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Abstract: Attentional focus and practice schedules are important components of motor skill 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 key-pressing task. Analyses were conducted at baseline, 10 minutes and 24 hours 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.

Highlights

- We explore the interactive relationship between dual-task paradigms and practice schedules.
- Assessed changes in performance using a novel key-pressing task.
- Evidence provided that a blocked practice schedule with an extraneous focus of attention is superior to a blocked practice schedule with a skill-focused focus of attention.
- Unique evidence that an extraneous focus of attention enhances learning (relative to baseline) regardless of practice schedule.

Influence of practice schedules and attention on skill development and retention

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Abstract

Attentional focus and practice schedules are important components of motor skill 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 key-pressing task. Analyses were conducted at baseline, 10 minutes and 24 hours 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.

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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, 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 (Wulf, 2013). 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 would likely 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 the focus of attention, 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, and Solomon, 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 and Gray, 2007; Gray, 2004). This hypothesis posits that attention directed towards skill execution (deemed 'skill-focus' attention) will cause a disruption in proceduralized knowledge compared to attention directed towards 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; whereas, those with less-skill may actually benefit when attention is directed towards skill execution (until the motor movements become more automatic). It is argued that dual-task methodology is more challenging than attentional manipulation through instruction (Castenada & 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 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 following hypotheses was made: (1) the combination of random practice and skill-focused attention would lead to superior skill retention relative to all other conditions; (2) significant improvements from baseline to retention would be exhibited for those engaging in random practice and skill-focused attention; (3) significant improvements from baseline to retention would be exhibited for those engaging in random practice with extraneous attention.

2. Methods

2.1 Participants

Forty-nine students participated in this experiment (*M* age = 21.54 ± 3.25). The study was approved by the local Institutional Review Board 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 Figure 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.

2.4 Procedure

Participants were instructed to sit in a chair at a comfortable position in front of the computer monitor. 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 800ms. However, the participants were instructed to complete the each task using one of two timing sequences (TS): (1) 200ms between “2” and “6 and 600ms between “6” and “5” or (2) 600ms between “2” and “6” and 200ms between “6” and “5”. Baseline measurements were taken on four blocked trials with both TS (eight trials total). Since no hypotheses were made regarding the influence of practice schedules and attentional focus on the short (200ms) or long (600ms) movement times (MT), the timing of the entire sequence (800ms target time) was examined as a measure of learning a novel timing sequence.

During each trial and across all blocks, all participants were presented with an auditory tone every 4-6 seconds. 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 minutes after the completion of experimental session (immediate retention [IR]) and 24 hours after the competition of the experimental session (delayed retention [DR]; Figure 1).

2.3 Data Analyses

This paper focuses on participant performance in the baseline and retention (both IR and DR) phases of the study. 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 form 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. 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 +/- 1.96 standard deviations of the mean were removed. Thus, 4 participants were removed from the TE analyses. Next, a 4 X 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 towards learning effects.

3. Results

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 in the BE condition ($M = 13.72$, $SD = 4.56$) had significantly faster TE times than 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 figure 3).

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 and Morgan, 1979), and when attention is skill focused (e.g., Beilock et al., 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, Landin, Hebert & Baum, 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 (Magill & Hall, 1990; Shea & Morgan, 1979; Wright & Shea, 1991; Landin & Herbert, 1997; Gaudagnoli, Holcomb & Weber, 1999). 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 towards 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. Future directions with this research would be to examine the relationship between practice schedules and attentional focus when developing optimal learning paradigms for new motor skills. The current work suggests that the most effective way to learn a new simple motor skill is through blocked practice with an extraneous focus of attention.

