1-1-2010

Effects of Practice Schedule on Wind Instrument Performance: A Preliminary Application of a Motor Learning Principle

Laura A. Stambaugh

Steven M. Demorest

Citation

Stambaugh, L. A. & Demorest, S. M. (2010). Effects of practice schedule on wind instrument performance: A preliminary application of a motor learning principle. Update: Applications of Research in Music Education, 28, 20-28.

MENC The National Association for MUSIC EDUCATION

Update
28(2) 20–28

DOI: 10.1177/8755123310361768
http://update.sagepub.com

Effects of Practice Schedule on Wind Instrument Performance: A Preliminary Application of a Motor Learning Principle

Laura A. Stambaugh[1] and Steven M. Demorest[2]

Abstract

The effects of three practice schedules on beginning instrumental achievement were explored. A total of 19 seventh-grade clarinet and saxophone students completed one 18-minute practice session using either a blocked schedule causing a low level of cognitive (contextual) interference, a hybrid schedule causing a moderate level of interference, or a serial schedule causing a high level of interference. No main effects were found at immediate acquisition testing or 24-hr delayed retention testing for technical accuracy, attitude toward practice, or musicality. A significant practice Condition × Trial interaction was found for musicality. The discussion examines the discrepancy between technical and musical achievement. Recommendations are given for future research applying motor learning principles to instrumental music contexts.

Keywords

practice, practice schedule, instrumental, beginner, music

> Let's see. I played my G major scale three times in a row, then A major three times and A major thirds two times. I did the two songs in my book three times each. Then I played all the way through my concert songs two times each. I even played that one bad measure slowly a couple of times and then went faster until I could play it right, three times in a row, just like Mr. Benson said to! I am so ready for band tomorrow.

Many an instrumental teacher would be pleased to have this student enrolled in their ensemble. This young student exhibited some use of self-regulated practice strategies (Miksza, 2007; Sloboda, Davidson, Howe, & Moore, 1996), such as the goal of preparing for rehearsal the next day. In addition, the student used repetition—a hallmark of the diligent practice session. It would be interesting to observe, however, if the student could in fact perform that problem measure correctly at rehearsal the following day. Although both students and teachers advocate the use of repetition in practice (Barry, 2007), evidence from the field of motor learning suggests repetition in practice may not be the most effective and efficient practice schedule (Shea & Morgan, 1979).

Motor learning research, the scientific study of how people acquire and refine movement, has investigated the effect of different practice conditions on motor skill development in basic and applied settings for more than a century. The execution of instrumental performance is largely a motor skill, as there could be no artistic performance without the motor aspects of performing. Therefore, aspects of motor learning research could inform instrumental music practice. In particular, many motor learning studies have examined how practice schedules used by novices affect skill acquisition and retention. The purpose of this study was to examine the effect of different practice schedules on the achievement of middle school clarinet and saxophone students.

Practice Schedule Research

When there is more than one task to practice, as there usually is in a wind student's practice assignment, there are three possible options for ordering the tasks: *blocked* practice (completing all practice on one task before moving to the next), *random* practice (practicing each task

[1]Western Washington University
[2]University of Washington

Corresponding Author:
Laura A. Stambaugh, Western Washington University, Music Department, 516 High Street, Bellingham, WA 98225
Email: Laura.Stambaugh@wwu.edu

an equal number of times in a constantly switching order), and *serial* practice (using a defined order whereby no successive trials are of the same task) (Schmidt & Lee, 2005). Participants in laboratory tasks using blocked practice schedules demonstrated superior performance immediately following practice (acquisition) compared to participants using random or serial practice schedules. However, when tested the next day or later (retention), participants who used random or serial practice schedules demonstrated superior performance to those in the blocked practice schedule (e.g., Lee & Magill, 1983; Shea & Morgan, 1979). An exception to this result has been found, with no significant effect of practice schedule used by older women (age $M = 65$) performing a timing task (del Rey, Wughalter, DuBois, & Carnes, 1982). It is possible cognitive function at this age moderated the effects of blocked and random practice for motor tasks.

This paradox of random practice impairing performance at acquisition but improving performance at retention has been termed the *contextual interference hypothesis* (Battig, 1978; Shea & Morgan, 1979). *Contextual interference* refers to the cognitive disruption, or interference, present during a practice session. Most often, contextual interference is operationally defined as the frequency with which a new task is undertaken in a practice session. For example, consider the first three tasks practiced by the band student presented in the introduction: G major scale, A major scale, and A major thirds. If the student were to practice using a low level of contextual interference, she would play all trials of the G scale, then all trials of the A scale, then all trials of the A thirds. This is termed *blocked practice* because each task is practiced in a block. At the other end of the continuum is a high level of contextual interference, most commonly defined as serial (G scale played one time, A scale played one time, A thirds played one time, and keep repeating that sequence) or random (G scale, A thirds, A scale, A thirds, G scale, etc.).

