PRACTICING ALONG THE CONTEXTUAL INTERFERENCE CONTINUUM: A COMPARISON OF THREE PRACTICE SCHEDULES IN AN ELEMENTARY PHYSICAL EDUCATION SETTING

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Abstract:

Few studies have explored the contextual interference effect with children. The findings from these investigations have produced inconsistent results. The purpose of this study was to investigate further how the contextual interference effect influenced children learning a fundamental motor skill in a physical education class. Elementary students (N=36) practiced overarm throwing following traditional blocked or random scheduling. They were compared to a third group of participants practicing the same tasks following a schedule with systematic increases in contextual interference. Analysis revealed that all three groups improved during practice. Post-test results revealed performance differences in favor of the group that practiced with systematic increases in contextual interference. The findings reported here extend the results of previous studies by demonstrating that children can learn a motor skill by practicing with systematic increases in contextual interference. Theoretical considerations are discussed, as well as the relevance of the findings for practitioners and avenues for future research.

Key words: *overarm throwing, motor learning, children, sport*

Introduction

Over the past 30 years numerous studies have examined contextual interference (CI) and its influence on motor skill learning (for reviews see Barreiros, Figueiredo, & Godinho, 2007; Brady, 1998; Magill & Hall, 1990). CI is defined as the interference in learning and performance that occurs when practicing a task in the context of other tasks (Schmidt & Lee, 2005). CI exists on a continuum, with blocked (i.e. low CI) and random (i.e. high CI) scheduling comprising the extreme ends of the CI spectrum. Much of the research investigating CI has compared the acquisition of skills following a random ordering of practice trials compared to practicing the same tasks following blocks of the same task trials. For example, in a basketball unit a physical education teacher would likely have students practice dribbling, passing, and shooting. In a low CI practice schedule (i.e. blocked), students would practice each of these tasks independently, in blocks of the same task trials. However, in a high CI practice schedule (i.e. random), students would participate in drills that would combine all three skills together randomly. Empirical comparisons of blocked and random scheduling typically yield learning benefits in favor of the practice schedule that introduced the learner to higher rather than lower CI (see Goode & Magill, 1986; Porter, Landin, Hebert, & Baum, 2007 for examples). In addition to comparing extreme high and low CI, some studies have investigated the learning benefits of practicing with a moderate amount of CI. For example, a study conducted by Landin and Hebert (1997) demonstrated that participants practicing basketball shooting displayed superior performance after practicing with a serial (i.e. moderate CI) order of trials compared to blocked and random scheduling (see also, Al-Ameer & Toole, 1993; Hebert, Landin, & Solmon, 1996; Pigott & Shapiro, 1984).

In a recent study, Porter and Magill (2010) proposed an alternative form of practice schedule which offered systematic increases in CI compared to traditional fixed schedules. In a pair of experiments, novices practiced golf putting (Experiment 1) and basketball-related passes (Experiment 2) with gradual increases in CI. Specifically, learners performed the first one-third of practice following a blocked schedule (low CI), then the middle portion of practice followed serial ordering (moderate CI), and the final one-third of practice followed a random practice schedule (high CI). Porter and Magill (2010) proposed that offering repeated trials in the initial stage of learning allowed learners to explore efficient problem-solving strategies, correct movement errors, and develop a basic movement pattern to achieve the action goal successfully. These are features of practice that Gentile (1972) considers critical in the initial stages of motor skill learning. Porter and Magill (2010) also suggested that as a learner practices, his or her skill level increases, effectively reducing the relative difficulty of the practiced task. Therefore to challenge the learner continually at the appropriate difficulty level, the practice environment should evolve and become progressively more challenging/demanding in accord to the learners newly improved skill level. One way to challenge a learner continually at higher levels is by increasing the amount of CI they encounter during practice. This conclusion is consistent with the “challenge-point hypothesis” (Guadagnoli & Lee, 2004) and Bjork’s perspective of “desirable difficulties” (1994, 1999).

Desirable difficulties (Bjork, 1994, 1999) refer to practice conditions which engage learners in effortful learning processes during practice, resulting in enhanced performance and learning. Bjork (1994, 1999) suggests incorporating various amounts of CI into a practice schedule is one way to introduce a desirable difficulty during motor skill acquisition. The challenge-point hypothesis (Guadagnoli & Lee, 2004) expands on this perspective by proposing that the difficulty of a practiced task is relative to the learner’s skill level. Meaning, as a learner becomes more skilled during practice, the functional difficulty of the practiced task is consequently reduced. This implies in order to challenge the learner appropriately at a “desirable” level of task difficulty the practice environment should change as the learner’s skill level changes. One way to accomplish this type of change is to vary the amount of CI in the practice schedule.