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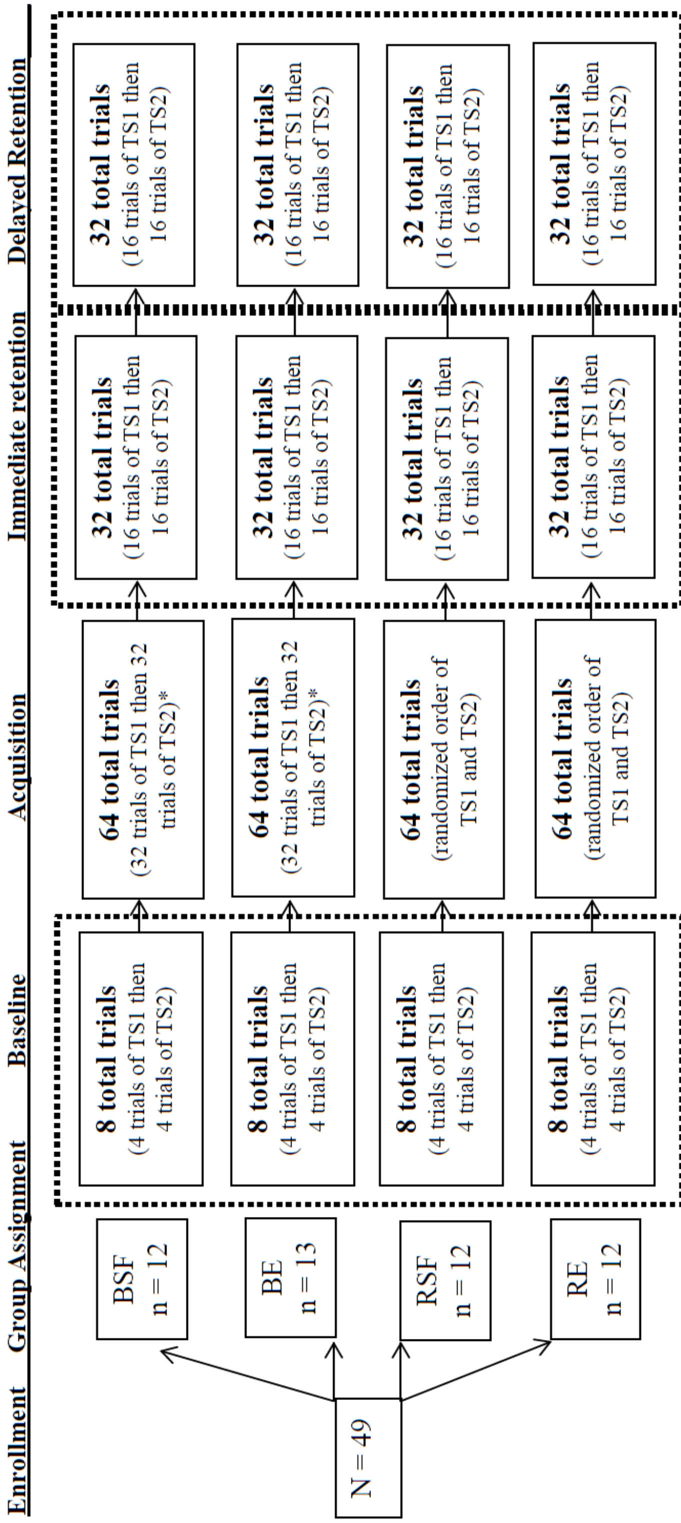
Figure captions

Figure 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 (200ms and 600ms), TS2= time sequence #2 (600ms and 200ms). Asterisk indicates that the blocked order was counterbalanced between participants.

Figure 2. **. Mean Timing Error (TE) in milliseconds for reach phase separated by condition.** Error bars represent +/- 1 standard error of the mean.

Figure(s)


