

# Specificity Part VI: The effect of Practice Distribution & Contextual Interference on Performance & Learning



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## Abstract

Hull (1943) was the first to formally examine the effect of practice distribution on performance and learning. He found that given an equal number of trials, distributed practice for both cognitive and motor tasks produced better performance and skill acquisition than massed practice (Wilson, 2005).

William F. Battig (1956) was a pioneer in the study of randomized practice. The reigning paradigm of Battig's day was that learning was directly correlated to performance—meaning that the greater performance was the greater retention would be. However, Battig suggested just the opposite. Battig (1956) found that the more difficult a task was for a participant, the more they retained. Battig hypothesized that *intertask* facilitation (the transfer of one motor task, to a similar motor task) was enhanced random practice, which caused *intratask* interference (or contextual interference; the hindrance caused by attempting to keep multiple items in working memory at once).

Building on the findings of Hull and Battig, the purpose of this paper was to analyze the effect of practice distribution and contextual interference on performance and learning under various scenarios.

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## Mass vs. Distributed Practice

Mass versus distributed practice has been covered extensively in past issues of JHR. Here is a quote from Wilson (2005) in [Hull's Quantitative Equation on Human Performance](#) to introduce the topic:

Hull was the first to examine the effect of massed practice. Massed practice can be defined as practice in which work is longer than rest periods (Schmidt, 1999). In weight training this would entail 1 minute sets, with only 30 seconds of rest between sets. Several reviews on the subject (Lee and Genovese, 1988, Newell et al. 1988) support what is known as Hull's 8<sup>th</sup> postulate. Hergenhahn and Olson (2005) summarize the 8<sup>th</sup> postulate as follows: 'Responding Causes Fatigue, which operates against the elicitation of a conditioned response.' This is known as reactive inhibition. Reactive inhibition entails the organism reacting to inhibit the action which caused fatigue. Bourne and Archer (1956) had 5 groups perform a tracking task with 0, 15, 30, 45, and 60 seconds of rest. It was found that as rest increased that performance increased. Of particular interest is that performance was severely depressed in the zero second condition, however after a day of rest performance had risen drastically from the end of the last trial.

The effect of improving in the absence of practice is known as reminiscence (Hergenhahn and Olson, 2004). This effect denoted by Hull provides the current basis for tapering. According to Hull (1943) suggested that reactive inhibition was masking the positive effects of practice, and a period of rest was needed to dissipate this effect.

Here is an additional quote from Wilson and Wilson (2005) [Tapering Part 2 - Manipulation of Load for Peak Performance](#) further clarifying this topic:

### Mass vs. Distributed Practice

...If volume is analyzed over a one week period, as opposed to a single training session, then frequency of training will have a direct influence on this training variable. Therefore, lowering weekly frequency can also lower weekly volume. In this context, an optimal combination of frequency and training volume should be established.

The earliest studies to examine such a combination entailed massed versus distributed practice. Massed practice can be defined as practice in which the work time period is longer than the rest time period (Schmidt and Lee, 1999). Distributed practice can be defined as practice in which the rest period is longer than the work period (Schmidt and Lee, 1999). In weight training, 1 minute sets with 20 seconds of rest would be massed scheduling, whereas 30 seconds of work followed by 1 minute of rest would constitute distributed practice. Hull (1943, 1952) inspired the examination of this phenomenon (See Wilson, 2005 on Hull's contribution to performance for a review) and found that given equal trials, distributed practice for both cognitive and motor tasks

produced better performance and skill acquisition than massed practice (Wilson, 2005; Schmidt and Lee, 1999).

The relative distribution of time has also been found to have an effect on skill acquisition. For example, in a classic study, Archer (1916) found that if a skill is performed for a total of 34 days, then a group of subjects who performed the skill 5 days a week for 7 weeks did not increase performance to the same extent as participants who performed the same total of 34 days spread over 12 weeks, at a frequency of 3 days a week

In this context, Hakkinen and Kallinen (1994) investigated the effect of distribution of volume on neuromuscular adaptations in 10 strength athletes. The athletes participated in two 3 week conditions. In both conditions volume was held constant; however, in condition one the volume was distributed in one session. In condition two, the volume was divided into two sessions, at separate times in the same day. No significant strength or cross sectional area gains were found in condition one. However, in condition two, both an increase in strength and cross sectional area were found. They concluded that 'The present results with female athletes suggest that the distribution of the volume of intensive strength training into smaller units, such as two daily sessions, may create more optimal conditions not only for muscular hypertrophy but by producing effective training stimuli especially for the nervous system. These kinds of training conditions may lead to further strength development in athletes being greater than obtained during "normal" strength training of the same duration.'

In another study Mclester et al. (2000) investigated a comparison of 1 day and 3 days per week with equal volume resistance training in experienced subjects. Participants trained various upper and lower body exercises over 12 weeks. In group one, 3 sets per exercise were performed in one day during the week. In group two, one set was performed on three separate days. It was found that the higher frequency group gained 38 % more strength than the lower frequency condition, suggesting that higher frequency, even when volume is held constant, is superior for strength gains. Further, greater lean body mass gains were found in the higher frequency than lower frequency group.

Building on the findings of Wilson (2005), and Wilson and Wilson (2005), Wilson, Wilson (2005), will add the following incites to this topic:

- Differentiation between massed and distributed practice
- Studies on the effect of massed and distributed practice on performance and learning for discrete and continuous tasks under various scenarios
- Theoretical Rationales
- Vince Lombardi

### **Mass vs. Distributed Practice Continued...**

Wilson and Wilson (2005) suggested that "Massed practice can be defined as practice in which the work time period is longer than the rest time period. [And that] distributed practice can be defined as practice in which the rest period is longer than the work period."

However, the current authors suggest that mass vs. distributed practice should be viewed on a continuum—meaning that practice is relatively more massed or distributed. For instance, if a set of squats lasts for 30 seconds, a 1 minute rest period and a 5 minute rest period would both be considered distributed, using the former definition. But, if viewed on a continuum, the 5 minute rest period was relatively more distributed than the 1 minute rest period. The current authors will therefore view these practice conditions on a continuum for the remainder of the article.

