Distributed Practice and Procedural Memory Consolidation in Musicians' Skill Learning

Amy L. Simmons[1]

Abstract

This research was designed to determine whether musicians' learning is affected by the time intervals interposed between practice sessions. Twenty-nine non-pianist musicians learned a 9-note sequence on a piano keyboard in three practice sessions that were separated by 5 min, 6 hr, or 24 hr. Significant improvements in performance accuracy were observed in Session 2 only in the group whose sessions were separated by 24 hr. There were significant increases in performance speed in Session 2 in all three practice conditions, results which likely were attributable to the inclusion of all Session 1 data in the analysis. Additional significant speed increases were observed in Session 3 only in the groups whose sessions were separated by 6 and 24 hr. These results suggest that sleep-based procedural memory consolidation may enhance performance accuracy in music skill learning, whereas enhancements in performance speed may be attributable to both wake- and sleep-based consolidation processes.

Keywords

distributed practice, procedural skill learning, memory consolidation

Most musicians and teachers accept the notion that music learning is advantaged when practice time is distributed among multiple sessions rather than massed in a single session. The positive effects of distributed practice have been observed in numerous domains of motor skill learning (for reviews, see Donovan & Radosevich, 1999; Lee

---

[1]Texas State University–San Marcos, San Marcos, TX, USA

Corresponding Author:
Amy L. Simmons, Texas State University–San Marcos, School of Music, 601 University Drive, San Marcos, TX 78666-4616
Email: amy.simmons@txstate.edu

& Genovese, 1988; Lee & Wishart, 2005). Surprisingly little research in music has examined this phenomenon directly, although nearly all research in music practice cites as primary evidence for this approach the work of Rubin-Rabson (1940), who reported that pianists who distributed practice over time performed a memorized melody more accurately than did pianists who engaged in an equivalent amount of practice in a single session.

Only recently have the processes that underlie the effectiveness of distributed practice in skill learning been elucidated. Musicians know that extended rest intervals between practice sessions provide relief from mental and physical fatigue; less commonly understood is that rest intervals allow time for the neurophysical processes of memory consolidation (for an overview, see Walker, 2005).

Theories of memory consolidation were first proposed in 1895 by Oerhn (as cited in Eysenck & Frith, 1977), who observed improvements in performance following periods of rest. More recent investigations of human memory have revealed a great deal about the time course of memory encoding and storage. Although the biological processes of memory consolidation have yet to be characterized fully, it is well understood that acquiring and forming memories for motor skills involve structural and functional reorganization in the brain (Walker & Stickgold, 2006).

Consolidation is the mechanism through which motor skills and other memories are encoded and refined, resulting in their resistance to interference and forgetting (Walker, 2005; Walker & Stickgold, 2004). The processes of consolidation are thought to begin during physical practice and to continue covertly after practice ends (Luft & Buitrago, 2005).

Wake-based consolidation allows for the intact encoding and storage of fragile new memories. Studies of motor learning in humans have shown that learners who recall newly acquired skills prior to sleep perform with the same levels of accuracy and speed that were achieved by the end of previous practice (Fischer, Hallschmid, Elsner, & Born, 2002; Robertson, Pascual-Leone, & Miall, 2004; Robertson, Pascual-Leone, & Press, 2004; Shea, Lai, Black, & Park, 2000; Walker, Brakefield, Hobson, & Stickgold, 2003; Walker, Brakefield, Morgan, Hobson, & Stickgold, 2002; Walker, Brakefield, Seidman, et al., 2003). Memory consolidation processes are further activated during sleep. Sleep-based consolidation that occurs during intervals between practice and recall sessions has been shown to enhance motor skill memory significantly (Cash, 2009; Duke & Davis, 2006; Fischer et al., 2002; Kuriyama, Stickgold, & Walker, 2004; Maquet et al., 2003; Mednick, Nakayama, & Stickgold, 2003; Vertes & Eastman, 2000; Walker, Brakefield, Hobson, et al., 2003; Walker, Brakefield, Seidman, et al., 2003).