Application of the contextual interference hypothesis to educational and coaching settings introduced additional variables. These included participants' prior experience with the task or a similar task, the use of complex tasks such as sports skills, variety in the number of tasks involved, extended periods of practice, and moderate levels of contextual interference (for complete reviews and meta-analyses, see Brady, 2004, 2008). Few of these studies have included children as participants, and given the numerous variables studied, it is difficult to draw conclusions about the reliability of the contextual interference hypothesis in applied settings (Brady, 2004, 2008). However, the following trends may be noted: More complex tasks may benefit from higher levels of contextual interference than less complex tasks (Bortoli, Robazza, Durigon, & Carra, 1992; Keller, Li, Weiss, & Relyea, 2006; Ollis, Button, & Fairweather, 2005); even when group performances are similar at acquisition, groups who practiced with high levels of contextual interference may show superior performance at retention or transfer (Landin & Hebert, 1997; Pigott & Shapiro, 1984; Pollock & Lee, 1997); and some motor skills, including basketball shooting and throwing beanbags at a target, benefit more from moderate levels of contextual interference than high levels (Landin & Hebert, 1997; Pigott & Shapiro, 1984).

Music Practice Research

Although motor learning research examines skill acquisition, or practice, through experimental methods, research investigating musical practice has employed both descriptive and experimental methods. Experimental investigations of instrumental music practice have examined the effectiveness of a variety of practice strategies, finding that structured and deliberate practice were more effective than free or informal practice (Barry, 1992; Ericsson, Krampe, & Tesch-Romer, 1993), the use of models improved performance at all levels (Hewitt, 2001; Linklater, 1997), comparisons of whole and part practice were dependent on the nature of the task and level of the learner (Chang, 2000; Overman, 2002), and physical practice was more effective than mental practice and no practice, but physical practice alternating with mental practice was as effective as physical practice alone (Coffman, 1990; Rosenthal, Wilson, Evans, & Greenwalt, 1988; Ross, 1985; Rubin-Rabson, 1941).

Regarding the length and distribution of practice sessions, Jorgensen (1997a) noted, "There is almost a complete lack of research in this area and [into] the complexity of this issue" (p. 95). Existing research has found less accomplished musicians benefit from distributed practice, or distributing practice on a specific task over several practice sessions (Jorgensen, 1997b; Rubin-Rabson, 1940). This finding is reflected in beginning band method books, which usually encourage students to distribute their practice over several days during a week rather than practicing for one long session in a single day (Lautzenheiser et al., 1999; Pearson, 2005). However, professionals are more likely to use massed practice, or completing the majority of practice on a specific task in one session (Hallam, 1997). Very little research has examined the specific internal structure of music practice sessions.

Music researchers have also been interested in attitudes toward practice, including what motivates a musician to practice and if practice is satisfying. At the middle school level, motivation to practice is affected by enrollment in private lessons (Hamann & Frost, 2000), use of self-regulatory strategies (Miksza, 2007), and practice frequency and duration (Austin & Berg, 2006). Hewitt (2001) examined practice attitude "to determine whether students in a particular treatment group possessed different levels of enjoyment and satisfaction with the treatment process" (p. 312). The attitude questionnaire used in the present study was designed to address similar concerns.

Application of Motor Learning Principles to Music Contexts

Sidnell (1981) charged music educators to consider the many ways music skills involve motor learning. Initially, music researchers applied constructs from Schmidt's (1975) schema theory. Variable practice and knowledge of results yielded inconsistent results for improving vocal pitch matching (Harvey, Garwood, & Palencia, 1987; Welch, 1985) but did improve university instrumental performance (Owen, 1988) and beginning string performance (Pacey, 1993). More recently, researchers have begun to examine other motor learning principles in music settings. Consistent with findings in motor learning research, Duke, Davis, Allen, and Goins (2006) found an external focus of attention on sound was more effective than an internal focus of attention during a keyboard task. Henninger (2007) found intermittent feedback was more effective than constant feedback during instrumental lessons. Investigations into consolidation have supported the inclusion of a sleep interval between practice sessions of simple keyboard sequences (Davis, 2007; Duke & Davis, 2006; Simmons & Duke, 2006). Rose (2006) conducted the first investigation of the contextual interference hypothesis in a musical context. University music majors who were novice percussionists were randomly assigned to one practice session in a blocked, varied, or free (control group) schedule. Retention delays were between 30 min and 24 hr. No significant differences were found for group assignment or retention delay, although a significant effect was found for primary performance area, with instrumentalists performing significantly more accurately than vocalists.

