2011, 2013) and for university pianists (Abushanab & Bishara, 2013). However, when I (Stambaugh, 2013) found that brass players learned better using blocked practice, I proposed the reason for this finding was the combination of a high level of intrinsic load (brass instrument) with a high level of extrinsic load (random practice), resulting in overload.

If performers and teachers consider intrinsic and extrinsic cognitive loads when selecting practice or instructional strategies, this may improve skill retention. Blocked and random practice orders provide an appropriate and practical paradigm to test extrinsic load. The purpose of this study was to examine the effects of two levels of extrinsic cognitive load when three levels of adult woodwind musicians practiced. More specifically, the study compared blocked and random practice orders used by three levels of adult learners on a woodwind instrument. The research question was:

When beginning, intermediate, and advanced adult woodwind players practice brief technical passages, what are the effects of low and high levels of extrinsic cognitive load on pitch accuracy and how quickly they play the passages (speed)?

**Method**

**Participants**

Forty-three university music majors and minors voluntarily completed three individual study sessions. The novice group included brass players, percussionists, pianists, string players, and vocalists (n = 14, four females, 10 males; M<sub>age</sub> = 21, SD = 2.8 years). Novice participants had no prior experience playing a woodwind instrument. The intermediate group included brass players, percussionists, and vocalists (n = 14, six females, eight males; M<sub>age</sub> = 22, SD = 1.6 years). Intermediate level participants had the widest range of prior woodwind experience, including students who had completed a university woodwind techniques course, as well as students who had played a woodwind instrument in secondary school. The advanced group included clarinetists, flutists, and oboists (n = 15, 11 females, four males; M<sub>age</sub> = 20, SD = 1.6 years). Participants in the advanced group were woodwind majors or minors. All participants completed an IRB-approved Informed Consent process.

**Materials**

The repeated-measures design required six performance tasks for each participant group: three tasks for the blocked practice order and three tasks for the random practice order, at novice, intermediate, and advanced levels (see Figure 1). The tasks were modified from previous research with university woodwind players (Stambaugh, 2013). To play the pitches in the novice tasks, the player only needed to move adjacent fingers on the right hand. The intermediate tasks used fingers from both hands, as well as one more complex fingering (F#). The advanced tasks required left and right hand fingerings, plus a side key to play G#. Each technical task was
comprised of seven pitches, making it brief enough to eventually be considered one motor unit (Stambaugh & Demorest, 2010).

Three additional study participants pilot tested the tasks. One participant qualified as a beginner, another as intermediate, and the third as advanced. Each participant attempted to perform all the study tasks without knowing what level the tasks were designed for (e.g., novice played the novice, intermediate, and advanced tasks). Next, each participant decided which task seemed most appropriate for his or her playing level. One-hundred percent agreement was found between the tasks the pilot participants selected for their level and the level that the tasks were designed for (e.g., beginner chose the beginner-level tasks as being most appropriate for him or her to play). Based on this 100% agreement, the tasks were included as intended in the full study design. Post-hoc analyses were also undertaken to determine if the tasks were of similar difficulty for each level. These results are presented below.

A woodwind instrument was selected for this study because, as an oboist, I am most familiar with woodwind instruments. In addition, all participants could play the same instrument, thereby eliminating any potential confounds imposed by performers playing on different instruments. Participants played on a Yamaha WX-5 MIDI wind controller. It has a mouthpiece, synthetic reed, and fingerings similar to a saxophone. The validity of using this MIDI instrument in instrumental research was determined through previous research (Barthet, Guillemain, Kronland-Martinet, & Ystad, 2010; Guillemain, Kergomard, & Voinier, 2005; Stambaugh, 2015). The wind controller was connected to a Yamaha VL70-m sound module set to the “AirSax” sound. The sound module was connected to a MacBook Pro computer running Cubase LE4 software. This software provided numerical and graphic outputs for pitch, duration, and volume.

**Figure 1.** Practice tasks. Novice Woodwind Player tasks require only right finger movements. Intermediate Woodwind Player tasks use left and right finger movements. Advanced Woodwind Player tasks use fingers of both hands and one left hand pinky key.
Design
The independent variables were ability level (novice, intermediate, and advanced) and practice order (blocked and random). The dependent variables were pitch accuracy and speed (the duration of each performance trial). A repeated-measures design was used, with each participant practicing in both blocked and random practice orders for two study sessions. At the third study session, participants performed retention trials.

