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Differential effects of cognitive load on university wind students' practice

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Abstract

The purpose of this study was to investigate the effects of cognitive load during practice on university wind students' learning. Cognitive load was manipulated through instrument family (woodwind or brass) and the amount of repetition used in practice (highly repetitive or random). University woodwind and valved-brass students (N = 46) completed two practice sessions and two retention testing sessions. Participants practiced three seven-pitch tasks in either a blocked, repetitive order or in a random order. Performance trials were scored for accuracy, speed and evenness. At 24-hour retention, woodwind players who had practiced in a random order were able to play significantly faster, $F(4,80) = 4.448$, $p = .003$, $\eta 2 = .15$, and more evenly, $F(4,80) = 4.464$, $p = .003$, $\eta 2 = .16$, than woodwind players who had practiced in a blocked order. However, for brass players, blocked practice supported better accuracy, $F(4,64) = 3.508$, $p = .012$, $\eta 2 = .15$, and speed, $F(4,64) = 4.489$, $p = .003$, $\eta 2 = .18$, than random practice. A secondary research question examined participants' judgment of learning. At the end of the second practice session, participants predicted the tempo they expected to be able to play the tasks at during the 24-hour retention session. A significant correlation between predicted and performed tempo was found for brass players using blocked practice ($r = .360$, $p = .04$).

Keywords

cognitive load, contextual interference, judgment of learning, performance, practice

Can the phrase 'one size fits all' apply to instrumental practice? Certainly there are many aspects of effective practice that are shared across instruments, ages of musicians, and prior experience of performers. Yet given the variety of physical and cognitive demands shared among so many instruments, the differences in neurological development between the young beginner and the mature performer, and the contrast in prior musical experience between a novice learner and an experienced professional, it seems likely that there may be aspects of practice that are not universal. Certain strategies may be effective for one experience level but not another, or for

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certain instrument families but not others. As the research base examining practice continues to grow, it is important to examine these potential sources of differences.

Skilled behaviors such as instrumental performance are cognitive tasks. Sweller (1988) defined cognitive load as the amount of executive processing required to perform a task. Both the mental and physical aspects of instrumental performance contribute to cognitive load, as motor control is a cognitive process. This study is concerned with two aspects of cognitive load. The first is the *intrinsic* cognitive load (Sweller, Merrienboer, & Pass, 1998) required to play woodwinds compared to that required to play brass instruments. For example, playing neighbor notes middle C and D on the clarinet at a moderate speed is a musical task with a low level of intrinsic cognitive load. Playing C and D on the trombone, however, is a musical task with greater cognitive load because the performer must move the slide to the correct, nonadjacent position while also manipulating air and embouchure to change partials. The second aspect of cognitive load investigated in this study was evident in the practice structure assigned to the learner, *germane* cognitive load (Merrienboer, Schuurman, Croock, & Pass, 2002). Germane cognitive load enhances schema formation during learning. A highly repetitive practice order has a low cognitive load, while a practice structure that constantly shifts the order of passages to be practiced has a higher cognitive load. Either of these practice conditions may become germane cognitive load if they promote schema formation.

A second area of interest in this study is the ability to evaluate one's learning. Alone in the practice room, how does an instrumentalist know when to stop or to continue practicing a particular passage? This is a compelling question, essential to the process of self-regulated practice. A beginning student may use predetermined cues provided by his or her teacher, such as playing a prescribed number of trials or for a certain amount of time. More advanced students, however, may have developed their own method for deciding when they have learned a passage. This perception of how well a learner believes he or she has learned a task has been termed 'judgment of learning' (Dunlosky & Bjork, 2008; Dunlosky & Nelson, 1992). As described later, the judgment of learning paradigm provides a quantitative method for gaining insight into this critical skill.

The extant body of research about musical practice is quite extensive and constantly expanding. Several lines of research have examined the underlying cognitive processes that support successful practice, including internal and external attributions of motivation (Asmus Jr., 1986; Hallam, 1997; Schmidt, 2005); deliberate practice (Ericsson, Krampe, & Tesch-Romer, 1993; Lehmann & Ericsson, 1997), self-regulated learning strategies (McPherson & McCormick, 1999; McPherson & Renwick, 2001; McPherson & Zimmerman, 2002; Miksza, 2011), and the effects of visual and aural feedback (Banton, 1995; Finney, 1997; Finney & Palmer, 2003; Repp, 1999). Descriptive and experimental methods have been used to investigate the effectiveness of specific practice strategies. Model recordings are useful for beginners when additional guidance is provided to the student, while more accomplished instrumentalists can benefit from the model recording alone (e.g., Henley, 2001; Hewitt, 2001; Rosenthal, 1984; Rosenthal, Wilson, Evans, & Greenwalt, 1988). Other beneficial practice strategies include mental practice alternated with physical practice (e.g., Ross, 1985), whole-part-whole practice (Miksza, 2006, 2011), varying tempo (Donald, 1997). Distributing practice sessions across the week was more commonly used by conservatory students (Byo & Cassidy, 2008; Jorgensen, 2002) than professional musicians (Hallam, 1997; Williamon & Valentin, 2000).