Collectively, this research in music practice from a motor learning perspective shows both consistencies and inconsistencies between the fields. The present investigation seeks to add to this emerging field by applying the motor learning principle of contextual interference to the real-world skill of wind instrument performance. The study explored an area that has received almost no empirical attention by music researchers: the order of tasks practiced within one practice session. The purpose of this study was to examine the effects of practice schedules causing low, moderate, and high levels of contextual interference on seventh-grade clarinet and saxophone players' acquisition and retention of instrumental skills. Clarinet and saxophone were selected as the instruments to limit the number of variables involved in pitch accuracy: Pitch production on these instruments is more singularly a function of finger placement on the keys than pitch production on flute and brass instruments.

The research questions were the following:

1. What effect will practice using low, moderate, and high levels of contextual interference have on students' technical accuracy immediately following one practice session (acquisition) and after 24 hr (retention)?
2. What effect will practice using low, moderate, and high levels of contextual interference have on students' musicality immediately following one practice session and after 24 hr?
3. Will there be a significant difference in attitude scores among groups?

Method

The independent variable was level of contextual interference during practice, operationalized as practice groups of low (blocked), moderate (hybrid), and high (serial). Participants in the blocked condition completed all 6 min of practice on one song before starting to practice the next song. In the hybrid condition, students switched songs every 2 min, until each song was practiced 6 min. Students in the serial condition switched songs every 1 min, until all songs were practiced a total of 6 min.

Participants ($N = 19$) were seventh grade clarinet ($n = 12$) and saxophone ($n = 7$) students who volunteered to participate from two urban middle schools, which were selected as a convenience sample. Students (female $n = 7$, males $n = 12$) had begun playing their instruments in the school band program in either Grade 4, 5, or 6. Of the students, 8 had no private lesson experience, whereas the remaining 11 averaged 1.5 years of private lessons.

All study procedures were approved by university and school district human participants committees. Each student's legal guardian signed an informed consent form, and all students signed an assent form. Participants were rank ordered by their band teachers, within instrument (clarinet student 1, 2, 3, etc.; saxophone student 1, 2, 3, etc.). The researchers distributed students among the three practice conditions by rank (top 3 then next 3), so that each condition contained students of varying ranks (blocked $n = 6$, hybrid $n = 7$, serial $n = 6$). Preliminary examination of the final data set revealed that one female participant's scores in the hybrid group were too low for inclusion in the study (more than 3 standard deviations below the group mean).

Figure 1. Musical examples

Materials

Three songs were modified from existing method books not currently in use by the participating schools to conform to the following requirements: an equal number of measures (8) and pitches (50), one quarter rest, rhythmic values of eighth and quarter notes, and two songs staying within the clarinet chalumeau range (see Figure 1). To account for differences between students' ability levels, the songs were designed to represent three different difficulty levels by nature of the intervals, chromatics, dynamic markings, accent marks, slurs, and tempo. A second expert instrumental teacher confirmed the variety in degree of difficulty among the songs. Musicality was operationally defined as performance of articulation and dynamics. Of course, musicality is much more complex than mere dynamics and articulation. Our primary concern was to select criteria that were as objective as possible for these 8-measure examples performed by young instrumentalists.

Procedure

A pilot test was conducted with two students from another area middle school. The purpose of the pilot test was to evaluate the difficulty of the experimental songs as well as the feasibility of the experimental procedure and questionnaire. Because both students made errors during these practice trials, we deemed the songs to be appropriate test materials. Postpilot conversations with the students revealed the students could follow the experimental procedures and understood the questionnaire.

A model performance of each song was recorded using a Samson Q1U microphone. Six procedure CDs were compiled, one for each instrument at each independent variable level. The CDs began with the model recording of each song the first time it was to be practiced, directions to "practice as you usually would," and then verbal cues directing how long to practice each piece. A verbal warning was given when two thirds of the practice time had elapsed during each interval. Students in all groups practiced all three songs for 6 min each. The difference between groups was the frequency with which each song changed: blocked group after 6 min, hybrid group every 2 min, and serial group every 1 min.