Recent studies have demonstrated a practice schedule that systematically introduces the learner to increases in CI is beneficial for motor skill learning in low and moderately skilled adults (Porter & Magill, 2010; Porter & Saemi, 2010). One question that remains unanswered is if the same learning benefits generalize to children. Few studies have explored the CI effect with children. The findings from these studies have produced mixed results. For example, some studies have shown that children can benefit from practicing with high or moderate CI (Pigott & Shapiro, 1984; Pollock & Lee, 1997; Vera & Montilla, 2003; Wegman, 1999), while others have not demonstrated a learning benefit (French, Rink, & Werner, 1990; Jarus & Goverover, 1999; Meira & Tani, 2003; Zetou, Michalopoulou, Giazitzi, & Kioumourtzoglou, 2007). Adding to the lack of consistent findings, one study demonstrated that blocked practice was more effective than random practice for first, second, and third grade students learning an anticipation timing task (Del Rey, Whitehurst, & Wood, 1983). This lack of consistent experimental evidence poses challenges for practitioners who desire to create optimal learning environments for young learners. Because of these mixed results, it is difficult to understand how CI impacts motor skill learning in children. It is well documented that motor and cognitive abilities are less developed in children compared to adults (Gallahue & Ozmun, 2006; Lambert & Bard, 2005; Payne & Isaacs, 2012). Therefore it is not surprising that young learners respond differently to CI compared to more developmentally mature learners. These cognitive and motor ability differences also suggest that practice schedules with higher levels of CI that enhance motor learning in adults may not be optimal for children, and an alternative form of practice may be ideal.

Therefore, the main purpose of this study was to further investigate how CI influences children learning a fundamental motor skill in a physical education context. Based on findings reported by Porter and Magill (2010), Gentile’s stages of learning model (1972), the theoretical perspectives of the challenge point hypothesis (Guadagnoli & Lee, 2004) and Bjork’s (1994, 1999) concept of desirable difficulties we predicted that children practicing with systematic increases in CI would perform better on a retention test compared to equally aged and skilled participants practicing with traditional blocked and random scheduling.

Methods

Participants

Male elementary school students (N=36, M age=10.47 years, SD=0.77) participated in this study. Participants were recruited from a local elementary school and were currently participating in the school’s physical education (PE) program. Informed consent was obtained from the elementary school, as well as parents of the participating students. All consent forms and experimental methods were approved by the university’s institutional review board.

Apparatus and task

The task was similar to the one used by Chiviacowsky, Wulf, Medeiros, Kaefer, and Tani (2008), and required participants to throw a tennis ball from three different start locations at distances of three, four, and five meters to a target consisting of a series of concentric rings on the floor. The target was similar to the ones used in related studies (Guadagnoli, Holcomb, & Weber, 1999; Porter, et al., 2007; Porter & Magill, 2010; Exp 1). This specific style of target was selected because a variation of this target had been used by PE teachers in the cooperating school to measure performance accuracy of a variety of motor skills (e.g. kicking, striking, underhand tossing). Because of this prior experience, we felt students could easily interpret their performances as they practiced the prescribed task. In addition, the cooperating teacher was familiar with this style of target, which promoted a simple integration of the target into the active PE class and facilitated the accurate performance measurements by the cooperating teacher. The center of the target had a radius of ten centimeters. Concentric rings with radii of 20, 30, 40, 50, 60, 70, 80, 90 and 100 centimeters were drawn around the center circle. These served as zones to assess the accuracy of the throws. If the tennis ball landed on the center target, 100 points were awarded. If the ball landed in one of the rings, or outside the marked target, 90, 80, 70, 60, 50, 40, 30, 20, 10, or zero points, respectively, were recorded. If the ball landed on a line separating two rings, the participant was awarded the higher score. This method of scoring was consistent with previous assessment techniques used by the cooperating PE teacher.

Presumably, all participants had experience with the overarm throwing motion utilized in the current study. This is a motor skill that all children had likely performed in recreational settings for several years. Because of this presumed prior experience the participants of this study where not considered novices, but they were not considered highly skilled either. Based on general observations made by the research team, all participants were considered low skilled at the initiation of the study. Moreover, none of the participants had prior experience with the specific task utilized in the current study.