Findings in verbal memory (Battig, 1966) and motor learning (for a review, see Brady, 2008; Shea & Morgan, 1979) suggest that higher cognitive loads during practice attenuate immediate learning but enhance performance at retention. Battig (1966) termed this phenomenon *contextual interference*. A common research paradigm for investigating contextual interference required participants to pick up a ball and use it to knock over a series of vertical platforms in a prescribed order and speed. Participants were cued with one of three different sequences and timings. A low level of cognitive load was induced in the blocked, repetitive order, where all the trials of one sequence were completed before the participant moved on to practice another sequence. The contrasting condition of high cognitive load was caused by having participants practice the three sequences in a random order. At the end of practice, denoted as 'acquisition,' participants who practiced in a blocked order performed more accurately than participants who practiced in a random order. However, at retention, the best performers had practiced in a random order. While this contextual interference effect is not true for all applied tasks, it has been consistent for fine motor skills like handwriting (Ste-Marie, Clark, Findlay, & Latimer, 2004), and for such gross motor skills as badminton (Goode & Magill, 1986), baseball (Hall, Domingues, & Cavazos, 1994), and basketball (Landin & Hebert, 1997).

Contextual interference has been applied in a limited number of music learning contexts. Given the inconsistency of results, it appears that the nature of the musical task may be a critical component that interacts with cognitive load during practice. Rose (2006) asked university music majors to practice right-hand-led snare drum sticking patterns in a repetitive order, a varied order, or in a free practice condition. None of the practice conditions demonstrated a learning advantage at retention tests for this nonpitched task. The musical tasks used by Stambaugh and Demorest (2010) were three eight-measure songs similar to those found in beginning band method books. Participants were seventh grade clarinet and saxophone students who practiced the three tasks in either one six-minute block, three two-minute blocks, or six one-minute blocks. Again, no learning advantage was found for accuracy among the differing levels of cognitive load. However, in a follow-up study with beginning clarinet students practicing short technical tasks (Stambaugh, 2011), those who used a random order were able to play significantly faster than students who practiced in a repetitive (blocked) order. Students practiced the seven-note tasks during study sessions on three days and then performed a retention test on the fourth day. Trials were scored for speed, accuracy, and evenness. Both practice conditions of the random, high cognitive load and blocked, low cognitive load supported similar accuracy and evenness scores. However, participants' speed scores indicated practice with a high cognitive load was more effective for beginners.

Given that the cognitive development and prior musical experience of 11- and 12-year-olds is not the same as that of university students, it would be presumptuous to assume that practice in a high cognitive load condition will also benefit older musicians. In addition, the previous study (Stambaugh, 2011) included only one instrument, which was a woodwind. When considering the many aspects of instrumental performance, the nature of the instrument may interact with the learning process: a strategy that is most effective for some instruments may not be the best practice strategy for other instruments. Brass instruments plausibly impart a higher intrinsic cognitive load than woodwind instruments because playing the correct pitch on a woodwind instrument is more singularly a function of pressing the right keys, while brass pitch accuracy is also dependent on air and embouchure. Combining the high cognitive load of random practice with the more demanding brass instruments may simply be too taxing for effective learning to occur.

Judgment of learning

The nature of self-regulated practice requires the learner to decide when to stop practicing a specific task during each practice session. Judgment of learning (JOL) statements are similar to feeling of knowing (FOK) statements (Hart, 1965) in a broad way in that both require the learner to evaluate how well one thinks he or she knows something. FOK statements have been applied to memory tasks, while JOL statements have been applied to behavioral skills.

A common JOL paradigm is for a learner to predict how well he or she will perform a task in the future. This prediction is then compared to the learner's actual performance. The accuracy of JOL statements is often poor, although the latency period and the nature of the prediction may affect accuracy (Rhodes & Tauber, 2011; Simon & Bjork, 2002; West & Stanovich, 1997). If JOL statements are made based on learners' performance level during practice, and blocked practice can lead to inflated performance at acquisition, then it follows that the learners using blocked practice may overestimate their learning. Jacoby, Bjork, and Kelly (1994) refer to this as 'illusions of competence.' Simon and Bjork (2001, 2002) investigated this potential interaction using a computer number pad key press task. Participants learned three keystroke patterns, each with a unique sequence of keystrokes and goal movement time, in either a blocked or random order. University students who used blocked practice overestimated how well they would perform at retention trials, while those who used random practice were quite accurate with their predictions.

