

## Influence of practice schedules and attentional focus on skill development and retention

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### Abstract:

Focus of attention during dual-tasks and practice schedules are important components of motor skill performance and learning; often studied in isolation. The current study required participants to complete a simple key-pressing task under a blocked or random practice schedule. To manipulate attention, participants reported their finger position (i.e., skill-focused attention) or the pitch of an auditory tone (i.e., extraneous attention) while performing two variations of a dual-task key-pressing task. Analyses were conducted at baseline, 10 min and 24 h after acquisition. The results revealed that participants in a blocked schedule, extraneous focus condition had significantly faster movement times during retention compared to a blocked schedule, skill focus condition. Furthermore, greatest improvements from baseline to immediate and delayed retention were evident for an extraneous attention compared to the skill-focused attention, regardless of practice schedule. A discussion of the unique benefits an extraneous focus of attention may have on the learning process during dual-task conditions is presented.

**Keywords:** Skill acquisition | Skill-focus | Extraneous focus | Practice scheduling | Contextual interference | Dual-tasks

### Article:

#### 1. Introduction

The early stages of motor learning are known to be cognitively demanding, interpretive, and effortful (Anderson, 1982; Ericsson, 2006; Fitts & Posner, 1967). Decades of research has focused on how skill development progresses through more advanced stages of learning,

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allowing skillful behavior to emerge (Adams, 1987; Salmoni, Schmidt, & Walter, 1984; Wolpert, Diedrichsen, & Flanagan, 2011). Two factors influencing skill development that have been extensively studied are practice schedules (Magill & Hall, 1990; Shea & Kohl, 1990) and the focus of attention during dual-tasks (e.g., Beilock & Carr, 2001; Beilock & Gray, 2012; Castaneda & Gray, 2007; Gray, 2004). While these factors have expansive literature explaining their importance in skill development, they have mostly been studied in isolation relative to the other. From a practical perspective, both practice scheduling *and* the focus of attention during attention-demanding situations (i.e., dual-tasks) would be manipulated in a real-world setting, and there may be an interaction between these factors influencing skill development. Thus, we provide a brief overview of the literature related to practice scheduling and dual-task literature, and then lay the foundation for examining both factors concurrently within a skill development context.

One way practice schedules are defined is in terms of blocked and random practice. The former refers to performing the same skill repeatedly, whereas the latter intertwines practicing different skills within the training session. Previous work has demonstrated that skill development is enhanced with blocked practice (Magill & Hall, 1990; Porter & Magill, 2010; Shea & Morgan, 1979; Simon & Bjork, 2001). However, the skill is more strongly retained and/or transferred to a similar movement pattern when a random practice schedule is used (Magill & Hall, 1990; Porter & Magill, 2010; Shea & Morgan, 1979; Shea & Zimny, 1983; Simon & Bjork, 2001). It has been posited that a random practice schedule forces learners to continuously reconstruct the to-be-learned skill through elaboration and/or forgetting. That is, providing interference during the learning process, termed contextual interference (CI), can actually enhance skill retention and skill transfer (Magill & Hall, 1990; Shea & Morgan, 1979; Shea & Zimny, 1983). CI is defined as interference occurring as a result of practicing a task alongside other tasks (Schmidt & Lee, 2005). It is important to note that the majority of research examining CI compares a blocked order of the same trials (low CI) with a random order of practice trials (high CI). Typical results from such studies demonstrate superior retention rates for learning when high CI is present (Porter, Landin, Hebert, & Baum, 2007). In addition to the typical blocked/random CI effects, studies have included a serial order of trials to manipulate a moderate level of CI compared to the high and low CI from blocked and random practice (Hebert, Landin, & Solmon, 1996). Results are mixed, some show that blocked practice is more beneficial for novices during retention; others found no differences (Jones & French, 2007). Porter and Magill (2010) conducted a study that provided systematic increases in CI compared to the traditional studies and the results showed that including moderate CI trials provided novice learners more time to correct errors and develop problem solving strategies to benefit performance.