Procedure

Participants were randomly assigned to one of three practice groups: Blocked, Random, or Increasing. All participants were instructed to use an overarm throwing motion to throw the ball so it hit the center of the target in front of them. Participants completed 27 trials from each of the three starting locations, totaling 81 practice trials each. Participants in the Blocked-group performed 27 same task trials from one start location, followed by 27 same task trials from a different location, and concluded practice with 27 same task trials from the final start location. The order of start locations was counterbalanced across the participants. Consistent with previous studies, participants in the Random-group performed 81 practice trials following a random schedule, with the constraints that no more than two consecutive trials were performed from the same start location and 27 trials were conducted from each start location. Each participant in the Random-condition followed a unique practice schedule. Similar to the Porter and Magill (2010) study, participants in the Increasing-condition practiced trials 1-27 following a blocked practice schedule (i.e. low CI), trials 28-54 followed a serial schedule (i.e., moderate CI), and trials 55-81 followed a random schedule (i.e. high CI). When participants were following the blocked portion of the increasing practice schedule (i.e. trials 1-27), they completed nine same task trials from each start location. When participants completed the serial portion of the increasing practice schedule (i.e. trials 28-54), they practiced nine trials of each throwing task one at a time in a repetitive order. For example, completing one trial from the three-meter start position, followed by one trial from the four-meter start position, then one trial from the five-meter start position, then the same pattern was repeated until nine trials were completed from each starting position. When completing the random portion of the increasing practice schedule (i.e. trials 55-81), participants once again performed nine trials from each start position in a random order with the constraint that no more than two same task trials were performed consecutively. Each participant in the Increasing-group practiced with a counterbalanced/re-randomized practice schedule. All participants returned the following day and completed a twelve-trial retention test. During the retention test, participants followed a novel alternating order of throws from the three- and five-meter distances. Participants completed six throws from each location.

All practice and testing trials took place during normal PE class periods. Participants retrieved their thrown-ball after each attempt. The cooperating teacher recorded the accuracy score of each thrown-ball and verbally reported the score to the student. This form of skill assessment was consistent with prior skills testing conducted in the PE class. No additional feedback was provided to participants. During all practice and testing sessions, the cooperating teacher stood in the same location, which was perpendicular to the center of the target. When participating students were not involved in the procedures of the current study, they were active in non-throwing activities with other students. Parents of participating students were asked not to allow their child to participate in outside of school overarm throwing activities for the two-day duration of the study. It took participants approximately 15-20 minutes to complete the practice trials. This *amount* of practice is consistent with motor skill development recommendations made in a popular elementary PE methods text (Thomas, Lee, & Thomas, 2003)

Results

The scores of the first trial for each start location (i.e. three, four, and five meters) were averaged within each of the three groups (i.e. Blocked, Random, and Increasing) and were analyzed using a one-way analysis of variance (ANOVA). Results indicated the groups were similar at the initiation of practicing from each of the three throwing distances, $F(2, 35)=0.014$, $p=.98$ (see Figure 1). Practice trials were analyzed using a 3 x 9 (Practice Schedule x Trial Block) ANOVA with repeated measures on the last factor. Identical to the method used by Porter and Magill (2010), trial blocks comprised the mean scores for nine trials, which included three trials from each of the three practice locations. For example, trial block 1 consisted of the scores from the first three attempts from each start location. Trial block 2 consisted of scores from the next three attempts from each start location. This analysis indicated a significant main effect for Practice Condition, $F(2, 33)=4.19$, $p<.024$, $\eta^2=.203$. The Trial Block main effect was also significant, $F(8, 264)=3.26$, $p<.001$, $\eta^2=.090$. *Post-hoc* analysis indicated that all three conditions improved during practice. The Practice Condition x Trial Block interaction was not significant, $F(16, 264)=0.44$, $p=.97$.

Retention test scores were analyzed using a one-way ANOVA. This analysis indicated a Practice Condition main effect, $F(2, 35)=3.51$, $p<.041$, $\eta^2=.175$. A Tukey-Kramer *post-hoc* analysis indicated the Increasing group (M=70.97, SE=2.28) was significantly better than the Blocked group (M=59.02, SE=4.16). The *post-hoc* analysis also indicated the Increasing (M=70.97, SE=2.28) and Random groups (M=63.19, SE=2.97) were not significantly different. In addition, the Random and Blocked groups were not significantly different (Figure 1).

Discussion and conclusions

The purpose of the current study was to investigate how CI influences children learning a throwing task in a PE context. Traditional blocked and random scheduling was compared to an alternative form of practice where learners practiced with systematic increases in CI. We hypothesized that the children practicing with systematic increases in CI would perform better on a retention test compared to the participants practicing with blocked and random scheduling. Albeit weak, the results of the current study provide some evidence in support of the experimental hypothesis. Specifically, the only significant differences observed during the retention test were between the Blocked and Increasing practice conditions. Thus, the only benefits observed in the current study, as a result of practice, were demonstrated by the participants practicing with gradual increases in CI compared to the participants who practiced with blocked scheduling.