Research in human movement has demonstrated that learners who distribute practice over time (i.e., dividing practice trials across multiple sessions that span several days) perform better than learners who engage in massed practice (i.e., completing all practice trials in one session on 1 day) when skills are recalled at least 24 hours after practice ends (Dail & Christina, 2004; Shea et al., 2000; Tsutsui, Lee, & Hodges, 1998). In

recent years, researchers in this domain of human learning have attributed the observed performance differences between massed and distributed practice to the processes of memory consolidation (Dail & Christina, 2004; Shea et al., 2000).

Many of the studies cited earlier required learners with no skill-related experience to practice relatively simple motor skills (i.e., skills that have one degree of freedom, can be acquired in one practice session, and typically are not skills executed outside laboratories). There is much less research that has examined procedural memory consolidation in the context of more complex motor skills (i.e., skills that include multiple degrees of freedom, require multiple practice sessions for skill acquisition, and are often skills people perform outside of laboratories), a category under which music performance inarguably falls (Wulf & Shea, 2002).

Music learners negotiate many skill components simultaneously (e.g., reading notation, translating notation into motor output, processing resulting auditory information, modifying motor behavior based on auditory feedback), and the acquisition of music skills often requires multiple practice sessions. In new learning situations, musicians' perceptions of skill complexity are modified by individual performance ability and prior training and are more aptly characterized as existing on a continuum of skill complexity than by dichotomous terms (e.g., accomplished musicians who are in the early stages of learning a secondary instrument often perceive they are negotiating quite complex motor skills even when performing simple melodies).

Evidence for consolidation-based enhancement of complex motor skills has been observed in music learning (Allen, 2007; Duke, Allen, Cash, & Simmons, 2009; Simmons & Duke, 2006). In these studies, nonpianist musicians (who had a moderate amount of secondary-instrument training in piano performance) practiced an unfamiliar keyboard melody in a 12-min training session, then completed a brief retest session following an interval of rest. Simmons and Duke (2006) observed that musicians who slept during the 12-hr rest interval between sessions performed more accurately at retest than did those who remained awake between sessions. Allen (2007) and Duke et al. (2009) reported similar enhancements in the performance of musicians who slept during a 12-hr rest interval between practice and retest. These studies were the first to demonstrate consolidation-based enhancements with experienced learners performing a music skill.

The purpose of the present study was to examine musicians' learning of a complex motor skill over multiple equivalent practice sessions separated by different rest interval conditions. There are currently no published studies that compare experienced learners' performance under practice schedules that are either massed (including 5-min rest intervals that do not allow sufficient time for consolidation to observably affect performance; see Muellbacher et al., 2002; Walker, Brakefield, Seidman, et al., 2003) or distributed to include different time intervals of memory consolidation (6-hr and 24-hr rest intervals). I sought to answer the question: Will differences exist in the accuracy and speed of experienced learners' performances across multiple practice sessions separated by these rest intervals?
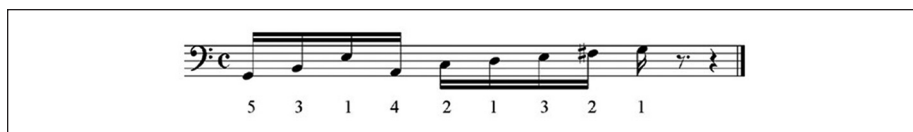
Figure 1. Target melody. Numbers below the notation indicate left hand fingerings; 1 = thumb.

Method

Participants were 29[1] music majors at The University of Texas at Austin (17 males). All were right-handed, between 18 and 40 years of age, and had no neurological, psychiatric, or sleep-disorder histories. All reported no extensive training or experience on the piano beyond a maximum of five semesters of undergraduate group piano instruction; in those classes, students learned to read, perform, and improvise beginner-level keyboard music and typically demonstrated various levels of rudimentary skill. Graduate and undergraduate music majors were solicited via e-mail and classroom announcement, which provided them with the participation criteria described above and information regarding monetary compensation. Students who fit the criteria and chose to participate gave informed consent.