There have been limited instances of measuring JOL and FOK in music contexts. Korenman and Peynircioglu (2004) included FOK statements in their music memory research. After hearing very brief instrumental excerpts, participants performed recall and recognition tasks, demonstrating more accurate FOK statements for more familiar musical excerpts. The only behavioral musical task found in the literature was investigated by Harvey, Garwood, and Palencia (1987), who compared active and passive procedures for learning to sing an interval. Adult participants either listened to and sang, or only listened to, 24 intervals. At the end of the practice period, the active singing participants 'rated their [singing] performance for the previous trial on a seven-point scale' (p. 95), with 1 being the most confident rating and 7 indicating they believed they failed to sing the interval correctly. After a rest break, all participants sang transfer trials to a novel interval (*transfer* trials are commonly used to test a skill or concept in a new context). The relationship between the confidence ratings and the actual transfer performances was quite low for both repetitive and variable practice groups. The authors suggested the participants made their confidence ratings based on factors other than their actual performance.

Stepping into the practice room, consider a student's practice from the perspectives presented above. First, what instrument is the student playing? Second, is the student using repetitive practice, as advocated by many teachers and professionals (Green, 2006; Maynard, 2006), or a more cognitively demanding practice order? Finally, how is this student deciding when he or she has finished practicing each technical task? These questions are the foundation for this study. The purpose of this study is to examine the effects of cognitive load during practice by university wind students and to determine the accuracy of their judgment of learning statements. Two hypotheses tested cognitive load during practice:

1. After practicing in either a blocked or random practice order, university woodwind players would show no significant differences at acquisition, retention, and transfer for (a) pitch accuracy, (b) speed, or (c) evenness.
2. After practicing in either a blocked or random practice order, university brass players would show no significant differences at acquisition, retention, and transfer for (a) pitch accuracy, (b) speed, or (c) evenness.

The secondary research questions were: will there be a significant relationship between the predicted tempos and the performed tempos of university wind students? Does practice condition affect this judgment of learning assessment?

Method

Participants were 46 undergraduate students who were members of concert bands at two universities in the United States (woodwinds: $n = 21$ females, $n = 4$ males; brass: $n = 6$ females, $n = 15$ males). Instruments were represented as follows: flute ($n = 10$), oboe ($n = 2$), clarinet ($n = 9$), saxophone ($n = 4$), trumpet ($n = 14$), French horn ($n = 5$), and tuba ($n = 2$). Twenty-three students were randomly assigned to a blocked practice group ($n = 12$ woodwind; $n = 11$ brass) and 23 students were randomly assigned to a random practice group ($n = 13$ woodwind; $n = 10$ brass). Students completed an institutional review board-approved informed consent process and received minor financial compensation for their time.

Materials

One practice task was composed and then transposed into two additional keys (see Figure 1) to make a total of three practice tasks with the same melodic contour. This process eliminated possible confounds from using practice tasks with differing melodic contours. With seven pitches, the tasks were designed to represent one motor unit. The chromatic pitches were included to prevent ceiling effects. To be consistent with previous motor learning research (e.g., Shea & Morgan, 1979), transfer tasks were composed to present some of the same intervals as the practice tasks, but in different contexts. All instruments performed the tasks as presented in Figure 1, except for octave displacement required by instruments with a lower range than the flute. Tasks 1, 2, and 3 were played during all the study sessions; transfer tasks 4 and 5 were only played at 24-hour and one-week retention.

Procedure

Individual study sessions took place in a small room with the researcher present. All performance trials were recorded at 16 bit 44.1 kHz sampling rate with a Nady CM-60 miniature condenser lavalier microphone. This was connected to a PreSonus FireStudio interface into a MacBook Pro laptop running Cubase LE4 software. A music stand had a sheet of paper that listed the order of the practice trials. Participants were told to check off each practice trial as they completed it, to ensure they practiced the tasks in their assigned blocked or random practice order. Each music task was printed on a separate piece of paper to limit the potential for extra mental practice that could occur if all the tasks were on the music stand concurrently. A pencil and metronome were on the stand during all study sessions, and participants were informed they could use these items as they pleased.

Participants attended four study sessions at approximately the same time each day. Days 1, 2, and 3 took place consecutively in one week and day 4 occurred one week after day 3. On Day 1, participants in the blocked practice order played nine trials in a row of either task 1, 2, or 3 (Figure 1), then nine trials of another task, and finally nine trials of the third task. At the beginning of the session on day 2, participants were given a paper with the following instructions: 'Please predict how well you think you will play task 1, 2 and 3 tomorrow. Metronome speed (1) _______ (2) _______ (3) _______.' Participants were told they would need to