It is plausible that the results from the blocked/random practice schedule literature are influenced by where attention was focused during skill development. For example, and in line with the forgetting hypothesis (Lee & Magill, 1983), when participants shift from one task to another during random practice, participants ‘forget’ how to perform the previously learned skill. Thus, random practice facilitates learning through solution generation (see Cuddy & Jacoby, 1982). Alternatively, it is possible that shifting from one task to another compels performers to focus on skill execution to ‘relearn’ the skill, but allows performers to behave more reflexively and focus attention away from skill execution during retention tests. Motor learning literature has studied this phenomenon through dual-task methodology (Beilock, Bertenthal, McCoy, & Carr, 2004;

Beilock & Carr, 2001). These studies are designed to explore the de-automatization of skills hypothesis (see Castaneda & Gray, 2007; Gray, 2004). This hypothesis posits that attention directed toward skill execution (deemed 'skill-focus' attention) will cause a disruption in proceduralized knowledge compared to attention directed toward an irrelevant aspect in the environment (deemed 'extraneous' attention). In line with this, participants who have high levels of experience in a task would be particularly affected by a skill-focus manipulation, as they would be required to switch from an automatic, global mode of control to a more localized mode of control that focuses on a single component of the skill. However, those with less-skill may actually benefit when attention is directed toward skill execution until the motor movements become more automatic. It is argued that dual-task methodology is more challenging than attentional manipulation through instruction (Castaneda & Gray, 2007), and is the type of paradigm we believed would best answer our research questions. Specifically, we were interested the interaction between practice type and attention while learning a new motor task in a challenging dual-task environment.

The purpose of the present study is to extend the current motor learning literature by examining how practice scheduling and attentional focus interact while learning a new task under challenging conditions. To our knowledge, only a single study has investigated the interrelationship of practice scheduling and focus of attention to show how they contribute to performance and learning (Modaberi & Nehbandanian, 2013). This study, however, manipulated attention through instruction, and we hoped to further our understanding of attention and practice scheduling by incorporating a more challenging (i.e., dual-task) environment. To do this, we required participants to complete a novel key-pressing task while attention was manipulated through a secondary task. Based on current consensus in the literature regarding optimal practice conditions and dual-task conditions, the three hypotheses were made. First, the combination of random practice and skill-focused attention would lead to superior skill retention relative to all other conditions. This hypothesis is based off of the contextual interference literature that has reliably showed the beneficial effects of a random compared to blocked practice schedule (Magill & Hall, 1990; Shea & Kohl, 1990), and the dual-task literature that has demonstrated novice performance enhancement when using a skill-focused mode of attention relative to an extraneous focus of attention (see Beilock & Carr, 2001; Gray, 2004). Our second hypothesis stated that significant improvements from baseline to retention would be exhibited for those engaging in random practice and skill-focused attention. Our third hypothesis stated that significant improvements from baseline to retention would be exhibited for those engaging in random practice with extraneous attention. Similar to the first hypothesis, the second and third hypotheses were developed from the contextual interference literature that show enhanced learning effects when a random practice schedule is utilized (Magill & Hall, 1990; Shea & Kohl, 1990). However, since the dual-task literature typically looks at transitory performance (e.g., Castaneda & Gray, 2007) we were unsure how this would influence learning. We suspected that, during a random practice schedule, performance would increase from baseline to retention for both types of focus (skill focused and extraneous).