The CDs were presented to students during individual practice and testing sessions with a researcher present, in a practice room or empty rehearsal room. The researcher placed the sheet music on the student's music stand to ensure the correct amount of time was spent practicing each song. The entire practice and testing sessions were recorded using a Tascam DAT 1 recorder with an Audio-Technica AT825 stereo microphone and Maxwell HS-4/90 data cartridges, using 16 bit 44.1 kHz sampling rate.

At the conclusion of the practice time on Day 1, two acquisition trials were recorded. The same directions were given on Day 1 for acquisition trials and Day 2 for retention trials: "Play the song all the way through without stopping, as best as you can." Students heard a four-beat count off in the tempo assigned to the song and played the song. On Day 2, students were given as much warm-up time as they desired before playing the two retention trials.

Participants completed the same practice questionnaire on Day 1 after acquisition and Day 2 after retention trials. Items for the practice questionnaire included background information and attitude statements modified from Baddeley and Longman (1978), Hamann and Frost (2000), and Hewitt (2001). Modifications to the statements included rewording to align statements with the practice schedules used in this study. Participants responded using a 4-point Likert-type scale to indicate if they believed their practice improved their performance, if it was satisfying, and if they would use their schedule in future practice. Cronbach's alpha was .748, which was considered acceptable for this investigation.

Analysis

Although two trials were recorded for both acquisition testing and retention, only the second trials were analyzed. The first trial for each song was considered practice of the testing procedure, and several of these trials were used as training for the expert judge. The acquisition and retention trials were selected from the session recordings and transferred from digital tape to a computer hard drive. A master scoring CD was burned with all trials of Song 1 in random order, then all trials of Song 2, and then Song 3.

Performance accuracy was determined by the following method, based on Demorest and May (1995): 1 point deduction for each incorrectly played pitch; 1 point deduction for each incorrectly played rhythm; 1 point deduction for each repeated, skipped, or added pitch; 2 point deduction for each episode of starting over or stopping (with mistakes prior to starting over not included); and 1 point deduction for each tempo change. The total possible score was 100 points (50 pitches + 50 rhythms – 0 deductions). Technical accuracy scores were summed across the three songs for acquisition and retention scores. Musicality was judged on a rating scale of 1 (*lowest, dynamics and articulation not heard*) to 10 (*highest, dynamics and articulations clearly heard*). Musicality scores for individual songs were summed to determine musicality acquisition and retention scores. An experienced music educator, blind to condition, listened to each trial on the master CD as many times as necessary to determine the performance accuracy and musicality scores. Of the 114 trials, 20% were evaluated by one researcher to determine reliability, which was acceptable for both measures (technical accuracy $r = .98$, musicality $r = .85$). Scores from the individual items on the practice questionnaire were summed to determine the practice attitude score at acquisition and retention.

Given the small sample size, groups were not normally distributed. However, the parametric test of repeated measures ANOVA was selected for analysis because a suitable nonparametric test was not available and repeated measures ANOVAs are commonly used in motor learning research. Although this choice may limit the generalizability of results, it was decided to proceed with the parametric analysis because of the exploratory nature of the study.

Results

To answer the first research question exploring the impact of differing levels of contextual interference at acquisition and retention, students' technical accuracy scores were compared across the three practice conditions in a repeated measures ANOVA. The dependent variable of technical accuracy was represented by students' combined score for the three test melodies. Table 1 gives the means and standard deviations by group for both test sessions. There were no significant main effects for practice condition at acquisition, $F(2, 15) = 1.34$, $p > .05$, or retention, $F(2, 15) = 0.31$, $p > .05$, no significant effect of trial (acquisition to retention), $F(1, 15) = 0.150$, $p > .05$, and no significant interaction between trial and practice condition,

Table 1. Technical Accuracy, Musicality, and Attitude Scores and Standard Deviations by Condition

	Accuracy				Musicality					
	Acquisition		Retention		Acquisition		Retention		Attitude	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Blocked	284.67	11.61	288.00	4.53	12.00	3.69	15.40	2.07	3.25	0.31
Hybrid	291.33	6.83	289.17	8.61	16.00	4.56	14.33	2.80	3.11	0.39
Serial	282.17	10.98	282.20	16.90	14.50	4.51	16.20	6.26	3.08	0.38
Grand mean	286.06	10.23	286.63	10.78	14.17	4.36	15.25	3.86	3.14	0.35

$F(2, 15) = 0.413$, $p > .05$. The average technical accuracy score for all participants summed across all three melodies was 286 out of a possible 300, or the 95th percentile.