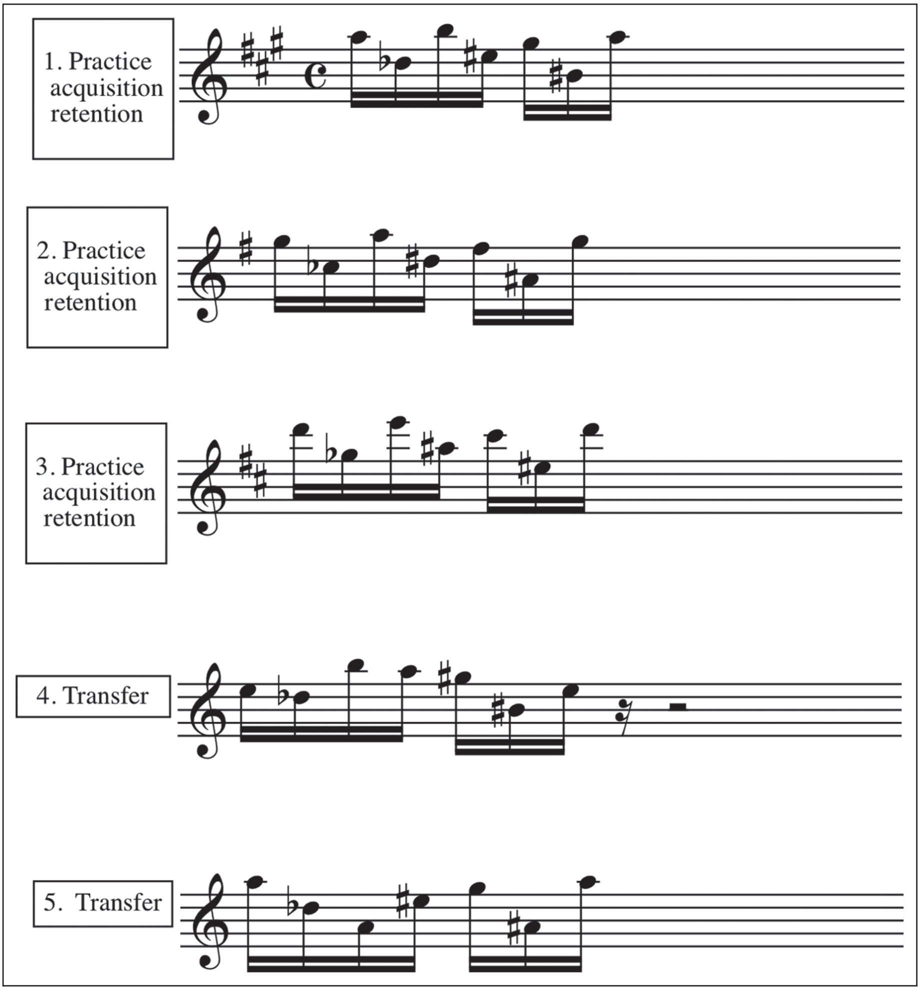

Figure 1. Musical tasks as presented to flutes.

write down metronome speeds for each of the three tasks when they had completed all the practice trials for day 2. The researcher answered any questions the participant had about this procedure. In the blocked practice groups, participants then performed nine more practice trials of each task, in the same repetitive order used on day 1. The scores from the last three trials of each task were later averaged to serve as the 'acquisition' score.

Day 3 was termed '24-hour retention' and day 4 was termed 'one-week retention.' The procedure was identical for both days. Within the blocked practice condition, participants within instrument family were assigned to either a blocked or random retention order through stratified random sampling. For example, five flutes had practiced in a blocked order: three were assigned to a blocked retention order (task 1 1 1 2 2 2 3 3 3) and two were assigned to a random retention order (2 3 1 3 1 2 1 2 3). The participants performed each task three times in their assigned blocked or random retention order. Finally, all participants performed the two transfer tasks three times each, in an alternating order (task 4, 5, 4, 5, 4, 5). The three trials of each task performed on day 3 were designated as '24-hour retention' and the three trials of each task performed on day 4 were 'one-week retention.' For transfer tasks, the three trials performed of each transfer task on day 3 were termed '24-hour transfer' and the three trials of each transfer task performed on day 4 were 'one-week transfer.'

In the random order practice group on day 1, participants also performed nine trials of each task. Unlike the repetitive order used by the blocked practice group, the random practice group used a mixed up order such that the same task was never performed more than two times consecutively (e.g., 1 2 3 2 3 1 3 1 2 . . .). On day 2, random practice order participants were given the same instructions as the blocked order participants for completing the JOL task. Then they performed nine trials of each task in a random order. Days 3 and 4 were conducted in the same manner as the blocked order practice group. The research design was fully counterbalanced.

The validity of the JOL task was ensured through two means suggested by Widner and Smith (1996). First, participants were asked to make their predictions using a tool that was familiar to all university instrumentalists – namely, metronome speed. Second, participants were informed that they would be making these predictions before they started the second practice session. For the retention trials on days 3 and 4, participants within practice groups were divided into blocked and random retention orders. This was done to examine any encoding/retrieval effects that could be present (Tulving & Osler, 1968). For instance, musicians who practiced in a blocked order may perform better at retention when the presentation order is also blocked. While such effects were found in Shea and Morgan (1979), they were not present for beginning clarinet players (Stambaugh, 2011).