### **The Effect of Mass vs. Distributed Practice on Performance and Learning of Continuous Tasks**

A continuous task is a task with no discernable beginning or ending point. This would include swimming, running, and driving a car. Hull (1943) was the first to formally examine this phenomenon, and found that given an equal number of trials, distributed practice for both cognitive and motor tasks produced better performance and skill acquisition than massed practice (Wilson, 2005). And this has been supported by numerous studies since then (Schmidt and Lee, 1999). These studies will be analyzed subsequently.

Bourne and Archer (1956) investigated the effects of practice distribution on a pursuit rotor tracking task. Participants were divided into five experimental conditions. All participants performed 21 acquisition trials with work periods of thirty seconds. Participants in conditions one through five were given 0, 15, 30, 45, and 60 seconds of rest between trials, respectively. Comparison of tracking performance among conditions found that the longer the rest period was the better tracking performance was. The theoretical rationale for this is reactive inhibition—the organism was acting to inhibit the action which caused fatigue. Thus, inadequate rest would not allow for optimal recovery, resulting in decreased performance.

To assess the effect of practice distribution on learning a pursuit rotor tracking task participants were instructed to perform a retention trial with a 5 minute rest period following the last acquisition trial. The retention trial consisted of 9 trials, which were all massed, with 0 seconds of rest between 30 seconds of work. The authors postulated that if reactive inhibition was entirely responsible for the performance difference seen during acquisition trials, then the groups should have similar performances in the retention trials when given equal rest. Results found that the longer the rest period was in the acquisition trial, the better performance was during the first retention trial, suggesting that distributed practice had a relatively permanent effect.

Some interesting findings were that all participants improved from the last acquisition trial, to the first retention trial, after a 5 minute period of rest. This is known as reminiscence, or improving in the absence of practice. Hull (1943) suggested that reactive inhibition was masking the positive effects of practice, and a period of rest was needed to dissipate this effect. It is also important to note that the differences between the groups from the last acquisition trial to the first retention trial were smaller, suggesting that some of the performance effects seen were due to temporary influences. Results still found that the longer the rest period was in the acquisition trial, the better performance was at the end of the retention trial. Lastly, massing the practice during retention trials depressed performance in all groups.

One possible problem with this study is that a 5 minute rest period before the retention trial may not have been adequate to dissipate the reactive inhibition, meaning that the retention trial may have been influenced by the temporary nature of RI, rather than the relatively permanent nature of learning and/or both. However, a number of similar studies have yielded similar results to Bourne and Archer (1956), with longer retention trials of 1 day (Adams, 1952) and 10 weeks (Reynolds & Bilodeau, 1952), suggesting that distributed practice is better for learning continual tasks.

Ammons (1950) examined the relatively permanent improvement in performance from acquisition trials during distributed practice. Participants received rest periods of 0 and 20 seconds, and up to 12 minutes and 24 hours between 20 second acquisition trials on a pursuit rotor task. A 20 minute rest period followed the 36th practice trial, and thereafter the participants performed 36 transfer trials with no rest between trials. At first, distributed practice was better, but as the trials progressed, only small differences were seen between the groups. However, participants were asked to return to the lab one day later for another retention trial. Results found that during the first retention trial, distributed practice was superior to massed, suggesting that the benefits of distributed practice are relatively permanent.

In a long term study, Murphy (1916) found that participants practicing throwing a javelin for a total of 34 days, 5 days a week for 7 weeks, did not increase performance to the same extent as participants who performed the same total of 34 days spread over 12 weeks, at a frequency of 3 days a week. The retention trials took place at the end of the 34 days, and again three months later.

Another long term study by Baddeley & Longman (1978) investigated the effects of massed and distributed practice on learning for postal workers who trained on a keyboard. Participants trained for 60-80 hours total using one of four practice regimens. Practice was performed once or twice per day, for one to 2 hours per session. Retention tests were performed 1, 3, and 9 months later. Results indicated that the group that practiced twice a day, two hours per session, had the poorest performance throughout the retention trials; and while the group that practiced twice a day for just one hour was best in the first retention trial, after 9 months, the other three groups were very similar in performance. However, the most distributed group only trained for a total of 60 hours, slightly skewing the results.

And numerous other studies testify to the benefit of distributed practice on continuous tasks (for a meta-analysis and several reviews supporting this, refer to Donovan, Radosevich, 1999; Lee, Genovese, 1988; Lee, Genovese, 1989; Lee, Genovese, 1989, B).

### **The Effect of Mass vs. Distributed Practice on Performance and Learning of Discrete Tasks**

A discrete task is a task with a discernable beginning and ending point. This would include most weight lifting skills and swinging a bat or a golf club. Discrete tasks are characterized by rapid movements with very short movement times (I.e. less than 1 millisecond).

Recently, Dail et al. (2004) examined the effects of practice distribution on learning a discrete task (golf putting) and the relationship of judgment of learning (JOL) to the practice protocol and length of retention interval. Studies have found that the learner's confidence is enhanced with better performance in acquisition (James, 2000). In this context, the authors suggested that participants in the more distributed group, who typically have better acquisition trials, would have more confidence on the retention trails. Ninety participants—who were equally left and right handed, male and female—were randomly assigned to distributed and massed conditions. Participants in the distributed condition putted 60 times a day for 4 days, for a total of 240 puts. Participants in the massed group putted 240 times in one session. During the acquisition trials participants were asked, "If you were provided no further practice opportunities from this point forward, what do you predict your average score would be on the first 10 putts (trials) of the retention test -- (1/7/28) days from now?" Participants in each group returned 1, 7, and 28 days later for a retention trial, in which they putted 60 golf balls. Participants in the distributed groups had superior results during retention trials when compared to massed groups, with no differences seen between 1, 7, and 28 day retention trials. Further, as expected, participants performing distributed practice who had better acquisition performance scores predicted better retention performance scores than participants who performed massed practice.

Shea et al. (2000) had participants practice within one day (massed) to across days (more distributed) using a discrete key-press task. Results found that participants who performed distributed practice had significantly fewer errors in acquisition and retention 1 day later than participants who performed massed practice.

Thankfully, the field of science has done a great deal of research on the effects of mass vs. distributed practice on discrete tasks in the form of lifting weights. The following paragraphs will focus in on these studies.