The second research question considered students' musicality scores, which were represented as a summed score for the three melodies. Unlike accuracy, musicality scores averaged only 14.78 out of a possible 30, or the 49th percentile. A repeated measures ANOVA was employed to analyze Musicality × Condition across both trials. There were no significant main effects by condition at acquisition, $F(2, 15) = 1.34$, $p > .05$, or retention, $F(2, 15) = 0.568$, $p > .05$, and no significant effect of trial (acquisition to retention), $F(1, 15) = 3.333$, $p > .05$. However, the average musicality scores increased by more than a point overall from acquisition to retention. A significant interaction occurred between practice condition and trial, Wilks's $\Lambda = .61$, $F(2, 15) = 4.84$, $p < .05$, $\eta^2 = .35$. As Figure 2 indicates, the hybrid condition showed a decline from acquisition to retention of almost two points, whereas the blocked and serial conditions had increases of more than two points.

The third research question concerned differences in student attitude among the three practice conditions. A one-way ANOVA on the attitude scores revealed no significant differences. The average responses ranged from 3.08 to 3.25 on a 4-point scale, indicating that students had an overall positive response to practice in all three practice conditions.

Discussion

The three practice schedules designed for this study were based on the contextual interference hypothesis, which predicts random and serial practice schedules are superior to block schedules for retaining newly acquired motor skills. In applying this principle to instrumental music practice, we found no significant differences in seventh grade students' technical accuracy or musicality scores based on the practice schedule used. These findings were similar to those reported in several applied studies, including volleyball skills by ninth graders (French, Rink, & Werner, 1990) and snare drum sticking by university students (Rose, 2006). A significant interaction was found for the musicality score between trial (acquisition to retention) and practice condition. Unlike laboratory findings, the differences were not between low and high contextual interference conditions but between the moderate condition and the two extremes. There were no differences in student attitude by practice schedule, and all students felt generally positive about their schedule

The application of motor learning principles to wind students' practice required compromises to merge the requirements of traditional motor learning paradigms with the practical issues of instrumental music education. An examination of these compromises can help contextualize the importance of these results and suggest directions for future research. For this study, we selected melodies that were eight measures in length for the motor learning task because that is a common length of songs in method books. Although each melody contained 50 pitches, typical motor learning tasks contain fewer than six elements. Perhaps the length of our melodies provided a high level of contextual interference simply by being played from beginning to end. This explanation would account for the lack of technical differences between schedules.

Another compromise concerned participants' prior experience. Most laboratory studies insist that the experimental task be entirely new to the participants, but our participants did have familiarity with the task of practicing and playing an instrument. Although removing prior experience may be admirable for experimental control, it is often impractical in real-world applications. Indeed, some authors have noted general or specific task-related experience may interact with the research task (Guadagnoli, Holcomb, & Weber, 1999).

A further intricacy of this type of research is identifying tasks that are challenging enough to provide variability while still maintaining a skill-appropriate level of difficulty. Despite pilot testing for technical difficulty, the three test melodies were relatively easy for the participants to perform with technical accuracy. The relative ease of the melodies may not have provided sufficient

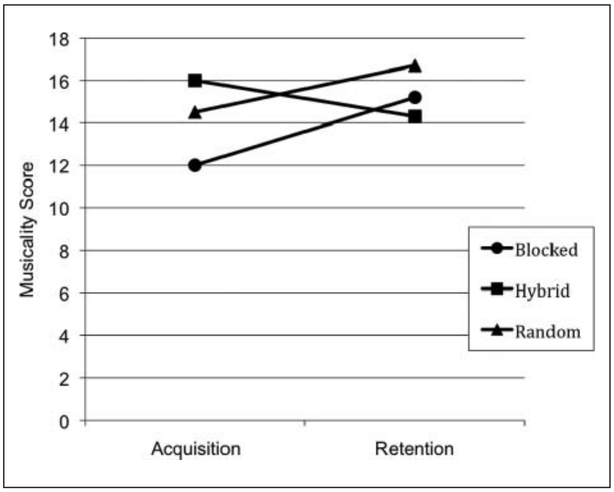

Figure 2. Musicality scores from acquisition to retention by practice condition

variability to distinguish among the practice conditions. This interpretation is bolstered by the presence of a significant interaction for the apparently more difficult task of playing these excerpts musically. The interaction between practice condition and trial for musicality scores is interesting but difficult to interpret. It would appear the hybrid condition, rather than representing the best of both extremes, somehow represented the worst at retention.