Analysis

The trials of interest were each participant's last three practice trials of each task on day 2 (acquisition), the three trials of each task at 24-hour retention and one-week retention, and the three trials of the two transfer tasks on day 3 (24-hour transfer) and day 4 (one-week transfer). The trials were prepared for scoring first by creating master audio files with all the trials of each task placed in a random order (for example, one master file was all the flute trials of task 1, randomly ordered). To score for accuracy, the researcher listened to each trial repeatedly and employed a point-deduction system used in previous research (Stambaugh, 2011; Stambaugh & Demorest, 2010). To score the speed of each trial, the trials were imported into Audacity version 1.2.6. The researcher highlighted the onset of the first pitch to the onset of the last pitch and documented the elapsed time to the hundredth of a second, automatically generated by Audacity. To determine evenness for each trial, the duration of each of the first six pitches was measured using the procedure just described. Then the average interonset interval (IOI) of the six intervals was determined (IOIm) and subtracted from the IOI of each individual interval (IOIx) in the trial. This produced six scores for the differences between individual IOIs and the mean within the trial. The sum of all difference scores (ΣIOIΔ) was divided by the sum of the IOIs for the trial (ΣIOI). The result of this equation was the average duration of each pitch within a trial, relative to the total duration of the trial.

Results

Pitch accuracy, speed and evenness scores were determined for day 2 acquisition trials, 24-hour retention, one-week retention, 24-hour transfer, and one-week transfer (1,794 trials). Preliminary analyses examined retention order: for example, within woodwinds who practiced in a blocked order, did it matter if they played their retention trials in a blocked or random order? These comparisons were made using independent samples Mann-Whitney *U* tests. Within woodwinds who had practiced in a blocked order, there were no significant differences between musicians who performed 24-hour retention tasks in either a blocked (n = 7) or random (n = 5) order for accuracy (U = 28.0, $p > .05$) or for speed (U = 6.0, $p > .05$). Within woodwinds who had practiced in a random order, there were also no significant differences between musicians who performed 24-hour retention tasks in either a blocked (n = 6) or random (n = 7) order for accuracy (U = 20.5, $p > .05$) or for speed (U = 15.5, $p > .05$).

Similar results were found for brass players. After practicing in the blocked order, brass musicians who performed 24-hour retention tasks in a blocked order (n = 6) or a random order (n = 5) demonstrated no significant differences in performance accuracy (U = 16.0, $p > .05$) or speed (U = 17.0, $p > .05$). Within brass players who had practiced in the random order, there were no significant differences between musicians who performed 24-hour retention tasks in a blocked order (n = 4) or a random order (n = 6) for accuracy (U = 8.0, $p > .05$) or speed (U = 9.0, $p > .05$). Because no significant differences were found by retention task order, subsequent analyses were conducted at the level of practice groups: blocked woodwinds, random woodwinds, blocked brass and random brass.

Blocked versus random practice

Two covariate scores were used to control for differences in individual playing abilities: the accuracy and speed scores of the first practice trial of each task. Other than the covariate scores, all analyzed scores represent a trial block which is the average of three trials (e.g., accuracy at acquisition score = mean of trials 16, 17, 18). Histograms indicated most performance blocks met the assumption of normality and Box's tests indicated the assumption of homogeneity of variance was tenable. Due to a linear relationship between the means and standard deviation in most evenness blocks, evenness scores were logarithmically transformed. Table 1 shows the adjusted mean and standard error for the trials of interest.

Three sets of repeated measures analysis of covariances (ANCOVAs) examined between-group and within practice-group changes from acquisition to 24-hour retention and one-week retention, and from 24-hour transfer to one-week transfer. One ANCOVA was run for each performance variable of speed, accuracy, and evenness. The a priori alpha level was set at .016 per comparison using a Bonferroni adjustment to control for Type I error. For woodwinds, no main effect for accuracy ($p = .365$) and no accuracy × practice group interaction ($p = .245$) was found (see Figure 2). However, a significant speed × practice group interaction was revealed, $F(4,80) = 4.448$, $p = .003$, $\eta^2 = .15$ (see Figure 3). Woodwinds who used random practice were able to play significantly faster than woodwinds who used blocked practice without compromising accuracy. In addition, woodwind players in the random practice group performed significantly more evenly than participants in the blocked practice group, $F(4,80) = 4.464$, $p = .003$, $\eta^2 = .16$. No significant differences ($p > .016$) were found for accuracy, speed, or evenness of transfer tasks.