Participants learned a 9-note sequence (see Figure 1) on a digital piano with their left (non-dominant) hand, with the goal of performing the sequence "as quickly, accurately, and evenly as possible." They practiced the sequence in three 15- to 20-min individual sessions. Each practice session consisted of three blocks of 15 performance trials, with each block separated by 30 sec of rest. Each performance trial was followed by 3 sec of silence and an audiovisual cue for the next performance trial to begin.

I created three experimental conditions to assess possible effects of sleep- and wake-based memory consolidation on performance accuracy and speed by assigning different rest intervals between sessions: 5 min (massed practice, rest intervals included physical and mental rest, $n = 9$), 6 hr (distributed practice, rest intervals included wake-based consolidation, $n = 10$), and 24 hr (distributed practice, rest intervals included both wake- and sleep-based consolidation, $n = 10$). Participants in the 5-min group completed all three sessions in 1 hour between 4:00 and 8:00 p.m.; sessions for the 24-hr group were scheduled between 10:00 a.m. and 12:00 p.m. on 3 consecutive days. The 6-hr group completed all sessions in 1 day with one session scheduled during each of the following intervals: 8:00-10:00 a.m., 2:00-4:00 p.m., and 8:00-10:00 p.m. Conditions were assigned randomly to participants.

Participants agreed to abstain from engaging in behaviors that are known to affect cognitive function and motor performance; specifically, participants agreed to avoid drinking alcoholic and caffeinated beverages and to avoid using other mind-altering drugs for 12 hr prior to and for the duration of their participation in the study. Participants

whose practice sessions were separated by 6 hr agreed to avoid napping between sessions, and participants in the 24-hr group agreed to sleep at night between sessions.

I used a Musical Instrument Digital Interface (MIDI) device to connect a Macintosh PowerBook computer to a Roland digital piano for data collection. Notation for the sequence was presented to participants on the laptop computer, which was placed on the keyboard's music rack. Participants listened to all electronic cues (the sound of the piano during every performance trial and a bell-like tone that served as the auditory start cue) through Bose noise-cancelling headphones. The test proctor listened through a second set of headphones. A computer program written specifically for this research using Max/MSP software was set up to display the sequence, to run the protocol, and to collect MIDI performance data.

The computer continuously displayed the sequence in music notation for all groups. Also displayed were dots that appeared above each note on the staff. The dots illuminated in red from left to right with each keypress to help participants keep track of where they were in the sequence as they practiced. The lights above each note were illuminated regardless of whether the correct pitch was performed. The computer stopped recording on each trial after the ninth note was played.

The Max/MSP software recorded MIDI data during all three sessions. Data for the following variables were analyzed: accuracy, defined as the number of keypress errors per sequence, and speed, defined as the time elapsed between first and last keypresses in each sequence (expressed in milliseconds).

Before participants began each practice session, they rated their feeling of alertness using the Stanford Sleepiness Scale (Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973), answered questions about their music backgrounds (e.g., duration of principal instrument study, secondary instrument training), described how they felt at the moment, and reported on their compliance with study criteria (e.g., no consumption of caffeine, alcohol, drugs), instrumental practice they had engaged in, and sleep time for the previous night.

Participants then played through the sequence one time as slowly as needed to play the correct notes with the correct fingerings. If participants struggled with this, feedback was offered and repetitions were allowed until one correct performance of the sequence was achieved. During this time, participants were free to ask questions about the procedure and the sequence. Participants were told, "Do your best to play the melody from beginning to end each time without stopping. Do not practice specific parts out of context or vary the rhythm pattern; in other words, play it just as written." Before data collection began, participants played two test trials with the computer program so they could orient themselves to the way the program worked. They were given another opportunity to ask questions and then began their performance.