Finally, although the three melodies represented different levels of technical challenge, they engaged essentially the same skill set. Perhaps the benefit of high contextual interference schedule is more relevant when moving between discrete skills. This approach has yielded results consistent with the contextual interference hypothesis when learning different badminton serves (Goode & Magill, 1986) and hitting different baseball pitches (Hall, Domingues, & Cavazos, 1994). It would be interesting to explore if the use of different instrumental skills might be developed through various schedules, possibly increasing the contextual interference effect.

Recommendations

For Music Teaching

What about our student described at the outset of this study? Should she change her practice routine? Generalizations from these data to the practice room should be made extremely cautiously. This is a preliminary investigation designed to explore applications of motor learning theory to music education practice, and the small sample size affected normality. If the results of this study are accurate, students might utilize a variety of practice schedules with equal benefits. The serial condition, which had students skipping from one excerpt to another, is very different from typical recommendations for music practice strategies yet showed no learning disadvantage at retention. Also, attitude scores were generally high and tightly grouped. Perhaps students found this approach is not as different from their usual practice as we, their teachers, would like to believe.

The results of this study suggest that students may need more guidance in practicing aspects of musicality such as articulation and dynamics. Although most participants had very high technical accuracy scores (95th percentile), their musicality ratings were relatively low (49th percentile), despite hearing a model performance. Consistent with previous research (Hallam, 2001), our observations suggest that even when students have mastered the technical challenges of a melody, they do not necessarily turn their attention to musical issues.

The results of this study suggest practical applications of motor learning principles should be carefully tested before teachers consider altering instructional approaches. It should be noted that although the blocked condition was assumed to be most similar to a "traditional" approach to practice, there was no control condition in which students were asked to simply practice the three melodies as they normally would. Thus, all three conditions represented some form of "structured" practice (Barry, 1992; Ericsson et al., 1993), so we do not know if the scores students achieved here were better or worse than they might have achieved with their own spontaneous approach.

For Future Research

Results of this study provide guidance for future studies applying motor learning principles to music contexts. Although the time frame for the study may seem short for studying instrumental practice, it was consistent with the majority of laboratory motor learning research. It would be interesting, nonetheless, to explore the impact of different practice schedules over a longer time period. The sample size for each of the three groups was relatively small, which is also common in laboratory motor learning studies. However, given motor studies often measure highly stylized tasks with performance differences recorded in milliseconds, future practical studies like this one might benefit from larger samples to offset task complexity and variability in scoring and performance. Although all groups contained participants of varying ability levels, future research might use a screening test to ensure a sample with more homogenous skill level and prior experience.

Finally, practice blocks can be operationalized either as periods of time, as we did here, or as a certain number of attempts or trials, which is more common in motor learning research. Although the trial approach is further removed from how we currently conceive of musical practice, it does standardize the number of attempts students have to develop a particular motor skill. Students in the serial and hybrid conditions were given shorter blocks of practice time spread over the session, but the number of trials within that time may have been sufficient to produce a miniblock effect, negating the contextual interference effect. A trial approach may be useful in future studies to more carefully control the number of attempts at a particular skill and eliminate the possibility of a miniblock effect.

Future research should explore the application of these and other motor learning models under a variety of conditions including a longer learning cycle, a true random practice condition, and the acquisition of specific skills rather than simply accuracy of performance. Combining the findings of applied research with more controlled laboratory research approaches (Davis, 2007; Duke et al., 2006; Simmons & Duke, 2006) will allow music educators to begin to understand the utility of motor learning principles for our field.

The skills involved in playing a musical instrument are a complex and unique combination of motor and cognitive skill development in the service of an expressive artistic goal. Despite this uniqueness, our approach to teaching instrumental skills could benefit from exploring the application of research findings in related domains such as motor learning that may lead to more efficient and effective practice and more rapid development of skills. Although motor learning principles have a wealth of empirical study to support them, the ultimate test of these principles is their successful application to real-world learning settings.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interests with respect to the authorship and/or publication of this article.

Financial Disclosure/Funding

The authors received no financial support for the research and/or authorship of this article.

References

Austin, J. R., & Berg, M. H. (2006). Exploring music practice among sixth grade band and orchestra students. *Psychology of Music, 34*, 535-558.

Baddeley, A. D., & Longman, D. J. A. (1978). The influence of length and frequency of training session on the rate of learning to type. *Ergonomics, 21*, 627-635.

Barry, N. H. (1992). The effects of practice strategies, individual differences in cognitive style, and gender upon technical accuracy and musicality of student instrumental performance. *Psychology of Music, 20*, 112-123.

Barry, N. H. (2007). A qualitative study of applied music lessons and subsequent student practice sessions. *Contributions to Music Education*, *34*(1), 51-65.