Procedure
The procedures were pilot tested with the three additional volunteers noted above and found to be suitable for use in the primary study. Participants attended individual study sessions in a small room with the researcher present. At the beginning of the first study session, I instructed them how to hold the wind controller, produce a sound, and read the fingering chart. They played a series of warm-up activities including long tones, tonguing, and repeated pitches. Participants had as much time as they wanted to warm-up and become familiar with the instrument. After telling me they were ready to move on, I gave them a printed copy of their first three practice tasks and a checklist of the order to practice those tasks. I told them to play each task as accurately and quickly as possible, and to check off each task on the checklist as they played to ensure each task was played in the correct order for the correct number of trials.

In the repeated measures design, all participants practiced three tasks in a blocked order (e.g., Task 1 nine times, then Task 2 nine times, and then Task 3 nine times) and the other three tasks in a random order (e.g., Task 5, 6, 4, 6, 4, 5, ...). They played nine trials of each task. Half the participants were randomly assigned to practice in the blocked order first, while the other half practiced the random order first. Then participants practiced the other three tasks in the other order. Participants were permitted to write on the sheet music, and a pencil and metronome were available at all times. At the end of the first session, participants were told not to practice these tasks between study sessions.

Approximately 24 hours after the first study session, participants returned for a second practice session. Individuals completed the exact same practice tasks and orders on the second day. On the third day, participants completed a retention testing session. They played all six tasks, three times each, in two blocks of serial orders (e.g., Task 1, 2, 3, 1, 2, 3 followed by 4, 5, 6, ...). The serial order was selected for retention testing to reduce any advantages that could be afforded by a match between encoding and retrieval conditions (Tulving & Thomson, 1973). Serial orders lack the trial-by-trial repetition of a blocked order, while retaining the predictability of a blocked order. Direct comparisons between random and serial orders have led to inconsistent results (Schmidt & Lee, 2005).

Scoring
The dependent variables were pitch accuracy and speed. The performance trials of interest were the last three practice trials of each task on the second day, termed acquisition, and the retention trials on the third day. I determined pitch accuracy by comparing the Cubase outputs for pitch to the original practice tasks. I used the following system to deduct points from a perfect score of seven: 1 point for each skipped, added, repeated, or wrong pitch; 2 points for stopping and starting over, excluding errors that happened in first instance of the repeated section. This system was found to be reliable in previous research (Stambaugh, 2011; Stambaugh & Demorest, 2010). To determine the speed of each trial, I highlighted the onset of the first pitch
through the onset of the last pitch and the internal software in Cubase calculated this duration. Once the accuracy and speed scores were determined for each trial, I determined the mean of every three trials (e.g., Acquisition trials 16 + 17 + 18), as in previous research (Allen, 2013).

**Results**

The means and standard error of the accuracy and speed scores for all practice conditions and levels are presented in Table 1. To determine if the performance tasks were of similar difficulty for each participant level, two one-factor ANOVAs were conducted using the mean accuracy and speed scores at Acquisition. The omnibus test for accuracy indicated a significant main effect of level, $F_{(2, 754)} = 9.299$, $p < .0001$, $\eta^2_p = .024$, and pairwise comparisons showed the intermediate level songs were played significantly more accurately than the advanced level songs (intermediate, $M = 5.52$; advanced, $M = 4.93$; $p < .001$). The omnibus test for speed was also significant, $F_{(2, 752)} = 42.862$, $p < .001$, $\eta^2_p = .102$, with pairwise comparisons indicating the advanced group ($M = 1.56$ seconds) was significantly faster than the intermediate ($M = 2.24$ seconds; $p < .001$) and the novice ($M = 2.31$ seconds; $p < .001$) groups. Next, two-factor repeated measures ANOVAs (practice condition: blocked or random; performance trial: acquisition or retention) examined differences within and between practice conditions for pitch accuracy and speed.

**Novice group**

The histograms for accuracy variables indicated negative skew for some practice conditions. Therefore, accuracy scores for the blocked condition at acquisition and retention were exponentially transformed ($x^2$). Histograms for speed variables in both conditions showed positive skew, so they were logarithmically transformed. Repeated measures ANOVAs examined within-practice condition differences from acquisition to retention. For accuracy, neither condition experienced significant differences from acquisition to retention. However, for speed, the blocked condition played significantly faster at acquisition than at retention, $F_{(1,13)} = 88.588$,
In other words, the blocked condition played more slowly at 24-hour retention than they did at the end of practice. Only one between-condition analysis was significant: at acquisition, the blocked condition played significantly faster than the random condition, $F_{(1,13)} = 70.948, p < .001, \eta^2 = .67$.