Kraemer (1997) investigated the effects of practice distribution on performance during the leg press and bench press. Participants were given 3 versus 1 minute rest periods. Results indicated that participants in the distributed group (3 minutes rest) achieved 10 reps with a 10 RM for 3 sets on both apparatuses. However, participants in the massed group (1 minute rest) performed 10, 8, and 7 reps, respectively. This is in support of the findings of Tharion et al. (1991), who displayed that shorter rest periods during weight lifting resulted in greater psychological anxiety and fatigue.

Robinson and colleagues (1995) had participants perform squats over a 5 week period of time, with 3 or 30 second rest periods between sets. Results demonstrated a 7% increase in squatting performance in the 3-minute condition, and only a 2% increase in squat performance in the 30 second condition. Similarly, Pincivero and colleagues (1997) found a 5-8% greater increase in weight lifting performance in the criterion task when participants had 3 minute rest periods compared to 40 second rest periods.

Hakkinen and Kallinen (1994) investigated the effect of distribution of volume on neuromuscular adaptations in advanced weight lifting athletes. The athletes participated in two 3 week conditions. In both conditions volume was held constant; however, in condition one volume was done in one session. In condition two, the volume was divided into two sessions, at separate times in the same day. No significant strength or cross sectional area gains were found in condition one.

However, in condition two, both an increase in performance and cross sectional area was found. They concluded that 'The present results with female athletes suggest that the distribution of the volume of intensive strength training into smaller units, such as two daily sessions, may create more optimal conditions not only for muscular hypertrophy but by producing effective training stimuli especially for the nervous system. These kinds of training conditions may lead to further strength development in athletes being greater than obtained during "normal" strength training of the same duration.' The current authors fully understand that the term "strength" is flawed, but the point for distributed practice is nicely made, nonetheless.

In another study Mclester et al. (2000) investigated a comparison of 1 day and 3 days per week with equal volume resistance training in experienced participants. Participants trained various upper and lower body exercises over 12 weeks. In group one, 3 sets per exercise were performed in 1 day during the week. In group two, one set was performed on 3 separate days. It was found that the higher frequency group had 38% higher performance gains than the lower frequency condition, suggesting that higher frequency, even when volume is held constant, is superior for performance. Further, greater lean body mass gains were found in the higher frequency than lower frequency group.

### **Theoretical Rationales for the Benefit of Distributed Practice on Learning**

The mechanisms by which distributed practice yields its benefits have yet to be satisfactorily explained. However, much time and interest has been invested into this topic, and several theories exist.

Larry Jacoby posited that "the value of a repetition lies in the degree to which it promotes full consideration of the information in each presentation and that processing can best occur when the information is forgotten from trial to trial" (Dail et al., 2004). In other words, in order to maximally retain information, the learner needs to go through the entire learning process on each trial. Thus, if the information was stored in working memory after the first trial, during the second trial the information would not have to be fully processed, impeding learning (Cuddy and Jacoby, 1982; Jacoby, 1978; Jacoby & Dallas, 1981). Jacoby suggested that this could be induced by the "spacing effect," which suggests that performing skills that have been repeated with long spaces between trials, is more beneficial to learning than performing skills with little or no spacing between trials. It is easy to see how this theory can be used to explain the benefits of distributed practice. This hypothesis will be discussed more under the topic of random vs. blocked practice.

Next, the encoding variability hypothesis suggests that the more neurological routes, which are created to get to a piece of information, the greater the probability of retrieving that information (Dempster, 1996). From a behavioral standpoint, Guthrie (1952) suggested that learning was a product of attaching more and more stimuli to responses. In this context, it is suggested that distributed practice creates, "more possibilities for variable contexts [to] exist due to longer, more frequent rest periods in which differences in subjective contexts can be created (Dail et al., 2004)."

Sawyer (2005) suggests that the learner thinks about positive experiences during rest, thereby reinforcing correct movements. In this context, distributed practice would allow participants to rest more between sets and workouts, permitting them to mentally reinforce correct movement.

Sleep may also play an important role. Evidence suggests that sleep may facilitate learning (Karni, Tanne, Rubenstein, Askensasy, & Sagi, 1994; Stickgold, Hobson, & Fosse, 2001; Stickgold, James, & Hobson, 2000). In this context, enhancing the amount of sleep between trials in a distributed format may enhance learning partially through this mechanism. For instance, if you perform 10 sets of squats on Monday in a massed schedule, or 5 sets on Monday and 5 sets on Wednesday in a distributed schedule, you would get to sleep at least 2 times between trials in the latter schedule, enhancing learning.

Another factor is specificity. During a retention trial, the participants will be fresh, with little physiological fatigue. A distributed format comes closer to matching this state; however, massing practice results in an accumulation of fatigue, which is a much different state than the retention trial. This is in line with the set point theory, which suggests that there are various temporary internal states, such as arousal, that underlie or support the skill in question (Schmidt and Lee, 1999).

Further, in numerous sporting events, such as baseball, power lifting, and golf, the practice is clearly distributed. Therefore, practicing in a distributed fashion would be closer to the game time environment, helping to maximize transfer. Further, the athlete must be cognizant of the rate and pattern of each rep for maximum transfer. In this context, high physiological fatigue, caused by mass practice, is suggested to impair performance and lead to sloppy form, and often injuries (Schmidt and Lee, 1999).

One acute training variable that can be used to enhance performance is manipulation of exercise intensity, or the percentage of a 1RM. In this context, distributed practice allows an athlete to maximize exercise intensity and perform more total work than massed practice. Decreased performance between sets during massed practice can be attributed to the accumulation of metabolic bi-products such as lactic acid (Wilson, 2003). And the benefits of distributing the work to several workouts can be partially attributed to enhanced glycogen stores (King, 2003).

Hormones must also be taken into consideration. Cortisol is an extremely catabolic hormone, which has been found to selectively degrade fast twitch fibers (Wilson and Wilson, 2005). Consequently, this hormone is released proportional to exercise intensity and duration. So the longer the workout, the more cortisol will be released. Further, evidence suggests that cortisol is released in response to metabolic needs, meaning that hypoglycemia, which can be promoted by a long training session, would enhance cortisol release. And numerous other catabolic hormones will also be released to a heightened extent. In this context, separating the workouts up into two sessions would suppress total cortisol release, among other catabolic hormones. For more information on this topic, refer to Wilson and Wilson, 2005, in their articles on hormones in [JHR, January 2005](#).