Battig, W. F. (1978). The flexibility of human memory. In L. S. Cermak & F. I. M. Craik (Eds.), *Levels of processing in human memory* (pp. 23-44). Hillsdale, NJ: Lawrence Erlbaum.

Bortoli, L., Robazza, C., Durigon, V., & Carra, C. (1992). Effects of contextual interference on learning technical sports skills. *Perceptual and Motor Skills, 75*, 555-562.

Brady, F. (2004). Contextual interference: A meta-analytic study. *Perceptual and Motor Skills, 99*, 116-126.

Brady, F. (2008). The contextual interference effect and sport skills. *Perceptual and Motor Skills, 106*, 461-472.

Chang, Y. S. (2000). *A comparison of four practice procedures for learning polyphonic piano music* (Doctoral dissertation, University of Texas at Austin, 2000). *Dissertation Abstracts International, 60*, 3300.

Coffman, D. D. (1990). Effects of mental practice, physical practice, and knowledge of results on piano performance. *Journal of Research in Music Education, 38*, 187-196.

Davis, C. M. (2007, February). *Placement of a 5-min rest interval affects acquisition and retention of a keyboard sequence*. Poster session presented at the Texas Music Educators Association, San Antonio, TX.

del Rey, P., Wughalter, E., DuBois, D., & Carnes, M. M. (1982). Effects of contextual interference and retention intervals on transfer. *Perceptual and Motor Skills, 54*, 467-476.

Demorest, S. M., & May, W. V. (1995). Sight-singing instruction in the choral ensemble: Factors related to individual performance. *Journal of Research in Music Education, 43*, 156-167.

Duke, R. A., & Davis, C. M. (2006). Procedural memory consolidation in the performance of brief keyboard sequences. *Journal of Research in Music Education, 54*, 111-123.

Duke, R. A., Davis, C. M., Allen, S. E., & Goins, K. R. (2006, April). *Focus of attention affects performance of motor skills in music.* Poster session presented at the MENC National Biennial In-Service Conference, Salt Lake City, UT.

Ericsson, K., Krampe, R. T., & Tesch-Romer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100*, 363-406.

French, K. E., Rink, J. E., & Werner, P. H. (1990). Effects of contextual interference on retention of three volleyball skills. *Perceptual and Motor Skills, 71*, 179-186.

Goode, S., & Magill, R. A. (1986). Contextual interference effects in learning three badminton serves. *Research Quarterly for Exercise and Sport, 57*, 308-314.

Guadagnoli, M. A., Holcomb, W. R., & Weber, T. J. (1999). The relationship between contextual interference effects and performer expertise on the learning of a putting task. *Journal of Human Movement Studies, 37*, 19-36.

Hall, K. G., Domingues, D. A., & Cavazos, R. (1994). Contextual interference effects with skilled baseball players. *Perceptual and Motor Skills, 78*, 835-841.

Hallam, S. (1997). Approaches to instrumental music practice of experts and novices: Implications for education. In H. Jorgensen & A. C. Lehman (Eds.), *Does practice make perfect? Current theory and research on instrumental music practice* (pp. 89-107). Oslo, Norway: NMH.

Hallam, S. (2001). The development of expertise in young musicians: Strategy use, knowledge acquisition and individual diversity. *Music Education Research, 3*(1), 7-23.

Hamann, D. L., & Frost, R. S. (2000). The effect of private lesson study on the practice habits and attitudes towards practicing of middle school and high school string students. *Contributions to Music Education, 27*(2), 71-93.

Harvey, N., Garwood, J., & Palencia, M. (1987). Vocal matching of pitch intervals: Learning and transfer effects. *Psychology of Music, 15*, 90-106.

Henninger, J. C. (2007, February). *The effects of constant and intermittent verbal feedback on complex skill development*. Poster session presented at the Texas Music Educators Association, San Antonio, TX.

Hewitt, M. P. (2001). The effects of modeling, self-evaluation, and self-listening on junior high instrumentalists' music performance and practice attitude. *Journal of Research in Music Education, 49*, 307-322.

Jorgensen, H. (1997a). Strategies for individual practice. In H. Jorgensen & A. C. Lehmann (Eds.), *Does practice make perfect? Current theory and research on instrumental music practice* (pp. 85-103). Oslo, Norway: NMH.

Jorgensen, H. (1997b). Time for practising? Higher level music students' use of time for instrumental practising. In H. Jorgensen & A. C. Lehmann (Eds.), *Does practice make perfect? Current theory and research on instrumental music practice* (pp. 123-139). Oslo, Norway: NMH.