Recent studies (Porter & Magill, 2010; Porter & Saemi, 2010) demonstrated practicing with incremental increases in CI facilitates motor skill learning in novice and moderately skilled adults. The results of the current study partially extend those findings by demonstrating that benefits are observed with children learning a fundamental motor skill in a PE setting when they practice with systematic increases in CI compared to practicing with blocked scheduling. As noted above, investigations exploring the CI effect with children have produced mixed results, with some studies showing learning benefits of practicing with moderate to high CI (Pigott & Shapiro, 1984; Pollock & Lee, 1997; Vera & Montilla, 2003; Wegman, 1999), while other studies have not (Del Rey, et al., 1983; French, et al., 1990; Jarus & Goverover, 1999; Meira & Tani, 2003; Zeto, et al., 2007). The results reported here

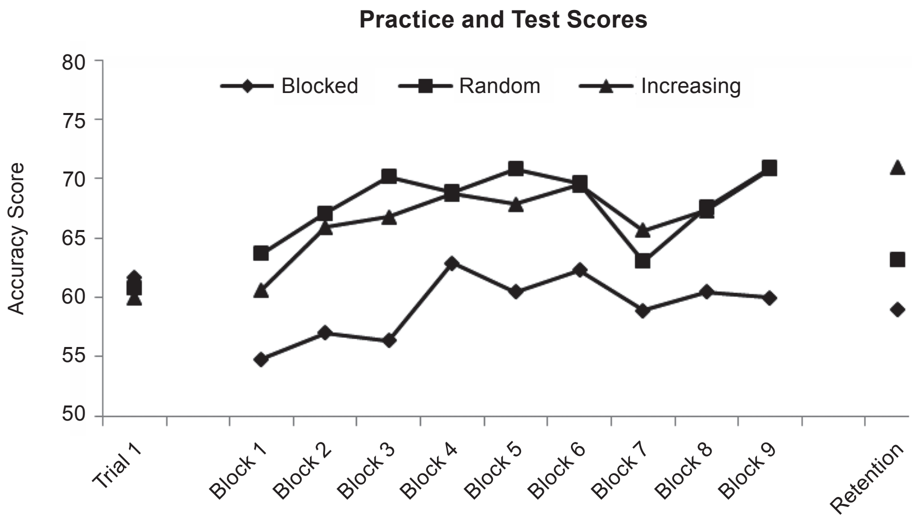

Figure 1. Accuracy scores for practice and retention test trials. Trial 1 is the average of the first trial from each location within each practice condition. Each Block of practice trials is comprised of the average of nine trials (three from each location).

provided initial evidence that practicing with systematic increases in CI may create a better learning environment for young learners compared to practice schedules with fixed low amounts of CI. The results also suggest that random practice environments may be no more effective than blocked scheduling for children learning the overarm throw.

As summarized by Porter and Magill (2010), research investigating stages of learning and information processing theory offer possible reasons why a practice schedule with gradual increases in CI may help create an enhanced learning environment for children. Gentile (1972) suggests when a learner is in the early stages of acquiring a motor skill they need repeated trials to correct movement-related errors, explore new movement patterns, and determine a way to achieve the action goal successfully. However, it is well documented that if learners only practice with blocked scheduling, they will develop a context dependency, which depresses motor skill learning (Magill, 2011). Perhaps offering a practice schedule with initial blocked trials may have allowed learners to develop effectively a basic throwing motor program to achieve the action goal of the task used in the present study. Then a progression to later serial and random scheduling not only discouraged the development of a context dependency but encouraged the efficient refinement of the motor program resulting in elevated performance compared to the blocked-scheduling condition. Future research using performance production measures is needed to validate this possibility.