## **2. Methods**

### **2.1. Participants**

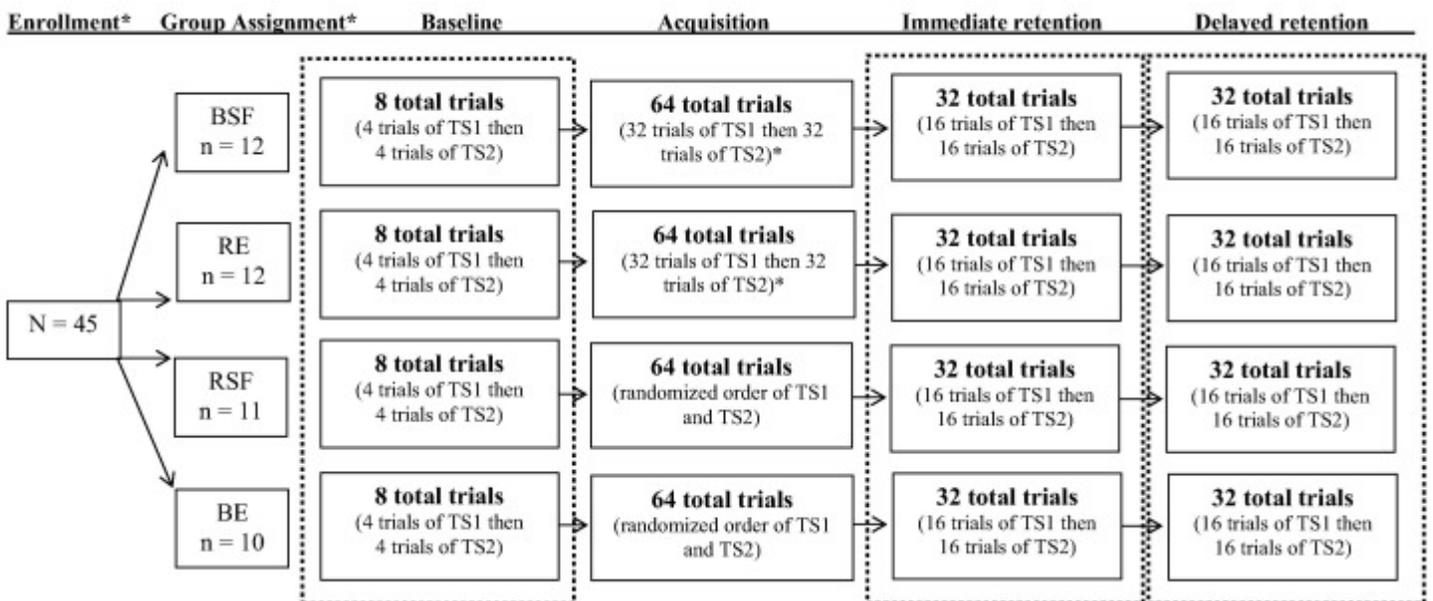
Forty-nine students participated in this experiment ( $M$  age =  $21.54 \pm 3.25$  years). All participants were recruited from the local university community via verbal communication and flyers posted around campus. The study was approved by the local Institutional Review Board to comply with all human subjects ethical requirements and all participants provided informed consent. All participants were right-hand dominant.

## 2.2. Apparatus

The key-pressing testing apparatus consisted of a Pentium-class PC-compatible microcomputer interfaced with a color display monitor and standard keyboard. A customized computer program written with E-Prime Professional (version 2.08, Psychology Software Tools, Pittsburgh, PA, USA) controlled all of the experimental procedures.

## 2.3. Design

A flow chart of the experimental design is shown in Fig. 1. For each task, participants were randomly assigned to one of four groups: (1) blocked-skill-focus [BSF], (2) blocked-extraneous [BE], (3) random-skill-focus [RSF] and (4) random extraneous [RE]. Participants in the blocked practice schedule groups consistently practiced the same variant of the task, before progressing to the next task variant. Participants in the random practice schedule groups practiced all variants of the task in an interleaved manner. In the skill-focused attention groups, participants directed their attention toward an important component of their movement pattern, whereas those in the extraneous attention groups directed their attention toward a something that was not a component of the skill. The specific directions for each of the two tasks are listed below.



**Fig. 1.** Descriptions of enrollment, group assignment, and the four testing phases. Dotted lines indicate focus of analyses (baseline, immediate retention and delayed retention). BSF = blocked-skill-focus, BE = blocked-extraneous, RSF = random-skill-focus, RE = random extraneous,

*TS1 = time sequence #1 (200 ms and 600 ms), TS2 = time sequence #2 (600 ms and 200 ms). Asterisk indicates that the blocked order was counterbalanced between participants. \* Enrollment and group assignment after the removal of four outliers.*

## 2.4. Procedure

Participants were instructed to sit in a chair at a comfortable position in front of the computer monitor and complete a modified key-pressing task adapted from Raisbeck, Wyatt, and Shea (2012). This key-pressing task was previously used to examine motor learning and retention of novel sequences, thus it was appropriate to address the research question posed in the current paper. Using their dominant hand, participants were required to perform the number sequence, “2-6-5” on a standard keyboard. When prompted to start via a ‘+’ on the computer screen, the task was to release the “2” key and push “6” key within a specified time constraint, and then release the “6” and push the “5” within a specified time constraint. The total time to complete the task was always 800 ms. However, the participants were instructed to complete the each task using one of two timing sequences (TS): (1) 200 ms between “2” and “6” and 600 ms between “6” and “5” or (2) 600 ms between “2” and “6” and 200 ms between “6” and “5”. While the timing of TS1 and TS2 were of interest, we were also interested in a global measurement of their performance across the two sub-tasks (TS1 + TS2) to determine if they were on task with the 800 ms requirement.