Keller, G. J., Li, Y., Weiss, L. W., & Relyea, G. E. (2006). Contextual interference effect on acquisition and retention of pistol-shooting skills. *Perceptual and Motor Skills, 103*, 241-252.

Landin, D., & Hebert, E. P. (1997). A comparison of three practice schedules along the contextual interference continuum. *Research Quarterly for Exercise and Sport, 68*, 357-361.

Lautzenheiser, T., Higgins, J., Menghini, C., Lavender, P., Rhodes, T. C., & Bierschenk, D. (1999). *Essential elements 2000*. Milwaukee, WI: Hal Leonard.

Lee, T. D., & Magill, R. A. (1983). The locus of contextual interference in motor-skill acquisition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 9*, 730-746.

Linklater, F. (1997). Effects of audio- and videotape models on performance achievement of beginning clarinetists. *Journal of Research in Music Education, 45*, 402-414.

Miksza, P. (2007). Effective practice: An investigation of observed practice behaviors, self-reported practice habits, and the performance achievement of high school wind players. *Journal of Research in Music Education, 55*, 359-375.

Ollis, S., Button, C., & Fairweather, M. (2005). The influence of professional expertise and task complexity upon the potency of the contextual interference effect. *Acta Psychologica, 118*, 229-244.

Overman, M. M. (2002). *Four-part marimba pedagogy: A part-practice approach* (Doctoral dissertation, Northwestern University, 2002). *Dissertation Abstracts International, 66*, 23.

Owen, J. E. (1988). *Improving instrumental practice techniques through use of a motor schema theory of learning* (Doctoral dissertation, Ohio State University, 1988). *Dissertation Abstracts International, 49*, 2575.

Pacey, F. (1993). Schema theory and the effect of variable practice in string teaching. *British Journal of Music Education, 10*, 91-102.

Pearson, B. (2005). *Standard of excellence* (Clarinet vol.). San Diego, CA: Neil A. Kjos.

Pigott, R. E., & Shapiro, D. C. (1984). Motor schema: The structure of the variability session. *Research Quarterly for Exercise and Sport, 55*, 41-45.

Pollock, B. J., & Lee, T. D. (1997). Dissociated contextual interference effects in children and adults. *Perceptual and Motor Skills, 84*, 851-858.

Rose, L. P. (2006). *The effects of contextual interference on the acquisition, retention, and transfer of a music motor skill among university musicians* (Doctoral dissertation, Louisiana State University and Agricultural and Mechanical College, 2006). *Dissertation Abstracts International, 67*(08).

Rosenthal, R. K., Wilson, M., Evans, M., & Greenwalt, L. (1988). Effects of different practice conditions on advanced instrumentalists' performance accuracy. *Journal of Research in Music Education, 36*, 250-257.

Ross, S. L. (1985). The effectiveness of mental practice in improving the performance of college trombonists. *Journal of Research in Music Education, 33*, 221-231.

Rubin-Rabson, G. (1940). Studies in the psychology of memorizing piano music II: A comparison of massed and distributed practice. *Journal of Educational Psychology, 31*, 270-284.

Rubin-Rabson, G. (1941). Studies in the psychology of memorizing piano music V: A comparison of pre-study periods of varied length. *Journal of Educational Psychology, 32*, 101-112.

Schmidt, R. A. (1975). A schema theory of discrete motor skill learning. *Psychological Review, 82*, 225-260.

Schmidt, R. A., & Lee, T. D. (2005). *Motor control and learning: A behavioral emphasis* (4th ed.). Champaign, IL: Human Kinetics.

Shea, J. B., & Morgan, R. L. (1979). Contextual interference effects on the acquisition, retention, and transfer of a motor skill. *Journal of Experimental Psychology: Human Learning and Memory, 5*, 179-187.

Sidnell, R. G. (1981, April). *Motor learning in music education.* Paper presented at the National Symposium on the Applications of Psychology to the Teaching and Learning of Music, Ann Arbor, MI.

Simmons, A. L., & Duke, R. A. (2006). Effects of sleep on performance of a keyboard melody. *Journal of Research in Music Education, 54*, 257-269.

Sloboda, J. A., Davidson, J. W., Howe, M. J. A., & Moore, D. G. (1996). The role of practice in the development of performing musicians. *British Journal of Psychology, 91*, 353-376.

Welch, G. F. (1985). Variability of practice and knowledge of results as factors in learning to sing in tune. *Council for Research in Music Education Bulletin, 85*, 238-247.