Enrollment
Group Assignment
Baseline
Acquisition
Immediate retention
Delayed Retention
N = 49
BSF
n = 12
BE
n = 13
RSF
n = 12
RE
n = 12
8 total trials
(4 trials of TS1 then 4 trials of TS2)
8 total trials
(4 trials of TS1 then 4 trials of TS2)
8 total trials
(4 trials of TS1 then 4 trials of TS2)
8 total trials
(4 trials of TS1 then 4 trials of TS2)
64 total trials
(32 trials of TS1 then 32 trials of TS2)*
64 total trials
(32 trials of TS1 then 32 trials of TS2)*
64 total trials
(randomized order of TS1 and TS2)
64 total trials
(randomized order of TS1 and TS2)
32 total trials
(16 trials of TS1 then 16 trials of TS2)
32 total trials
(16 trials of TS1 then 16 trials of TS2)
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32 total trials
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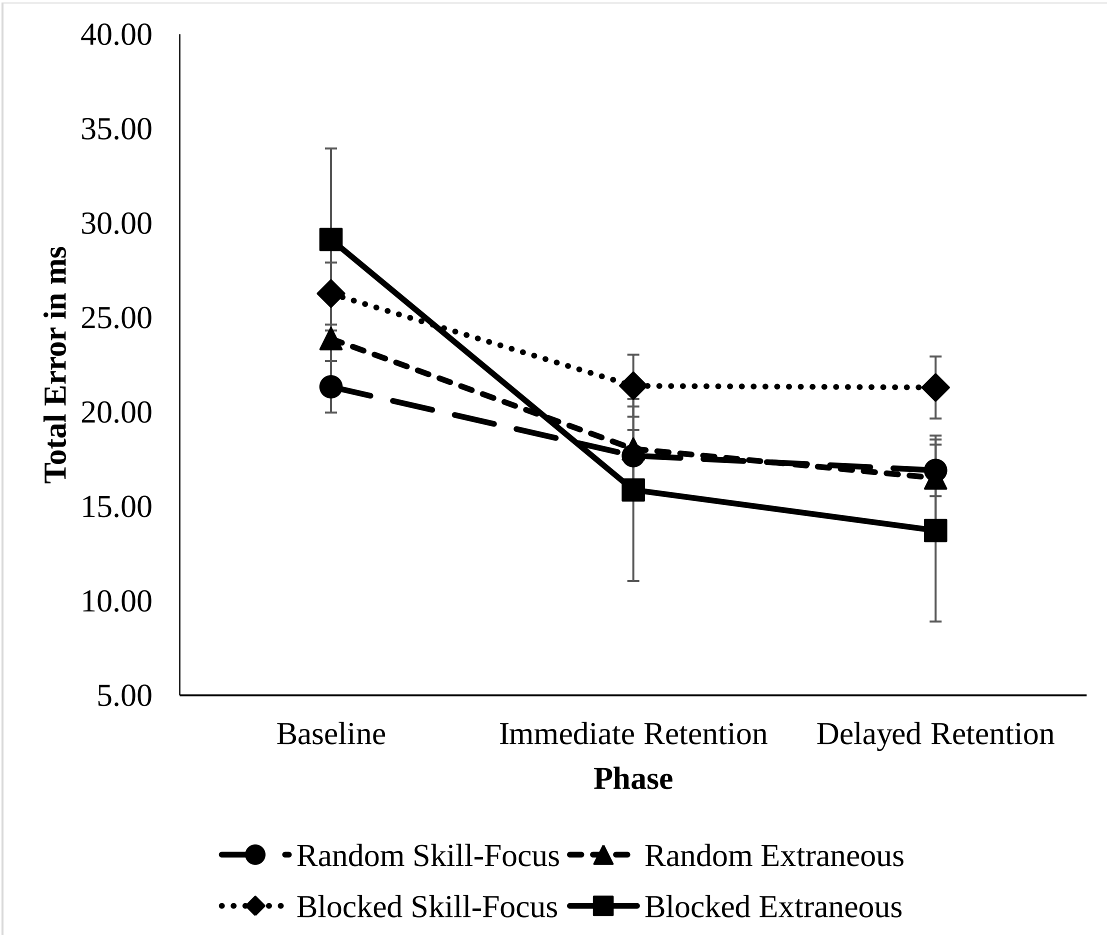
32 total trials
(16 trials of TS1 then 16 trials of TS2)

Figure(s)



40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
Total Error in ms
Baseline
Immediate Retention
Delayed Retention
Phase
Random Skill-Focus
Random Extraneous
Blocked Skill-Focus
Blocked Extraneous