**Intermediate group**

Histograms showed negative skew for all accuracy scores; these were transformed exponentially ($x^2$). All speed scores showed positive skew and were logarithmically transformed. Due to the wide range of prior woodwind experience in the intermediate group, two covariates were used in these analyses. The accuracy and speed scores of each participant’s first practice trial were accuracy and speed covariates. Within-practice conditions, repeated measures ANCOVAs indicated no significant differences for accuracy or speed between acquisition and retention ($p > .05$). Likewise, between-practice condition ANCOVAs indicated no significant differences between conditions for either accuracy or speed at acquisition or retention.

**Advanced group**

Histograms indicated all variables met the assumption of normality, except for the random condition’s retention accuracy. Because it showed only minor positive skew, it was not transformed. ANOVAs indicated no significant differences for any comparisons within or between blocked and random practice conditions at acquisition and retention ($p > .05$). The only comparison that approached significance was within the random practice condition: woodwind players who practiced in a random order played faster at retention than they did at acquisition, $F_{(1,14)} = 4.044, p = .064$. However, this finding was not significant.

**Discussion**

The purpose of this study was to examine the effects of two levels of extrinsic cognitive load when three levels of adult woodwind musicians practiced. In a repeated measures design, participants practiced brief technical tasks in blocked and random orders. Within each level, participants performed with similar levels of pitch accuracy at the end of practice and at retention testing. The only differences that occurred in performance were in speed. When novice adults practiced with a low level of extrinsic load, it resulted in an initial superior performance at the end of practice. However, this advantage disappeared at 24-hour retention testing. Advanced and intermediate woodwind players demonstrated limited differences from the impact of high and low levels of extrinsic cognitive load.

**Cognitive load theory and working memory**

This study built on previous research in woodwind practice and cognitive load (Stambaugh, 2011, 2013), which found both novice, child clarinet players and adult, university-level woodwind majors learned technical passages more effectively when using high levels of extrinsic load during practice. Those previous findings were unexpected for two reasons related to differences between the samples: (1) the novice children had no prior formal musical experience, while the adult music majors had much prior musical experience, and (2) working memory development of a child may be different from that of a university student. In the current study, the amount of prior musical experience in general was similar between the adult novice and
advanced groups because all participants were music majors or minors. Yet, the child novices (Stambaugh, 2011) and the adult novices were influenced by blocked and random practice in similar ways. Therefore, the effect of prior overall musical experience on working memory load may be limited during a specific practice task like the ones used in these studies. Next, previous research (Bayliss, Jarrold, Gunn, & Baddeley, 2003) found children and adults shared the same structure of domain-general processing efficiency and domain-specific storage capacity. Despite these structural similarities, these two factors predicted reading and math abilities differently between the two populations. The current study found child and adult novices were similarly affected by extrinsic load, although the adults were affected to a lesser extent than the children. The domain-specific storage demands of the tasks were largely consistent between the two samples, as both groups practiced technical tasks comprised of seven pitches. Therefore, the finding that adults were less affected by extrinsic load may be due to more efficient processing.

The study design included two other potential independent variables related to intrinsic load: the instrument and the practice tasks. The instrument was the same across all participants. I assumed that by using the same instrument with players of different levels of experience, I would be creating three different levels of intrinsic load (e.g., the novices would have the highest level of intrinsic load because they were most unfamiliar with woodwind instruments). The variable “practice task” would be held constant by matching the difficulty of the musical passages to each level of participant. However, results of ANOVAs comparing pitch accuracy and speed among the three participant levels indicated the research design placed the novice and intermediate woodwind players at a similar level of intrinsic load. It is difficult to interpret if the advanced players were at a similar or different level of intrinsic load compared to the novice and intermediate players because the advanced players’ accuracy was worse than that of the novice and intermediates, but the advanced players’ speed was significantly faster.