At the end of Session 1, participants in the 5-min group were given a break, during which time participants were engaged in conversation to prohibit mental and physical practice. Before being dismissed, participants in the 6-hr and 24-hr groups were reminded to abstain from drinking caffeinated or alcoholic beverages and from using other mind-altering substances and to refrain from practicing the sequence between

sessions. Participants in the 6-hr group also were reminded to avoid napping, and those in the 24-hr group were asked to note how long they slept at night. Sessions 2 and 3 were conducted in the same manner as Session 1.

Results

I found no significant correlations between reported sleep and note accuracy (.05 was the alpha level for all statistical comparisons): Session 1, $r = -.186$, $p = .352$; Session 2, $r = -.582$, $p = .078$; Session 3, $r = .119$, $p = .743$. Likewise, there were also no significant correlations between reports of sleep and speed: Session 1, $r = -.372$, $p = .056$; Session 2, $r = -.217$, $p = .548$; Session 3, $r = -.291$, $p = .414$.

I compared participants' reports of alertness on the Stanford Sleepiness Scale given at the beginning of each session with corresponding note accuracy and speed data. There were no significant correlations between reports of alertness and note accuracy: Session 1, $r = -.104$, $p = .590$; Session 2, $r = -.195$, $p = .411$; Session 3, $r = .064$, $p = .790$. Similar results were obtained between reports of alertness and speed: Session 1, $r = -.266$, $p = .163$; Session 2, $r = -.337$, $p = .146$; Session 3, $r = -.274$, $p = .242$. Although there was considerable variation among participants' reports of sleep and alertness, those differences had no consistent effect on performance.

Note accuracy. I compared the note accuracy in participants' performances using one-way repeated measures analyses of variance (ANOVAs) for each rest interval condition. In this study, as in Shea et al. (2000), all trials in each block were included in the analyses. Means for each group are presented in Figure 2.

I observed a significant difference among the three session means for the 24-hr group, $F(2, 18) = 4.924$, $p = .020$, $\eta^2_p = .354$. Post hoc analyses[2] indicate that the mean for the first practice session was significantly higher than the means for Session 2, $p = .033$, and Session 3, $p = .045$, which were not significantly different from one another, $p = .500$. There were no significant differences among the three session means for the 6-hr group, $F(2, 18) = 0.286$, $p = .754$; likewise, there were no significant differences among the three session means for the 5-min group, $F(2, 16) = 0.956$, $p = .405$.

It should be noted that the error rate in the 5-min group in the first practice session was near zero, much lower than that of the other two groups. The reason for this difference in the initial block is unknown, but it obviates meaningful comparisons between the accuracy scores of the 5-min group and the other two groups.

Mean note accuracy data for the 6-hr and 24-hr groups, whose Session 1 performances were similar, suggest differences between the effects of wake- and sleep-based consolidation. Put simply, I found significant enhancements in Session 2 performance for participants who slept between sessions. The 24-hr group's data indicate that participants performed with a mean of 10.8 errors in Session 1 (.24 errors per sequence in a 45-trial session); following sleep, these participants performed with a mean of 2.2 errors in Session 2 (.05 errors per sequence).
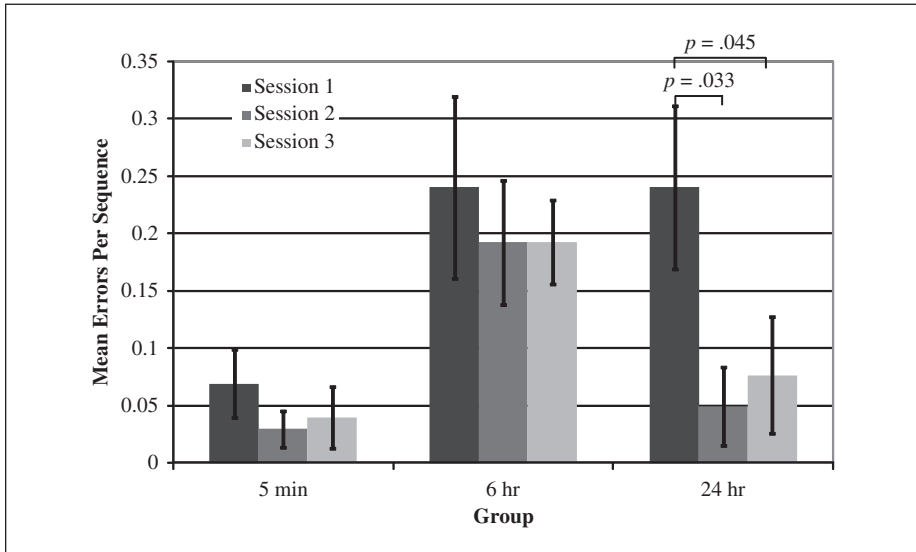
Figure 2. Mean errors per sequence for each session. Error bars represent ±1 standard error of the mean.