### **Distributed Practice vs. Total Training Time**

While distributed practice appears to be superior for learning, the issue is that you cannot perform as many practice trials as with massed practice. For instance, in the previously mentioned study of Baddeley and Longman (1978), though the most massed group performed worst, they performed the same amount of practice in half the amount of time or less than the other groups. If the group was allowed to train

for the same allotted amount of time, and got even more practice in than the other groups, perhaps they would have achieved better results.

So there is a trade-off here. Distributed practice is superior to massed practice for learning, given an equal number of trials. However, it takes much more time to complete those trials. More studies need to be done to investigate this trade-off, and find an optimal combination between the two.

However, while practicing more via mass practice may have benefit, it may also have a downside. First, massing the practice puts a lot more stress on the body and can promote overtraining. Moreover, the athlete risks the danger of conditioning reactive inhibition. What the athlete must be sensitive to is that you can actually condition reactive inhibition, such that when the athlete is confronted with a given training task or environment the body will react to inhibit the task *before* it causes fatigue, diminishing performance. Wilson (2005) masterfully explains this topic and how to avoid such a predicament in [Hull's Quantitative Equation on Human Performance](#).

### **More on Specificity & Practice Distribution**

Evidence strongly suggests that distributed practice is superior to massed practice for both discrete and continuous tasks. However, specificity must be taken into account. In this context, if an athlete performs a sport such as wrestling, in which the practice may be massed during competitions, it would be beneficial to practice at least in part using shorter rest times (Flick and Kraemer, 2004). Evidence suggests that such a training protocol will produce several advantageous adaptations such as an increased capacity to clear lactic acid. For more information on this topic, refer to Wilson and Wilson's (June, 2004) articles, bioenergetic transfers in the biosphere 1-3, in JHR.

#### **Important Note:**

It is vital that the reader understand that primary focus of this article is to cover various conditions of practice which optimize sensory motor skill acquisition. In this context, though distributed practice appears to be superior for motor learning of both discrete and continuous skills, it does not mean bodybuilders should not mass practice. Studies actually suggest that massing the practice during each set may have immense benefit for hypertrophy gains (Fleck & Kraemer, 2004). Ways to manipulate mass vs. distributed practice for bodybuilders will be covered in a future issue of JHR by Wilson and Wilson (2005), who will cover 5 acute training variables—including rest periods. Stay tuned!

### **Vince Lombardi**

"Winning is not a sometime thing; it's an all the time thing."

---Vince Lombardi



Vince Lombardi is considered by many the greatest coach in the history of football—and all of sports. His star-studded career included a 105-35-6 record, and not *one* losing season. During Vince's 9 year tenure as head coach the Green Bay Packers developed into one of the NFL's greatest dynasties, collecting six division titles, five NFL championships, and two Super Bowls (I and II). The NFL named Vince the 1960s Man of the Decade. He was later introduced into the illustrious hall of fame in 1971. But perhaps the greatest honor Vince received was when the NFL changed the name of the "Super Bowl Trophy" to the "*Vince Lombardi* Super Bowl Trophy," the leagues most prestige's award, forever etching his name into history.

It seemed that while teams would fade at the end of the year, Green Bay would get better. The reason being: they were a rested group. It turns out that Vince absolutely understood the issue of reactive inhibition. The following is an outline of his weekly in-season training schedule (Sawyer, 2005).

Monday: On Monday, the team would be battered and bruised because of the game they had on Sunday. So, Vince had his players do a light workout (active recovery) such as walking 10 yards, then running 10, then walking 20, then running 20, etc., until they got a full lap in. Then they would have a meeting and discuss strategies for the subsequent game. In the meantime, injured players would be treated.

Tuesday: The players would start hitting, and also go over the plays that would be used for the next game.

Wednesday: This was a nasty day—it was controlled violence, but full speed practice.

Thursday: Thursday the players dissipated the reactive inhibition by playing volleyball and other fun non-contact games.

Friday: Vince had the players practice at full game speed, but no contact. They would also run scripts for the game—if they could not perform the plays effectively on Friday, then he would throw them out on Sunday.

Saturday: This was a light day, and the kickers would get their work in.

Sunday: Game day! The players were well rested and ready to do some damage during the game!

Vince Lombardi effectively utilized the principles of distributed practice. Unlike other coaches, he avoided building up reactive inhibition and, even more dangerous, *conditioning* reactive inhibition. Principles such as these are what made Mr. Lombardi a legend and provides even more support for using distributed practice.

## Blocked vs. Random Practice

Blocked practice occurs when trials are performed sequentially without interruption. Random practice occurs when trials are never performed more than once in order. An example would be a bodybuilder performing 3 sets each of leg extensions, squats, and hamstring curls. A blocked schedule would entail performing 3 consecutive sets on each. A randomized schedule would entail switching exercises after each set; for example: one set of squats, one set of leg extensions, one set of hamstring curls, repeat.

William F. Battig (1956) was a pioneer in the study of randomized practice. The reigning paradigm of Battig's day was that learning was directly correlated to performance—meaning that the greater performance, the greater retention would be. However, Battig suggested just the opposite. Battig (1956) found that the more difficult a task was for a participant, the more they retained. For instance, to assess the learning of a finger task, Battig (1956) had participants practice finger movements while saying strange words such as XENF, or practice finger movements without saying words. Results found that the word and finger movement condition performed better on another version of the finger task than the finger movement only condition. Battig hypothesized that *intertask* facilitation (the transfer of one motor task to a similar motor task) was enhanced by *intratask* interference (or contextual interference--the hindrance caused by attempting to keep multiple items in working memory at once). Battig and others performed various other studies which supported this hypothesis (i.e. Battig, 1972; Hiew, 1977), yet these findings were practically ignored due to the radical nature of his theories.

In a classic publication, Battig (1979) made a huge impact in his field, presenting a proud framework of contextual interference, based on the accumulated findings of himself and others. One year later (Battig & Shea, 1980) his ideas were further elaborated on in the field of sensor motor skill acquisition, forever changing the way we view performance and learning.

Since the findings of Battig, hundreds of studies have brought support to his hypothesis (Sawyer, 2005; Schmidt and Lee, 1999). Evidence is now very clear on the effect of blocked and random practice on performance and learning. Relative to random practice, blocked practice enhances performance and depresses learning, while random practice depresses performance and enhances learning (Sawyer, 2005; Schmidt and Lee, 1999). Interestingly enough, Bill Walsh, the famous head football coach for the San Francisco 49ers, has been credited as the man who popularized the use of random practice during football practice. Incidentally, he was a kinesiologist (Sawyer, 2005).