Baseline measurements were taken on four blocked trials with both TS (eight trials total). During each trial and across all blocks, all participants were presented with an auditory tone every 4–6 s. Participants in the skill-focused groups were instructed to direct their attention on skill execution and verbally state the direction the finger was moving (still, up, or over) when they heard the auditory tone. Participants in the extraneous focus groups were instructed to direct their attention away from movement execution by verbally identifying the pitch of the auditory tone (high, medium, or low). The retention tests for the key-pressing task consisted of 2 blocks of 16 trials with each TS, for a total of 32 trials. The retention test was repeated twice; 10 min after the completion of experimental session (immediate retention [IR]) and 24 h after the completion of the experimental session (delayed retention [DR]; Fig. 1).

## 2.5. Data analyses

Participant performance in the baseline and retention (both IR and DR) phases of the study were analyzed. A different number of trials were used in the baseline testing (8 total) relative to the retention testing (32 total in both the IR and DR phases). However, performance was averaged across all trials within each testing phase in order to get a single measure of performance per participant within each phase. Further, the mean values of the first eight trials of IR and DR were compared to the mean values computed from all 32 trials within each retention phase and no significant differences were observed, so we elected to report the mean values computed from all 32 trials in the IR and DR phases in this paper.

Performance was quantified by examining the combination of constant and variable error relative to the goal MT at TS1, TS2 and TS1 + TS2. Constant error (CE) measured the average deviation of the actual MT from the goal MT and variable error (VE) examined the consistency of the

actual MT relative to the goal MT. CE and VE were combined into one measure of performance (total error [TE]) using the following equation, congruent with previous research (Wright, Magnuson, & Black, 2005):  $TE = \sqrt{(CE^2 + VE^2)}$ .

TE baseline scores were then transformed to Z-scores and outliers greater than  $\pm 1.96$  standard deviations of the mean were removed. Four participants met this criteria and were removed from the TE analyses. Specifically, 3 participants were removed from the BE condition and 1 participant was removed from the RSF condition. No outliers were present in either the BSF or RE conditions. Thus, our total group  $n$  was 45, with an  $n$  of 12, 12, 11, and 10 for the BSF, RE, RSF, and BE conditions, respectively. Next, a  $4 \times 3$  mixed-design analysis of variance was conducted with TE as the dependent variable. Condition (RSF, RE, BSF, BE) was used as the between-subjects factor and phase (Baseline, IR, DR) as the within-subjects factor. If a significant interaction was present, ANOVA's were conducted with condition as the between-subjects factor for each of the three phases; follow-up post hoc analyses were conducted (Tukey's) when appropriate. In addition, repeated measures ANOVA's were conducted with phase as the within subjects factor for each of the four conditions; protected samples  $t$ -tests were then used if significant differences were observed. Furthermore, it is important to note that no analyses were conducted during the acquisition phase of learning (scores between and across trial blocks would have been confounded by practice type) – our research questions were directed toward learning effects.

### 3. Results

#### 3.1. Homogeneity of data

Levene's test of equality of error variances showed there were no differences in the variances of each metric across conditions (all  $p > .05$ ). Thus, parametric tests were used for the main analyses.