For brass players, an ANCOVA indicated a significant accuracy × practice group interaction, $F(4,64) = 3.508$, $p = .012$, $\eta^2 = .15$ (see Figure 2). Participants who used blocked practice performed more accurately than participants who used random practice. Likewise, brass players who used blocked practice were able to play significantly faster than brass players who used random practice, $F(4,64) = 4.489$, $p = .003$, $\eta^2 = .18$ (see Figure 3). For temporal evenness by brass players, there was no main effect ($p = .198$) and no practice group × evenness

Table 1. Adjusted means and standard error for groups at acquisition, 24-hour retention, one-week retention, 24-hour transfer, and one-week transfer.

	Acquisition mean (SE)	24-hour retention mean (SE)	One-week retention mean (SE)	24-hour transfer mean (SE)	One-week transfer mean (SE)
Woodwinds					
Blocked					
Accuracy (0–7 points)	6.12 (.17)	5.69 (.23)	6.01 (.19)	5.79 (.19)	5.97 (.19)
Speed (in seconds)	1.50 (.12)	1.91 (.14)	1.85 (.13)	1.88 (.12)	1.76 (.13)
Evenness (in seconds)	.26 (.08)	.35 (.07)	.32 (.08)	.32 (.09)	.28 (.09)
Random					
Accuracy	6.27 (.16)	6.23 (.22)	6.03 (.17)	5.96 (.17)	5.86 (.17)
Speed	1.44 (.11)	1.47 (.13)*	1.51 (.12)	1.65 (.11)	1.76 (.12)
Evenness	.30 (.08)	.24 (.07)*	.27 (.07)	.29 (.08)	.33 (.08)
Brass					
Blocked					
Accuracy	5.33 (.29)	4.96 (.32)*	5.33 (.36)	4.17 (.31)	4.80 (.34)
Speed	1.55 (.22)	1.98 (.18)*	2.03 (.17)	2.27 (.19)	2.27 (.17)
Evenness	.09 (.02)	.32 (.11)	.12 (.02)	.14 (.03)	.16 (.03)
Random					
Accuracy	4.57 (.33)	4.26 (.36)	4.76 (.40)	4.76 (.35)	4.73 (.38)
Speed	2.35 (.25)	2.32 (.20)	2.05 (.19)	2.57 (.21)	2.28 (.19)
Evenness	.18 (.03)	.11 (.12)	.14 (.02)	.20 (.03)	.17 (.03)

Note: Covariates appearing in the model are evaluated at the following values: accuracy = 5.58, speed = 3.40; * = statistically significant finding ($p < .016$) between practice groups, within instrument family.

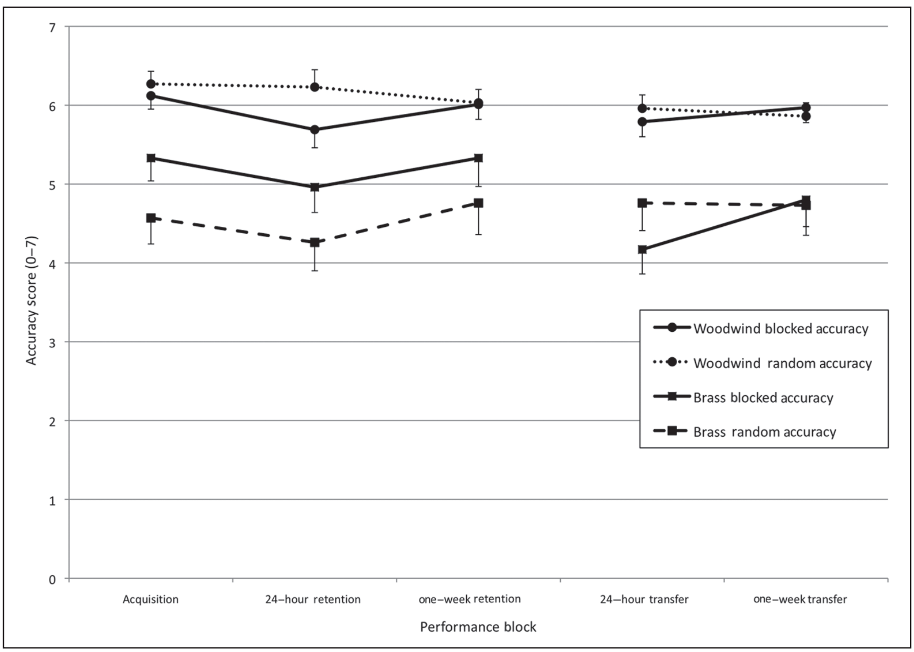

Figure 2. Adjusted means and standard error for accuracy.