An additional factor that could potentially influence the effects of CI with young learners is children's limited information-processing capabilities. Practicing a motor skill following a random practice schedule can be cognitively overwhelming for low-skilled learners (Guadagnoli, et al., 1999; Hebert, et al., 1996). The potential overwhelming characteristic of random practice may be exacerbated in children because they have reduced information processing capabilities compared to adults (Lambert & Bard, 2005; Sullivan, Kantak, & Burtner, 2008). The challenge point hypothesis (Guadagnoli & Lee, 2004) predicts if the practice environment is too challenging, then learning will be jeopardized. Consistent with this hypothesis, Bjork (1994, 1999) proposes that an optimal learning environment should create a constant and consistent amount of difficulty. A practice schedule that starts with low CI and progressively changes to higher amounts of CI may effectively improve a young learner's information processing abilities, in conjunction with improved skill development. Because of the parallel development between skill level and information processing ability (Porter & Magill, 2010), a practice schedule with systematic increases in CI may continually challenge a young learner at an appropriate difficulty level, resulting in successful motor skill learning. Research findings reported by French, Rink, Rikard, Mays, Lynn, and Werner (1991) provide additional support for this conclusion. French et al. (1991) demonstrated that when the level of practice was too difficult, young athletes did not improve their skill execution of the volleyball serve and set. However, following a practice progression of low to high skill difficulty resulted in elevated performance. Consistent with the findings of French et al. (1991), and conclusions presented by Porter and Magill (2010), the results of the current study suggest the practice schedule that changed (i.e. Increasing-CI) to match the developing skill level facilitated motor skill learning compared to the schedule that was constant and repetitive as was the case with the blocked schedule.

It is worth noting that the Blocked-group generally displayed poorer performances during acquisition compared to the Random and Increasing groups, and the Blocked and Random groups were not significantly different during the retention test. Rather than considering this a lack of a "typical" CI effect, we suggest this is a common finding for CI research using applied motor skills, especially those associated with sport and physical education (Barreiros, et al., 2007; Brady, 2008).

The findings reported here make a unique contribution to physical education, sport pedagogy, and motor learning literature by demonstrating that children can effectively learn a sport skill by practicing with gradual increases in CI within PE contexts. However, there are limitations to the current study, which should be addressed in future research. For example, it is worth noting that the retention test differences between the Increasing and Random groups were not significant using an alpha of .05. We suspect that a larger participant sample, or extended practice trials may have resulted in significant testing differences. Future research should use a larger sample and more practice trials as these have been shown to be limiting factors in the CI effect (Shea, Kohl, & Indermill, 1990).

The goal of the current study was to further investigate how CI influences motor skill learning in children. The findings reported here extend the results of previous studies by demonstrating that children can learn a motor skill more effectively by practicing with systematic increases in CI compared to following blocked-scheduling with low CI. However, many questions remain about the effectiveness of this form of practice. Consequently, we have proposed many directions for future research. The pursuit of these questions will make small contributions to the large body of literature striving to bring understanding to the motor learning process. Future studies should continue to investigate motor skill learning in practical settings. Doing so will increase the likelihood that practitioners are using evidence-based practices to develop their students' and athletes' motor abilities.

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TRENIRANJE U UVJETIMA KONTINUUMA OTEŽAVAJUĆEGA KONTEKSTUALNOG UTJECAJA: USPOREDBA TRIJU RAZLIČITIH NAČINA VJEŽBANJA NA SATOVIMA TJELESNE I ZDRAVSTVENE KULTURE U OSNOVNIM ŠKOLAMA

Premalo je istraživanja koja su ispitivala učinke kontekstualnog utjecaja na učenje motoričkih znanja u djece. Rezultati tih istraživanja bili su proturječni. Cilj ovog istraživanja bilo je daljnje istraživanje učinaka kontekstualnog utjecaja na djecu koja uče osnovna motorička znanja na nastavi tjelesne i zdravstvene kulture. Učenici osnovnih škola (N=36) vježbali su osnovno bacanja loptice jednom rukom iznad glave u uvjetima tradicionalne, blokirane ili nasumične strukture kontekstualnog utjecaja. Rezultati tih učenika uspoređeni su s rezultatima treće grupe ispitanika koji su izvodili/vježbali isti motorički zadatak u uvjetima sustavnog povećanja otežavajućega kontekstualnog utjecaja. Rezultati su pokazali da su sve tri grupe ispitanika napredovale tijekom vježbanja. Rezultati finalnog mjerenja pokazali su također da je veći napredak zabilježen u grupi koja je vježbala u uvjetima sustavnog povećanja otežavajućega kontekstualnog utjecaja. Rezultati ovog istraživanja proširuju spoznaje dosadašnjih znanstvenih istraživanja ukazivanjem na činjenicu da djeca mogu učiti motorička znanja u uvjetima sustavnog povećanja otežavajućega kontekstualnog utjecaja. U članku su raspravljene teorijske osnove eksperimenta i praktičan doprinos dobivenih znanstvenih spoznaja te su predstavljene preporuke za daljnja znanstvena istraživanja.

Ključne riječi: *osnovno bacanje iznad glave, motoričko učenje, djeca, sport*