The following paragraphs will analyze various studies which demonstrate the benefits of random practice, and further elaborate on the findings of Battig.

### **The Effect of Blocked vs. Random Practice on Performance and Learning**

Building on the work of Battig, Shea and Morgan (1979) performed one of the earliest experiments on the effect of contextual interference on performance and learning. In their study, participants were instructed to respond to various colored stimulus lights by making a movement with one arm to 4 targets, as fast as possible. Participants were instructed to use three varying arm movements paired with a given color. Participants performed 18 practice trials on each movement, for a total of 54 trials. Participants were divided into blocked and random conditions. Participants in the blocked conditions practiced all 18 trials of one movement before practicing a different movement, while participants in the randomized condition performed no more than two trials in a row on any particular movement. Results indicated that performance during acquisition trials was better in the blocked condition than the random condition. Half of the participants were then instructed to perform a transfer test after a 10 minute delay, while the other half was instructed to perform a transfer test after a 10 day delay to assure that all the temporary effects of performance were dissipated. Results indicated that learning, as inferred by the retention trials, was relatively greater in the random conditions than in the blocked conditions. Numerous similar experiments have brought support to the findings of Shea and Morgan (1979) (i.e. Shea & Wright, 1991; Wright, 1991; Del Rey, Liu, & Simpson, 1994; Lee and Magill, 1983).

Tsutsui, Lee, and Hodges (1998) had participants practice bimanual limb movements using random or blocked practice schedules. Results demonstrated that coordination skill for the criterion task was superior for the random condition than the blocked condition.

Hall, Domingues, and Cavozos (1994) investigated the effect of random and blocked practice on baseball batting. Participants consisted of college level baseball players who had a high capacity to express the skill of batting. Participants performed 2 additional batting practice sessions per week, for 6 weeks. A pitcher would throw the batting participants a total of 15 curves, 15 change-ups, and 15 fastballs in a blocked or randomized manor. The transfer design was then delivered in both random and blocked scheduling. Results established that learning, as inferred by the retention trials, was greater in the random conditions than the blocked conditions.

Ste, et al. (2004) examined the effects of blocked and random acquisition practice schedules on the retention and transfer of handwriting performance. Participants consisted of elementary students. Participants were divided into random and blocked schedules. Participants in the blocked condition were instructed to write each of three letters (h, a, and y) or a symbol, 24 consecutive times each. In the random condition, each letter or symbol was written 24 times, but in a randomized format. Results showed that random practice lead to greater retention of hand writing skills than blocked practice.

Tsutsui et al. (1998) examined whether or not contextual interference effects are observed when the task to be learned involves the acquisition and retention of new motor patterns. Participants were instructed to perform random or blocked practice

on a bimanual coordination task. Results again showed that acquisition performance was facilitated by blocked practice, but random practice resulted in better retention.

Lee and Magill (1983) investigated the effects of performing repetitive random schedules, to non-repetitive random schedules, and blocked schedules. For instance, a repetitive random schedule would be leg extensions, squats, hamstring curls, repeat; a non-repetitive random schedule would be squats, hamstring curls, leg extensions, hamstring curls, squats, leg extensions, etc. So in the former example, the next task was always predictable (this is sometimes referred to as "serial" random practice), whereas in the latter it was not. In this context, participants were instructed to perform three tasks in these three formats. Results indicated that learning in either random condition was almost identical, and both were superior to the blocked condition. These findings are significant and allow more leeway for the athlete's practice schedule.

Numerous other studies have found that random practice is superior to block practice for learning. These include studies on perceptual anticipation (Del Rey, 1989), timing (Lee & Magill, 1983), force regulation (Shea et al., 1991), error detection capabilities (Sherwood, 1996), learning badminton serves (Wrisberb, 1991), volleyball skills (Bortoli et al., 1992), rifle shooting (Boyce, & Del Rey, 1990), kayaking skills (Smith & Davies, 1995), and basketball (Landin & Herbert, 1997), to name a few.

### **Theoretical Rationales on Contextual Interferences Effect on Learning**

The original findings that contextual interference enhances learning but retards performance was perplexing to many in the scientific community of that day, as there appeared to be a great paradox for how learning occurred. Since then, numerous hypotheses have been generated which adequately explain the apparent paradox of contextual interference. The follow paragraphs will examine these hypotheses and show the evidence which supports them. It should be understood that these hypotheses are not competitive, but rather, complimentary to each other.

### **Elaborative and Distinctive Hypothesis**

Battig (1956, 1972, and 1979) found two important variables which affected contextual interference. First, Battig suggested that in a blocked schedule only one task was needed to be kept in working memory, and interference would be low. However, in a random format, in which multiple tasks were kept in working memory, interference would be high. Secondly, Battig suggested that in motor skills, for instance, if the tasks performed were similar, interference would be high, as the learner would have to work harder to distinguish between the two tasks. Conversely, two tasks which were entirely different would take little effort to distinguish from, and therefore would produce less contextual interference. However, there are conflicting results on this (Wood and Ging, 1991; Shea and Wright, 1991). Finally, Battig suggested that the learner would respond to high or low levels of contextual interference with correspondingly high or low levels of elaborative and distinctive processing.

Building on the findings of Battig, Shea and others have further brought support to this hypothesis (i.e., Shea and Morgan, 1979; and Shea and Titzer, 1993). The elaborative and distinctive hypothesis suggests that contextual interference,

facilitated by random practice, prompts the learner to compare and contrast between the tasks; this results in a more memorable and meaningful experience. Incidentally, evidence strongly suggests that the more meaning that is set to a task, the more the learner will retain (Hergenhahn & Olson, 2001).

There are several lines of evidence supporting this hypothesis. For instance, post interviews of participants have found that participants performing random practice understand the task in a different manner than participants performing blocked practice (Shea & Zimny, 1983). For example, participants in random groups give much more elaborate descriptions of the tasks performed, noting that one pattern was very similar to another, or that one was the same, with the exception of a reversal in direction (i.e. comparing and contrasting) (Shea & Zimny, 1983). However, participants performing blocked practice reported very little thought processing, and instead suggested that they ran the tasks off practically automatically. Shea & Zimny (1988) reported that participants performing random practice reported comments about and between tasks twice as much as participants performing blocked practice! Such like reports were also found in the study of Del Rey and Shewokis (1993).