No group showed evidence of improvements in accuracy between Sessions 2 and 3. It seems that a second night of sleep-based consolidation did not yield detectable performance enhancements in accuracy between Sessions 2 and 3 in the 24-hr group, nor did wake-based consolidation yield Session 3 enhancements in the 6-hr group.

Speed. Means for each group are presented in Figure 3. I compared the speed of participants' performances using one-way repeated measures ANOVAs for each rest interval condition and found a significant difference among the three session means in the 5-min group, $F(1, 8)^3 = 27.683$, $p = .001$, $\eta^2_p = .776$. Post hoc analyses[4] indicate that the mean for Session 1 was significantly higher (i.e., participants performed more slowly) than the means for Session 2, $p = .002$, and Session 3, $p < .001$, which were not significantly different from one another, $p = .232$.

Similarly, there were significant differences among the three session means in the 6-hr and 24-hr groups: 6-hr group, $F(1, 9)^3 = 28.321$, $p < .001$, $\eta^2_p = .759$; 24-hr group, $F(1, 9)^3 = 18.396$, $p = .002$, $\eta^2_p = .671$. Post hoc analyses indicate that the means for Sessions 1, 2, and 3 were all significantly different from one another: 6-hr group, Session 1 versus Session 2, $p < .001$; Session 1 versus Session 3, $p < .001$; and Session 2 versus Session 3, $p = .003$; 24-hr group, Session 1 versus Session 2, $p = .004$; Session 1 versus Session 3, $p = .003$; and Session 2 versus Session 3, $p = .004$.

Session means for speed reveal that the extent of performance improvements between Sessions 1 and 2 were similar in all three groups (speed means in Session 2 were 23–26 beats per minute [bpm] faster than Session 1 means), whereas the 6-hr and 24-hr groups showed greater speed gains in Session 3 than did the 5-min group (6-hr
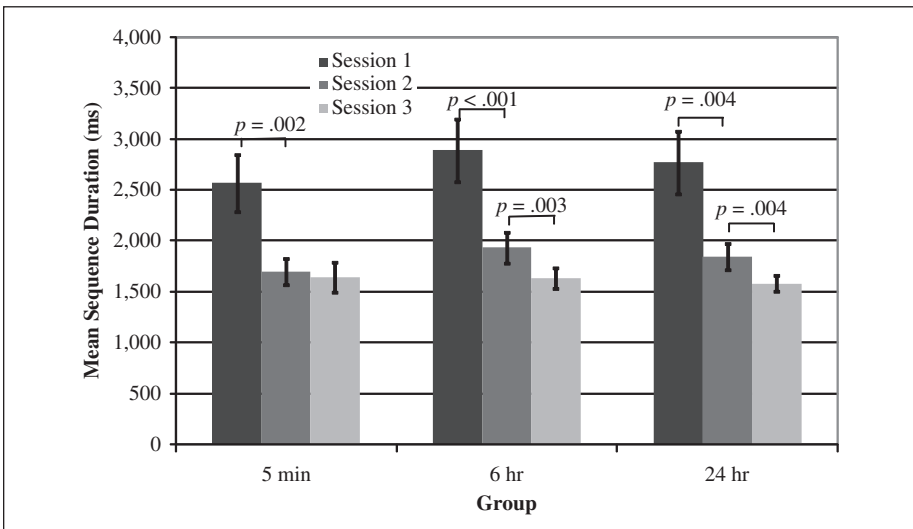
Figure 3. Mean sequence duration for each session. Error bars represent ±1 standard error of the mean.