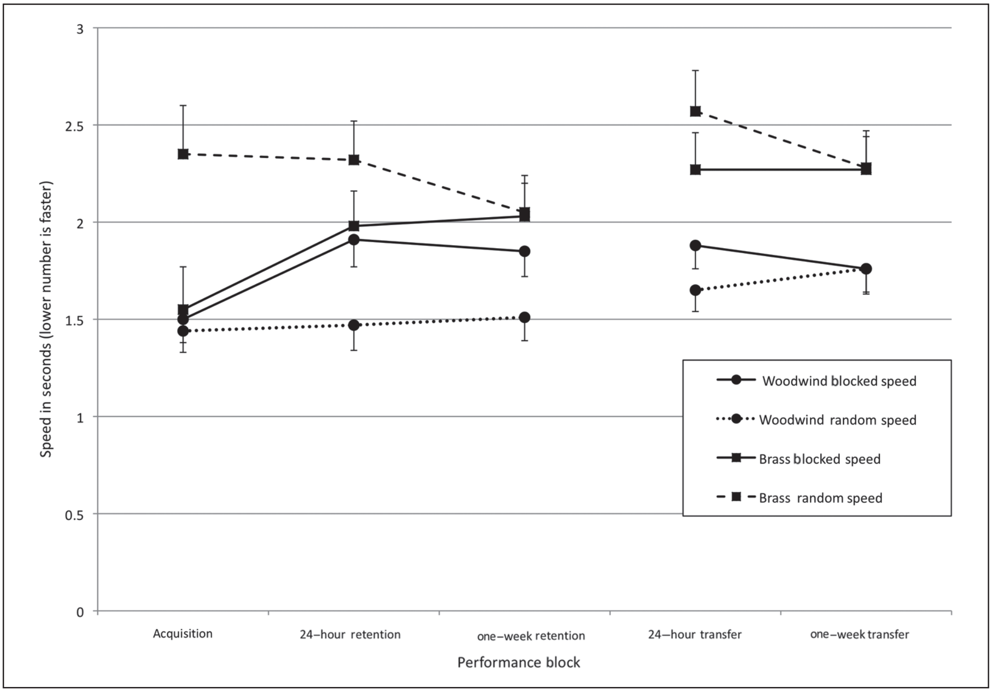

Figure 3. Adjusted means and standard error for speed.

interaction ($p = .190$). No significant differences ($p > .016$) were found for accuracy, speed, or evenness of transfer tasks.

Judgment of learning

At the end of day 2, musicians predicted performance tempos for all three practice tasks, resulting in three prediction scores per participant. Table 2 shows the means and standard deviations for musicians' predicted tempos and their actual performed tempos. Brass players in both practice groups consistently predicted speeds that were faster than what they played the following day (blocked practice group: 33 overestimates, 0 underestimates; random practice group: 28 overestimates, one underestimate, one exact prediction). Woodwind players showed less consistency in their predictions (blocked practice group: 14 overestimates, 18 underestimates; random practice group: 26 overestimates, 14 underestimates). The accuracy of JOL predictions was examined through Pearson correlations. Table 2 shows a significant positive correlation between predicted and performed tempos by brass players who used blocked practice ($r = .360$, $p = .040$). Woodwind players who used random practice demonstrated a significant negative correlation between predicted and performed tempos ($r = -.380$, $p = .017$).[1]

Discussion

Undergraduate woodwind and brass players practiced three short technical tasks in either a blocked order or a random order. The random practice order was more effective than the blocked practice order for woodwind players' speed and evenness. However, brass players demonstrated

Table 2. Mean beats per minute and standard deviations for predicted and performed tempo.

	Task 1		Task 2		Task 3		Correlation between predicted and performed tempo
	Predicted mean (*SD*)	Performed mean (*SD*)	Predicted mean (*SD*)	Performed mean (*SD*)	Predicted mean (*SD*)	Performed mean (*SD*)	
Woodwinds blocked	57.92 (12.77)	57.36 (25.66)	57.83 (14.31)	60.30 (24.65)	57.42 (13.23)	51.55 (24.57)	$r = .122$ ($p = .505$)
Woodwinds random	63.62 (14.03)	59.92 (20.87)	68.15 (17.14)	63.54 (22.13)	68.38 (18.54)	60.77 (16.52)	$r = –.380$* ($p = .017$)
Brass blocked	74.36 (14.05)	48.82 (5.93)	79.64 (15.55)	54 (9.33)	78.45 (13.34)	50.64 (10.06)	$r = .360$* ($p = .040$)
Brass random	65.40 (13.02)	40.20 (12.82)	69.70 (12.73)	45.70 (12.14)	69.60 (12.96)	41.90 (16.04)	$r = .001$ ($p= .996$)

Note: * = significant at the .05 level.

better accuracy and speed using a blocked practice order. Participants were also asked to judge their learning by predicting the metronome marking they would play each task at 24 hours after practicing. Brass players consistently predicted faster tempos than they played at 24-hour retention, and were able to better predict their learning after having practiced in the blocked order.