Another line of evidence is provided with studies on mental imagery. Gabriele, Hall, & Lee (1989) examined the effects of mental imagery between sets on retention. Participants performed blocked and random schedules, with trials separated with three imagery practice trials of the tasks performed. Participants in condition one and two were instructed to visualize the task that had just been performed between trials (blocked imagery). Participants in condition three and four were instructed to visualize the three tasks which had not just been performed between trials (random imagery). Results indicated that random imagery was greater for learning than blocked imagery in both blocked and random physical practice schedules, and equal to random physical practice. These results would suggest that contrastive mental processing during practice was beneficial for learning. These results are in agreement with the findings of Hall et al. (1995).

Finally, a powerful line of evidence for this hypothesis is studies on verbal communication between trials. Wright (1991; also see Wright, Li, and Whitacre, 1992) instructed participants to perform tasks very similar to the study of Shea and Morgan (1979); however, all groups of subjects performed blocked practice schedules. Participants in condition one performed no additional cognitive processing, while three groups performed varying cognitive activities between trials. Participants in conditions two and three were instructed to verbally describe, between trials, the order of movements either from the task they had just performed or from another task they had performed. Participants in condition four were instructed to compare and contrast between the task they had just performed and another task. Results found that learning, as inferred by the retention trials, was greater in condition four than in all other conditions. Moreover, condition two and three did not improve retention. This suggests that the intertask processing that occurs during random trials is important for retention, supporting the elaborative and distinctive hypothesis.

### **Forgetting and Reconstruction Hypothesis**

Larry Jacoby proposed that in order to retain information, the learner had to go through the entire learning process. Thus, if the information was stored in working

memory after the first trial, during the second trial the information would not have to be fully processed, impeding learning (Cuddy and Jacoby, 1982; Jacoby, 1978; Jacoby & Dallas, 1981). Jacoby suggested that this could be induced by the "spacing effect," which suggests that performing skills that have been repeated with long spaces between trials is more beneficial to learning than performing skills with little or no spacing between trials.

Building on the findings of Jacoby, Lee and Magill (1983, 1985) suggested the forgetting and Reconstruction Hypothesis (also known as action-plan reconstruction hypothesis), which can be summed up in one simple phrase—in order to learn you must forget. They suggested that during random practice the constructed plan had to be abandoned and reconstructed to perform a different skill. In this context, the effectiveness of practice for learning is dependent on the reconstruction processing taking place. Multiplication tables are a perfect example. If a 4th grader who is not very familiar with multiplication tables is asked to multiply  $3 \times 3$ , the student would go through the entire process like so:  $3+3+3=9$ . However, if the student is asked this same question over and over again, the student would simply spit out the solution—9—instead of going through the process of adding  $3+3+3$  to get 9. If, however, a randomized format was used, such as  $3 \times 3$ , then  $3 \times 5$ , then  $5 \times 10$ , and then back to  $3 \times 3$ , working memory would be cleared and the student would have to go through the entire learning process on each trial! In this context, if an athlete performs the same motor skill 5 times straight, Sawyer (2005) suggests that from a neurological standpoint this was actually only performed once!

A fascinating line of evidence for this hypothesis is found in modeling studies. Modeling is the demonstration of a task (with an auditory, still, or live model) before it is performed. Lee, Wishart, Cunningham, and Carnahan (1997) investigated the effects of introducing the information necessary for a proceeding skill into working memory through modeling. Three experimental conditions were used. Participants were instructed to perform a timing task by making patterns of key presses on a computer keyboard. Participants in condition one and two performed blocked and randomized practice, respectively. Participants in condition three also performed a random practice schedule, with the addition of a computerized model, which gave visual and auditory information about the timing of the task three times before the task was practiced by the participants. The authors hypothesized that the model would guide the learner through the process, disallowing the reconstructive processing benefits normally found in random practice. Results indicated that learning, as inferred by retention trials, was greater in the random condition without a model than in the blocked condition. However, in the random plus model condition, the learning advantage from randomized practice was eliminated.

Another line of evidence used for this hypothesis is theories on schema learning. In this context, if the skills practiced in a random format are too similar, a generalized motor program (GMP) may be used to simply scale the parameters to the new environment, eliminating the need for reconstruction. To elaborate, when features such as relative timing and relative force remain invariant, movements are considered to be in the same class and governed by the same GMP. Features that are free to vary from one performance to another, such as overall movement duration and overall force, are viewed as parameters of the GMP. Under this conceptualization, task variations that have different relative timing or relative force structures are controlled by different GMPs. Task variations, on the other hand, that share the same invariant features but vary in terms of parameters, are controlled by

the same GMP. For example, performing a bench press but varying the speed of the repetition, such as varying the time under tension from 1 second compared to 5 (relative duration) or varying the weight from 315 pounds to 350 on each set (relative force), would use the same GMP but have varying parameters. Such a task is thought to cause little contextual interference, negating the effects of random practice. However, the results are rather inconsistent in this field of work (Wulf, 1992; Wulf & Lee, 1993; Shea, Kohl, & Indermill, 1990; Sekiya, Magill, & Anderson, 1996). Therefore, the current authors advise that the athlete stick to methods which have stronger support for creating contextual interference, for now.

## The Guiding Hypothesis

The guidance hypothesis posits that a high relative frequency of augmented feedback during practice is detrimental to motor learning (Winstein, 1994). This is consistent with studies on the effect of feedback on retention (Sawyer, 2005). To elaborate, there are two types of feedback: intrinsic feedback and augmented feedback (Schmidt and Lee, 1999). Intrinsic feedback is inherent to the execution of movement and provided through various sensory channels. Augmented feedback is supplemental to intrinsic feedback. In this context, Knowledge of Results (KR), supplies augmented feedback about movement outcome. For instance, if a coach tells a basketball player who made a free throw shot, "You made it!", this would be a form of KR. Evidence suggests that too much feedback appears to degrade learning. For instance, several studies show that reduced relative frequency (the percent of KR trials given) produces more learning (Lee, White, & Carnahan, 1990; Sparrow & Summers, 1992; Vander Linden, Cauraugh, & Greene, 1993.). Salmoni, Schmidt, and Walker (1984) propose that when KR is given on every trial, participants become reliant on the feedback and fail to process the information required to learn the task. Participants with less KR, however, must attempt to detect their own errors, increase cognitive effort, and go through the full learning process. In this context, in the aforementioned modeling study, the model may have given the participants a reference of correctness, which they become dependent on, resulting in a failure to process the information necessary for learning.