and 24-hr groups, mean speed increase of 12 bpm; 5-min group, mean increase of only 2 bpm). The increases in speed between Sessions 2 and 3 were expected in the 24-hr condition, based on the results of previous research done with simple motor skills. Session 3 speed enhancements evident in the performances of the 6-hr group are inconsistent with results of studies using non-music tasks but are consistent with the Simmons and Duke (2006) observation that speed enhancements in music learning may be attributable to both wake- and sleep-based consolidation.

Discussion

My results suggest that performance accuracy is enhanced by sleep-based memory consolidation, a finding that is in line with research conducted using simpler motor skills (Cash, 2009; Duke & Davis, 2006; Fischer et al., 2002; Walker, Brakefield, Hobson, et al., 2003; Walker et al., 2002; Walker, Brakefield, Seidman, et al., 2003) and with research using music tasks similar to the one used in this study (Allen, 2007; Duke et al., 2009; Simmons & Duke, 2006). The effect of memory consolidation on performance speed remains less attributable to sleep-based consolidation, because all three groups demonstrated enhanced performance in Session 2, and both wake- and sleep-based consolidation groups demonstrated speed enhancements in Session 3.

The interpretation of the effects of consolidation in the current investigation are somewhat limited by participants having reached very high levels of accuracy early on in practice. In the first session of the 5-min condition and in the second session of the

24-hr condition, performance accuracy reached an apparent ceiling (approximately 2.25 errors per session), making it unlikely that continued improvements in performance accuracy would be observable in subsequent sessions. Based on the performance accuracy data from Session 1, it appears that, despite the random assignment of conditions, the ability level of the participants in the 5-min group was greater than that of the participants in the other two groups.

There are two important differences between the practice procedures of this study and those used in many previous investigations of memory consolidation. First, I controlled the number of repetitions performed in each block of practice. Second, I compared performance across three practice sessions of equal duration and content, a design based on the procedures used by Shea et al. (2000). These data nevertheless suggest effects of memory consolidation similar to reports of other music and non-music investigations that controlled for practice time (not number of trials) and compared performance at the end of practice with performance during a brief retest.

I noticed that participants in all groups demonstrated a clear preference for establishing and maintaining note accuracy over increasing performance speed, which is consistent with the reports of Simmons and Duke (2006) and Allen (2007). In informal conversations with me at the end of Session 3, many participants commented that they limited increases in speed for the sake of accuracy. This tendency may be unique to musicians, as it is not typically reported in motor learning research in other domains. This may explain the finding that participants in all conditions made increases in speed between Session 1 (which included the slowest performance trials in the initial stages of acquisition) and Session 2.

This is the first study that examines changes occurring in experienced learners' performance across multiple practice sessions that were spaced by very brief intervals of rest (massed practice) or by extended rest intervals (distributed practice) that allowed time for wake-based consolidation only or for both wake- and sleep-based consolidation. The findings from this and other investigations, which suggest that sleep-based consolidation may enhance performance accuracy and that both sleep- and wake-based consolidation may enhance speed, contribute to our understanding of human cognition, skill development, and memory formation. Explanations of the neurophysical processes that encode, refine, and retrieve memories are beginning to clarify the bases for the observation that distributing practice across time is an advantageous course of action in nearly all domains of human learning.