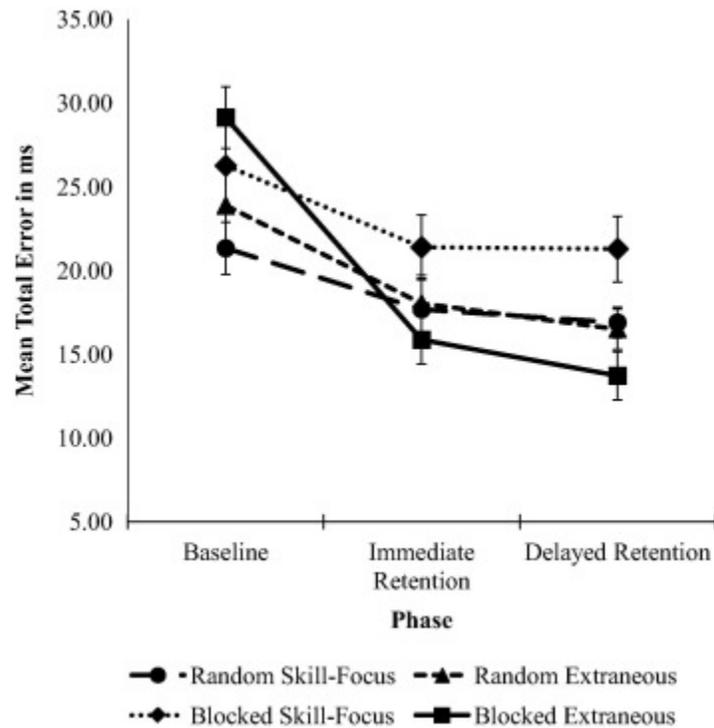
#### 3.2. Main analyses

No significant differences (interaction or main effects) between conditions and/or phase was found for TS1 or TS2 (all  $p > .05$ ). Thus, all of the subsequent results are for the global measurement of timing performance within the task (TS1 + TS2 = 800 ms).

For TE, the interaction between condition and phase was significant,  $F(6, 82) = 2.90, p = .01$ , partial  $\eta^2 = .18$ . No significant differences were observed at baseline,  $F(3, 41) = 2.22, p = .10$ , partial  $\eta^2 = .14$ , or during IR,  $F(3, 41) = 1.70, p = .18$ , partial  $\eta^2 = .11$ . However, significant differences were observed during DR,  $F(3, 41) = 4.56, p = .008$ , partial  $\eta^2 = .25$ . Tukey's post hoc procedure indicated that participants TE in the BE condition ( $M = 13.72, SD = 4.56$ ) was significantly faster than the TE of those in the BSF condition ( $M = 21.29, SD = 6.80$ ),  $p = .004, d = 1.31$ .

Additionally, the results revealed significant differences across the three phases for those in the BE condition,  $F(2, 18) = 34.43, p < .001$  partial  $\eta^2 = .79$ . Follow up analyses revealed a significant improvement from baseline ( $M = 29.13, SD = 5.82$ ) to IR

( $M = 15.86$ ,  $SD = 4.59$ ),  $t(9) = 6.91$ ,  $p < .001$ ,  $d = 2.53$ , and from baseline to DR ( $M = 13.72$ ,  $SD = 4.56$ ),  $t(9) = 6.02$ ,  $p < .001$ ,  $d = 2.95$ . There were also significant differences across the three phases for those in the RE condition,  $F(2, 22) = 6.12$ ,  $p = .008$ , partial  $\eta^2 = .36$ . Follow up analyses revealed a significant improvement from baseline ( $M = 23.88$ ,  $SD = 8.39$ ) to DR ( $M = 16.50$ ,  $SD = 4.21$ ),  $t(11) = 3.07$ ,  $p = .01$ ,  $d = 1.11$  (see Fig. 2).



**Fig. 2.** Mean Total Error (TE) in milliseconds for each phase separated by condition. Error bars represent  $\pm 1$  standard error of the mean.

#### 4. Discussion

The current study examined the influence of practice scheduling and attentional focus when learning a novel motor skill. Specifically, the current study had participants learn key-pressing tasks under blocked or random practice conditions while their attention was directed toward a skill-focused or extraneous component of the task. Past research suggests that individuals are able to learn and retain newly developed motor skills most effectively when exposed to practice environments that are randomized and/or difficult (Shea & Morgan, 1979), and when attention is skill focused (e.g., Beilock, Carr, MacMahon, & Starkes, 2002). Accordingly, we predicted that random practice and skill-focused attention together would lead to superior skill retention relative to all other conditions. The current data does not support this hypothesis. Instead our data is unique that it shows the blocked practice schedule appeared to benefit from an extraneous focus of attention more than the random practice schedule, as evidenced by retention scores. Since retention is predicted by learning, this suggests that the combination of blocked practice with an extraneous focus of attention elicited greater learning than a blocked practice schedule with skill-focused attention during skill acquisition.