In this context, Sawyer (2005) suggests that in order to learn, the learner must make mistakes. This may be another mechanism by which random practice facilitates retention. Hagman (1983) and Winstein, Pohl, and Lewthwaite (1994) revealed that guided (i.e., errorless) practice was detrimental to retention and transfer, especially if presented on every acquisition trial. This was also a proposed mechanism for the findings of Lee, Wishart, Cunningham, and Carnahan (1997) in their study on modeling. Four mechanisms may facilitate this process. The first two being that errors may increase cognitive effort and elaborative processing, enhancing learning (Sherwood & Lee, 2003; Shea and Morgan, 1979). Third, it may help develop a schema, as evidence suggests that there are positive benefits from correct and incorrect movements for schema learning, which is based on a relationship among all stored elements (Schmidt and Lee, 1999). And fourth, 100% relative feedback impedes the intrinsic processes, such as problem solving, in the inter-trial interval, known to be important for learning (Sawyer, 2005; Bjork, 1988; Landauer & Bjork, 1978; Schmidt, 1991). To elaborate, the inter-trial interval is the sum of KR delay (the delay from movement one completion and delivery of KR) and post KR delay (the delay from KR until the next movement; here it is presumed the person is processing the KR and deciding on the next movement).

## Retroactive Inhibition Hypothesis

Recent studies have popularized a third major alternative to the Forgetting and Reconstruction Hypothesis and the Elaborative and Distinctive Hypothesis to explain the benefits of contextual interference. This alternative has been termed retroactive inhibition, and can be defined as "the retention deficit due to intervening activities between the practice of a task and the retention test of that task (Buxton, 1940)" and "the poor retention of an activity as a result of another activity interpolated between the original learning and the retention test" (Underwood, 1945). To elaborate, if an athlete performs 5 sets of squats, leg extensions, and leg curls, respectively, in a blocked fashion, and then a retention test one day later, there would be 10 sets between the last set of squats in acquisition and the first set of squats on the retention trial. On the other hand, if this was performed in a randomized fashion, there would be at most only 2 sets between the last set of squats in acquisition and the first set of squats in retention.

Shewokis et al. (1998) examined the influence of retroactive inhibition on blocked performers' retention performances. Participants were instructed to perform coincidence anticipation timing, with three speeds presented to them: slow, moderate, and fast, for a total of 90 trials (30 each). Participants were divided into blocked and random conditions. Participants in the blocked conditions were randomly assigned to three retention tasks to assess the effect of retroactive inhibition on learning. Participants in the first blocked retention condition performed the slow task first, which resulted in 60 trials of retroactive inhibition, because the slow task was practiced first in acquisition. Participants in condition two performed the moderate-speed task, which resulted in 30 trials of retroactive inhibition. Participants in condition three performed the fast speed task, which resulted in 0 trials of retroactive inhibition, as the fast speed task was practiced last during acquisition trials. Results showed that there was not a significant difference between random and blocked with 30 or 0 retroactive inhibition trials; however, the 60 retroactive inhibition blocked trial decreased learning. These results were also in line with the findings of Shea and Titzer (1993).

Del Rey et al. (1994) examined the effect of retroactive inhibition on contextual interference on 75 female participants. Participants performed blocked trials without retroactive inhibition, blocked with moderate retroactive inhibition (18), blocked with high retroactive inhibition (36), and random practice. Results demonstrated that reaction time was faster during retention trials for the random condition than all blocked conditions; however, the blocked conditions without retroactive inhibition had faster reaction times than the moderate and high retroactive inhibition conditions. Also in accord with past studies, random conditions had slower reaction times during acquisition than blocked conditions. These results are in accord with the findings of Meeuwssen and Magill (1991).

Mechanisms by which retroactive inhibition effects learning is not well understood, however. Interestingly, Del Rey et al. (1994) found that retroactive inhibition produced slower reaction times, but did not affect movement time. Because reaction time is a measure of the time taken to plan cognitive events such as identifying the stimulus, comparing with past experience, selecting appropriate response, and initiating the response, it is suggested that the effects of retroactive inhibition are cognitive in nature. This is in line with an early study by Lewis, McAllister, and Adams (1951), who saw the effect of retroactive inhibition in their experiment and

reported that the participants were confused about the cognitive elements but did not demonstrate a loss of limb control.

More studies need to investigate this hypothesis, but there appears to be evidence suggesting that avoidance of retroactive inhibition is one of the benefits of random practice. Whether it is the sole reason is extremely questionable and, as shown, has yielded conflicting results.

### **Cognitive Effort Hypothesis**

Lee, Swinnen, & Serrien (1994) proposed the Cognitive Effort Theory of motor learning. Cognitive effort is defined as "the mental work involved in making decisions" (Lee, Swinnen, & Serrien, 1994, p. 329). More recently, Sherwood and Lee (2003) defined it as "those decisions that result in perceptual and motor processes involved in movement control. For example, an ice hockey goalie needs to learn how to anticipate where a shot will go to by using perceptual and decision-making processes." Because motor learning requires both cognitive and motor processes (Sawyer, 2005), Lee suggests that practice must encourage both the execution of skill described extensively by Schmidt, as well as the underlying cognitive processes which also underlie the task.

This theory may be complimentary to the Forgetting and Reconstruction Hypothesis proposed by Lee and Magill (1983, 1985). The current authors suggest that perhaps modifications to motor programs begin cognitively, before being integrated into unconscious motor memory.

The evidenced used to support both the Forgetting and Reconstruction Hypothesis and the Elaborative and Distinctive Hypothesis can be explained from the Cognitive Effort Hypothesis. It is suggested that random practice increases cognitive effort through mechanisms such as increased errors, thereby facilitating learning.