The effect of memory consolidation on complex motor skill learning has potential implications for instrumental music study, as these findings inform discussions of practice organization and scheduling. The efficiency of distributed practice may increase levels of students' enjoyment and motivation and also may provide students with more musically gratifying practice experiences and a greater sense of accomplishment than might otherwise be perceived with less effective practice strategies. Understanding the mechanisms by which distributed practice benefits learning not only leads to more informed planning and decision making by teachers but also may lead to more interesting and rewarding practice experiences for learners.

Studies of the most basic processes of procedural memory formation may prompt future explorations into memory processes that underlie more complex music learning. Results like those reported here and in related investigations undoubtedly will lead to additional research that will address how music teachers and performers may structure individual and group practice most effectively to exploit the neural processes that underlie skill development.

Author's Note

This article is based on the author's doctoral dissertation, "Effects of Practice Variability and Distribution of Practice on Musicians' Performance of a Procedural Skill," completed at The University of Texas at Austin in 2007.

Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

Notes

1. Data were collected from 31 participants. Out of 18 total data points (3 practice block means from each of 3 sessions for 2 dependent measures), the scores of two participants (one from the 5-min group and one from the 6-hr group) were greater than two standard deviations away from the group mean for each data point in at least 5 of the 18 blocks. They were considered outliers and their data were dropped from consideration.
2. Paired samples *t* test (one-tailed) with Bonferroni correction.
3. Corrected *df* for violation of the sphericity assumption (Greenhouse-Geisser).
4. Paired samples *t* test (one-tailed) with Bonferroni correction.

References

Allen, S. E. (2007). *Procedural memory consolidation in musicians* (Doctoral dissertation, The University of Texas at Austin). Retrieved from http://search.proquest.com/docview/304828824?accountid=5683

Cash, C. D. (2009). Effects of early and late rest intervals on performance and overnight consolidation of a keyboard sequence. *Journal of Research in Music Education*, *57*, 252–266. doi:10.1177/0022429409343470

Dail, T. K., & Christina, R. W. (2004). Distribution of practice and metacognition in learning and long-term retention of a discrete motor task. *Research Quarterly for Exercise and Sport*, *75*, 148–155.

Donovan, J. J., & Radosevich, D. J. (1999). A meta-analytic review of the distribution of practice effect: Now you see it, now you don't. *Journal of Applied Psychology*, *84*, 795–805. doi:10.1037/0021-9010.84.5.795

Duke, R. A., Allen, S. E., Cash, C. D., & Simmons, A. L. (2009). Effects of early and late breaks during training on overnight memory consolidation of a keyboard melody. *Neurosciences and Music III: Disorders and Plasticity. Annals of the New York Academy of Sciences*, *1169*, 169–172. doi:10.1111/j.1749-6632.2009.04795.x

Duke, R. A., & Davis, C. M. (2006). Procedural memory consolidation in the performance of brief keyboard sequences. *Journal of Research in Music Education*, *54*, 111–124. doi:10.1177/002242940605400203

Eysenck, H. J., & Frith, C. D. (1977). *Reminiscence, motivation, and personality: A case study in experimental psychology* (Vol. 21). Oxford, England: Plenum.

Fischer, S., Hallschmid, M., Elsner, A. L., & Born, J. (2002). Sleep forms memory for finger skills. *Proceedings of the National Academy of Sciences*, *99*, 11987–11991. doi:10.1073/pnas.182178199

Hoddes, E., Zarcone, V., Smythe, H., Phillips, R., & Dement, W. C. (1973). Quantification of sleepiness: A new approach. *Psychophysiology*, *10*, 431–436. doi:10.1111/j.1469-8986.1973.tb00801.x

Kuriyama, K., Stickgold, R., & Walker, M. P. (2004). Sleep-dependent learning and motor-skill complexity. *Learning & Memory*, *11*, 705–713. doi:10.1101/lm.76304

Lee, T. D., & Genovese, E. D. (1988). Distribution of practice in motor skill acquisition: Learning and performance effects reconsidered. *Research Quarterly for Exercise and Sport*, *59*, 277–287.

Lee, T. D., & Wishart, L. R. (2005). Motor learning conundrums (and possible solutions). *Quest*, *57*, 67–78.