The intermediate and advanced groups exhibited no significant differences between or within practice conditions. Yet, trends in Figure 2 are consistent with the contextual
interference hypothesis (Shea & Morgan, 1979) and developing germane cognitive load. After practicing in the blocked condition, participants performed more slowly at retention than at the end of practice, while after practicing in the random condition participants performed faster at retention than at acquisition. If these trends continued across more practice trials, as suggested by Shea, Kohl, and Indermill (1990), then the higher extrinsic load could support stronger schema formation. For the advanced group, another explanation is offered by Abushanab and Bishara (2013). When differences were not present between practice orders for their advanced piano students, they suggested all students’ expertise caused performance to approach asymptote and thereby limited the potential for group differences. While the mean accuracy scores in Table 1 do not appear to approach the perfect score of seven, many of the errors included in the accuracy scores are artifacts of playing the MIDI wind controller (see Stambaugh, 2015).

**Effects of extrinsic load on pitch accuracy and speed**

The blocked and random practice conditions affected pitch accuracy in similar ways within participant level, as no significant differences for pitch were found in any within-level comparisons. This finding that musicians placed a high priority on accuracy is consistent with previous research with 9-year-old clarinet players (Stambaugh, 2011), university and child piano students (Palmer & Meyer, 2000), university music majors with limited piano experience who performed in a piano study (Simmons & Duke, 2006), and university woodwind players (Stambaugh, 2013). The advanced level participants in this study did have significantly lower accuracy scores than the novice and intermediate participants. These advanced woodwind players experienced the speed–accuracy trade-off that is frequently found in other motor research (Schmidt & Lee, 2005). This result may have occurred because they were approaching ceiling levels of tonguing speed on the MIDI wind controller. Previous research with this wind controller found tonguing artifacts may occur because the synthetic reed enabled pitches to be recorded even when played at extremely brief durations (Stambaugh, 2015).

When differences occurred in performance, they were in speed. At the end of two practice sessions, novice adults were able to play the tasks they had practiced in a blocked order significantly faster than the tasks they had practiced in a random order. The lower level of extrinsic load supported more effective initial skill than the high level of extrinsic load. However, this advantage disappeared at 24-hour retention testing, when all tasks were played with similar pitch accuracy and speed. The novices had experienced “illusions of competence” (Jacoby, Bjork, & Kelley, 1994). At the end of practice, they were able to play quite quickly. However, when they returned for retention testing the next day, they had lost much of that speed. Their ability at the end of practice on Day 2 was temporary and did not represent the actual amount of learning that was demonstrated on Day 3. This disconnect has important pedagogical implications, since typical practice is a self-regulated activity. The repetitive nature of the blocked practice order did not support schema formation to the same degree as the random practice order, perhaps because the extraneous load was too low. In this case, the low task difficulty combined with low extrinsic cognitive load did not lead to adequate germane cognitive load. However, when playing in the random practice condition, novices were able to maintain speed from acquisition to retention. Since both conditions practiced the same tasks, the only difference was the practice order. The higher extrinsic load imposed by the random practice order combined with the low task difficulty to produce a strong schema. This finding is consistent with previous research with beginning wind players (Stambaugh, 2011), although those beginners were about nine years old. Repetitive practice orders may not be the most effective orders for beginning woodwind players practicing brief technical tasks.
**Limitations and future research**

While the novice and advanced groups were clearly defined, the intermediate group included a wide range of prior experience with woodwind instruments. Future research could include a screening task to assign participants to a specific intermediate sub-level. In addition, the participants, even the novices, were university music majors and minors. Given their level of prior experience with music in general, future research should include novice adults without extensive musical experience.

All participants performed the study sessions on the same woodwind instrument, a MIDI wind controller. The learning curve for the wind controller was reasonable for a voluntary experimental design, and it allowed the instrument to be held constant across ability levels. However, it would be interesting for this study to be replicated with traditional woodwind instruments such as flute, oboe, clarinet, and bassoon. Each instrument has particular pitches and pitch sequences that are more challenging than other pitches, even within the same instrument (e.g., flute second octave vs. third octave, bassoon middle range vs. lowest octave). These within-instrument difficulties may be suitable for investigations with cognitive load.

Cognitive load theory was not originally designed for motor tasks like instrumental performance. Yet, its primary constructs of prior experience, task difficulty, and structuring practice are frequently considered by performers when they practice and by teachers as they plan instruction. Despite the limited impact of cognitive load constructs demonstrated in this study, evidence in this and previous research suggests woodwind players should consider using more challenging practice orders when practicing technical passages.

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