The methodology of comparing blocked and random practice orders builds on previous research in motor learning (e.g. Shea & Morgan, 1979; Simon & Bjork, 2001) and music (Rose, 2006; Stambaugh, 2011; Stambaugh & Demorest, 2010). The contextual interference effect predicts that random practice supports better learning than blocked practice. Previously this was found to be true for beginning clarinet players. The consistency of this finding from the 12-year-old beginning clarinet player to the 21-year-old university student is especially interesting, given the two groups' differences in cognitive development and in the amount of prior musical experience. It may be that the match between task difficulty and age/prior experience was similar enough between these age groups that the same practice strategy was beneficial. Further research could elucidate this possibility by employing tasks with different levels of complexity for each age group. In addition, a research design using beginning adult players could discriminate prior experience from age.

Results of this study revealed differentiated effects of cognitive load during practice for university woodwind and brass performers. For woodwinds, the added cognitive load of random practice enhanced performance at 24-hour retention. This may be explained by the contextual interference elaboration theory (Lin, 2007; Shea & Morgan, 1979; Shea & Zimny, 1983), which posits that the brain makes comparisons among the cognitive representations of the different practice tasks while they sit concurrently in working memory. From the perspective of cognitive load theory (Merrienboer et al., 2002; Paas, Gog, & Sweller, 2010; Sweller, 1988), random practice for woodwind players increased germane cognitive load, the cognitive load that enhances learning. However, this added load may have been too much for brass players, who performed better following the blocked practice regimen. It is possible brass instruments have a higher intrinsic cognitive load due to the need for musicians to 'hear' pitches internally when playing. Likewise, one could argue brass instruments have more embouchure demands because changing partials on a brass instrument is more dependent on embouchure than it is on a woodwind instrument.

Of course there are embouchure demands on woodwind players, but octave keys provide assistance for woodwind players. The combination of the more demanding random practice structure with higher intrinsic cognitive load may have led to the random practice condition to be less effective than the blocked practice condition for brass players. This result is consistent with Sweller's (1988) guideline that cognitive overload inhibits schema formation, and with Owen and Sweller (2008) who examined cognitive load theory in learning time signatures. They suggested the effects of cognitive load are additive, in that the increased demands on working memory diminish the learning process. Future research should include other instruments, including the violin family, piano, and mallet percussion, to further examine the impact of intrinsic cognitive load on music practice.

Figure 2 highlights other notable aspects of participants' learning. Both woodwind and brass students who used random practice demonstrated stable performance for speed from acquisition to 24-hour retention. Conversely, both woodwind and brass players who used blocked practice showed a loss in skill from acquisition to 24-hour retention. A similar result was found with beginning clarinet players using blocked practice (Stambaugh, 2011) and for adolescents learning dance steps (Bertollo, Berchicci, Carraro, Comani, & Robazza, 2010). This presents a dilemma for brass students: they exhibited minimal change in speed from acquisition to 24-hour retention using random practice, but their speed was so much faster using blocked practice that, despite the performance loss from acquisition to 24-hour retention, blocked practice still resulted in faster speed. Another interesting finding was that performance at 24-hour retention and 24-hour transfer (tasks 4 and 5) was often considerably reduced at one-week retention and one-week transfer. A possible explanation for these within-group changes is that the two-day practice design was too brief to enable long-term learning to take place.

The secondary research questions asked if university wind students could accurately assess their learning through a JOL statement and if these assessments would be impacted by practice condition. The standard deviation scores in Table 2 show musicians' predicted tempos were often quite wrong when compared to their retention performance. There are several possible reasons for this, including how frequently students use a metronome in their regular practice, or possibly a relationship with how well an individual mastered the tasks (mean woodwind performance scores were higher and faster than mean brass scores). Also, as Simmons and Duke (2006) suggested in a study of sleep-based consolidation in keyboard playing, some participants may have had an ideal tempo in mind for performing these tasks that was not related to their actual ability to perform them. Practice condition did affect woodwind and brass players' JOL, as demonstrated by the array of correlation scores. Brass students were more accurate with their tempo predictions when they had practiced in the order that was most effective for them (blocked).

Limitations

The preliminary analyses examined the effects of retention task order on performance. The number of participants in each retention group was small, however, and future research should include larger samples. A second limitation of the present study is the unequal number of males and females playing woodwind and brass instruments. While this inequity was representative of the gender make-up of the instrumentalists at the sample institutions, it is possible gender could interact with JOL. Continued research in music JOLs should endeavor to balance gender within instrument groups.

This article began by asking if practice can be viewed as 'one size fits all.' Results of this study suggest the answer is 'no.' When learning brief technical passages, practicing in a repetitive manner was beneficial for university valved-brass players, but practicing under a higher cognitive load with a random order supported superior learning in woodwind players. The question was also raised regarding how musicians know when they have learned a task well enough to stop practicing it. This study is one of few investigations to examine this construct in a musical context. If we are to assume that self-regulated practice is predicated on the constant assessment of one's own learning, then it is imperative for future research to examine the ability of students to judge their own learning.

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Note

1. Partial correlations were also examined, controlling for gender. These results are not reported because of the extreme gender imbalance in the woodwind groups.

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