##### 4.1. Unique benefit of an extraneous focus of attention during blocked practice

The practice scheduling literature suggests that motor learning is the highest when a sufficient amount of CI is present during the skill acquisition phase (for a review see Magill & Hall, 1990; Porter et al., 2007; Shea & Morgan, 1979). This is beneficial because a high amount of CI is considered to be beneficial to the retention of motor skill learning; this has been shown in both laboratory and field-based settings (Guadagnoli, Holcomb, & Weber, 1999; Landin & Herbert, 1997; Magill & Hall, 1990; Shea & Morgan, 1979; Wright & Shea, 1991). In traditional practice scheduling literature, CI is provided by randomizing the practice conditions (Shea & Morgan, 1979). Thus, the formation of a skillful behavior is constantly challenged by changing task constraints, which appears to be advantageous relative to providing the same task constraints repeatedly. While our data may appear to conflict the traditional practice schedule literature, we contend that the focus of attention can be conceptualized as a factor contributing to CI. For example, having the participants focus their attention on an extraneous aspect of the task changes the constraints imposed on the primary motor task. In many cases, this type of dual-task environment leads to a decline in performance in one or both tasks when compared to performance when each task is completed independently (Li, Lindenberger, Freund, & Baltes, 2001), likely due to the high level of CI each task imparts on the other. However, there are cases where performance is maintained in both tasks (Grubaugh & Rhea, 2014), suggesting that CI was not at a level that interfered with task performance. Further, it has been argued that dual-task practice can lead to an increase in performance in the primary task when the secondary task was sufficiently difficult (Bright & Freedman, 1998), suggesting that CI from a secondary task may actually be beneficial to learning. Our data supports this notion and suggests that an extraneous attention focus possibly creates sufficient CI, similar to the effects observed when a randomized practice schedule is used in isolation. When random practice was combined with an extraneous attention focus, performance dropped, possibly indicating that the CI inherent in random practice combined with CI from extraneous attention may lead to a combined CI level that is not optimal for learning a novel motor skill.

We also predicted a greater improvement from baseline to retention would be exhibited for random practice as opposed to blocked practice regardless of attention condition. This hypothesis was predicated on the consistent finding that random practice enhances motor learning. Our data did not support this hypothesis and showed that the blocked-extraneous and random-extraneous conditions improved from baseline to retention. Our data highlight the role of extraneous attention in motor learning, as it superseded the traditional finding that random practice leads to stronger learning relative to blocked practice. As noted above, this is likely due to the influence of CI. When attention is directed toward skill execution, the focus of attention presents little or no CI. However, when the attention is directed extraneously, the focus of attention introduces CI. Thus, it can be conceptualized that the blocked-skill-focused condition had the least amount of CI (not optimal for learning), whereas the random-extraneous condition contained the most amount of CI (also not optimal for learning). Our data suggests that too little or too much CI led to lower performance on the retention tests, whereas the moderate amount of CI provided in the blocked-extraneous condition led to the best retention of the novel motor skill. This finding is congruent with previous research showing that a moderate level of CI is beneficial for novice learners (Porter and Magill (2010). Theoretically, the random-skill-focused condition in our study would also provide a moderate amount of CI. However, the CI effects from the random

practice may have been overridden by the skill-focused attention, ultimately leading to relatively poorer performance.

#### 4.2. Limitations and future research

Future research would benefit by identifying and selecting instructional methods that systematically direct participants' attention internally and externally. Exploring methods that employ manipulation checks to gauge the compliance of attentional demands would aid in the understanding of attentional focus on learning would benefit the literature. The interaction between attentional demands and designing practice schedules also warrants further attention. Our findings are counter to classic motor learning findings with respect to practice schedules. These differences, most likely, are a result of the differences in cognitive demands and contextual interference evoked across different skill complexities.

### 5. Conclusions

In conclusion, the current study provides us with new information about the interactive relationship between attentional focus and practice scheduling during the development of a simple motor skill in a dual-task paradigm. Based on the current findings, we believe that these results can be used to facilitate learning across a number of other domains and provide unique ways to design practice schedules. For example, it may be beneficial to integrate secondary tasks that require an extraneous focus of attention when practicing in a blocked fashion. The addition of such tasks may facilitate learning by moderately increasing CI without requiring a complete change in practice structure (i.e., through random practice). Our results suggest that utilizing an extraneous focus of attention is beneficial to the learning and retention of simple motor skills when performers are being asked to acquire skills during blocked practice. Future directions in this area, however, should continue to examine the relationship between practice schedules and attentional focus when developing optimal learning paradigm and begin exploring the role of extraneous focus as a form of CI in more complex athletic-based motor skills.

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