Luft, A. R., & Buitrago, M. M. (2005). Stages of motor skill learning. *Molecular Neurobiology*, *32*, 205–216. doi:10.1385/MN:32:3:205

Maquet, P., Laureys, S., Perrin, F., Ruby, P., Melchior, G., Boly, M., . . . Peigneux, P. (2003). Festina lente: Evidences for fast and slow learning processes and a role for sleep in human motor skill learning. *Learning & Memory*, *10*, 237–239. doi:10.1101/lm.64303

Mednick, S. C., Nakayama, K., & Stickgold, R. (2003). Sleep-dependent learning: A nap is as good as a night. *Nature Neuroscience*, *6*, 697. doi:10.1038/nn1078

Muellbacher, W., Ziemann, U., Wissel, J., Dang, N., Kofler, M., Facchini, S., . . . Hallett, M. (2002). Early consolidation in human primary motor cortex. *Nature*, *415*, 640–644. doi:10.1038/nature712

Robertson, E. M., Pascual-Leone, A., & Miall, R. C. (2004). Current concepts in procedural consolidation. *Nature Reviews Neuroscience*, *5*, 576–582. doi:10.1038/nrn1426

Robertson, E. M., Pascual-Leone, A., & Press, D. Z. (2004). Awareness modifies the skill-learning benefits of sleep. *Current Biology*, *14*, 208–212. doi:10.1016/j.cub.2004.01.027

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. doi:10.1037/h0061174

Shea, C. H., Lai, Q., Black, C., & Park, J. H. (2000). Spacing practice sessions across days benefits the learning of motor skills. *Human Movement Science*, *19*, 737–760. doi:10.1016/S0167-9457(00)00021-X

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. doi:10.1177/002242940605400308

Tsutsui, S., Lee, T. D., & Hodges, N. J. (1998). Contextual inference in learning new patterns of bimanual coordination. *Journal of Motor Behavior*, *30*, 151–157. doi:10.1080/00222899809601332

Vertes, R. P., & Eastman, K. E. (2000). REM sleep is not committed to memory. *Behavioral & Brain Sciences*, *23*, 1057–1063. doi:10.1017/S0140525X00984024

Walker, M. P. (2005). A refined model of sleep and the time course of memory formation. *Behavioral and Brain Sciences*, *28*, 51–104. doi:10.1017/S0140525X05000026

Walker, M. P., Brakefield, T., Hobson, J. A., & Stickgold, R. (2003). Dissociable stages of human memory consolidation and reconsolidation. *Nature*, *425*, 616–620. doi:10.1038/nature01930

Walker, M. P., Brakefield, T., Morgan, A., Hobson, J. A., & Stickgold, R. (2002). Practice with sleep makes perfect: Sleep-dependent motor skill learning. *Neuron*, *35*, 205–211. doi:10.1016/S0896-6273(02)00746-8

Walker, M. P., Brakefield, T., Seidman, J., Morgan, A., Hobson, J. A., & Stickgold, R. (2003). Sleep and the time course of motor skill learning. *Learning & Memory*, *10*, 275–284. doi:10.1101/lm.58503

Walker, M. P., & Stickgold, R. (2004). Sleep-dependent learning and memory consolidation. *Neuron*, *44*, 121–133. doi:10.1016/j.neuron.2004.08.031

Walker, M. P., & Stickgold, R. (2006). Sleep, memory, and plasticity. *Annual Review of Psychology*, *57*, 139–166. doi:10.1146/annurev.psych.56.091103.070307

Wulf, G., & Shea, C. H. (2002). Principles derived from the study of simple skills do not generalize to complex skill learning. *Psychonomic Bulletin & Review*, *9*, 185–211. doi:10.3758/BF03196276

Bio

Amy L. Simmons is assistant professor of music education at Texas State University. Her research focuses on motor skill acquisition and memory development in the context of music performance and on identifying characteristics of expert teaching.