In a fascinating study, Blandin et al. (1994) examined the effects of physically practicing or observing a model practice three variations of a timing task in a random or blocked schedule. Results from the retention data revealed that timing error for the models and observers was similar; as in other experiments, random practice enhanced learning for both physical practice and observation. Building on the findings of Blandin et al. (1994), Wright et al. (1997) replicated the aforementioned study. For every pair of participants one was assigned to be a model and the other was instructed to observe the model practice either a random or blocked schedule. Results were consistent with the findings of Blandin et al. (1994), in that observation of a random practice model enhanced subsequent efforts to enact physically the observed responses beyond the level achieved via observation of a blocked practice model. These studies suggest that the benefit of contextual interference may be from cognitive standpoint as well as a motor standpoint. This would seemingly support the cognitive effort theory.

More experiments need to be done on this hypothesis. Kahneman (1973) argued that pupil dilation was the most effective psychophysiological measure of effort, as increased pupil dilation corresponds with increased task load in a wide variety of cognitive tasks. Another experiment that could be done is to ask the participants to rate their rate of perceived cognitive exertion, using Borg's scale, to assess the correlation between the rate of perceived mental exertion and learning.

## Random Practice and Specificity

Another benefit of random practice to applied sport situations is specificity. It is rare that any sport uses a blocked format. For instance, in golf they may use a different golf club on each swing during a tournament. In hockey and basketball, not one shot taken, save for free throw shooting, may be from the same position. In baseball, the batter is thrown a variety of pitches during their at bats such as a curve ball, fastball, and changeup. Interestingly enough, as discussed earlier, Hall, Domingues, and Cavozos (1994) et al. found that using a randomized format for throwing various baseball pitches to advanced batters resulted in superior learning. Lastly, Bartlett (1932), who is considered the father of schema theory, stated that, "When I make the stroke (tennis) I do not, as a matter of fact, produce something absolutely new, and I never repeat something old." This quote is also a huge line of evidence for the use of variable practice, which will be discussed more later on.

The fact of the matter is that blocked practice rarely occurs during a sporting event. In this context, it would behoove the athlete to practice closer to the conditions of a game by using random practice.

## The Degree of Randomization

As plainly displayed, random practice is clearly superior to blocked practice for the acquisition of skills. Current research has, therefore, investigated the degree to which athletes should induce contextual interference.

Studies by Al-Ameer and Toole (1993) and Pigott and Shapiro (1984) investigated this question. In the Al-Ameer and Toole (1993) study participants performed a similar task to the Shea and Morgan (1979) study. Results again found that, relative to random practice, blocked practice enhances performance and depresses learning, while random practice depresses performance and enhances learning. However, they added a third group which performed randomized blocks, in which participants performed 2-3 trials, and then practiced another task for 2-3 trials, and so on. Results indicated that randomized blocks were better for performance in acquisition trials, relative to random practice, and just as beneficial to learning, as inferred from retention trials, as random practice. In the study of Pigott and Shapiro (1984), elementary school children were instructed to perform an underhand toss task, using blocked, random, and random-blocked schedules. Results showed that random blocks were actually better than traditional random practice for learning! Proteau, Blandin, Alain, and Dorion (1994) further investigated this phenomenon. Participants consisted of college students who were instructed to perform a barrier knockdown task using blocked, random, or randomized-blocked schedules. Results again demonstrated that random blocks were better for skill acquisition.

Building on the findings of these scientists, Landin & Herbert (1997) investigated the effect of the degree of contextual interference on learning. Participants consisted of 30 undergraduate college students with 2 years of high school basketball experience and no intercollegiate competition. Participants were instructed to perform a basketball shot from six positions, with varying distances and angles to the basket. Participants were assigned to three experimental conditions: blocked, random, and randomized blocks. All participants performed a total of 30 shots, 5 shots per position, for 3 days. Participants under the blocked schedule performed 6 successive trials from all positions. Participants in the randomized-blocked condition performed

three successive trials at each location and repeated the sequence twice. Participants in the random condition performed one trial per position in a serial arrangement and repeated the sequence six times. Results showed that randomized-blocks were better for learning than both groups, as inferred from the retention trial. Further, acquisition performance was also best in the random-block condition.

There are several theoretical rationales for these results. Proteau et al. (1994) suggest that moderate contextual interference allows for repeated trials under one condition, facilitating the learner's ability to make error corrections on the subsequent trial, while concomitantly providing the contextual interference benefits of changing tasks every couple of sets instead of every set.

It appears that the level of the learner may also influence these results. For instance, Del Rey, Wughalter, and Whitehurst (1982) found that advanced participants in an open sport skill task received much better results from random practice than novices. Shea, Kohl, and Indermill (1990) investigated the effect of contextual interference and the amount of practice on sensory motor skill acquisition in novices. Results indicated that blocked practice was actually better on retention tests after 50 trials. However, after 400 acquisition trials, random practice became superior to blocked practice for learning. Recently, Guadagnoli, Holcomb, and Weber (1999) examined the effects of CI on a relatively difficult task (golf putting) in novice and advanced learners. Results showed that novice participants experienced superior results in blocked practice, while advanced participants received superior results in random formats. Further, studies on children have found that blocked practice may be of greater benefit than random practice for learning (Del Rey, Whitehurst, & Wood, 1983).

These data suggest that blocked practice may be best to perform for novices practicing difficult tasks, and progress to random once a certain capacity to express a skill has been developed. It is suggested that for novices difficult tasks cause enough of a load at first so that the action-planning processes are being sufficiently challenged. Moreover, the attention demand would be higher in novices, and introducing a randomized format may cause information overload, suppressing learning (Magill and Hall, 1990).

It is further suggested that applied settings may favor a moderate level of contextual interference via random-blocks in comparison to laboratory settings. While Laboratories are strictly controlled environments, wherein nearly all possible confounding variables are repressed, applied settings have various environmental factors and cues which can influence the learner. In this context, Landin & Herbert (1997) suggest that, "moderate schedule may be best, because it provides learners with the opportunity to adjust to environmental as well as task variables." However, for professional athletes, who can perform tasks with relatively little attentional demand, it may be optimal to perform pure random practice. Studies need to investigate this hypothesis.

The current authors suggest that these results could be influenced by self efficacy, which is the confidence people have in their abilities to attain desired levels of performance (James, 2000). Random blocks appear to allow for the benefit of contextual interference while maintaining performance equal to or greater than blocked practice, increasing the learner's confidence within themselves to perform the skill (self efficacy). This hypothesis was supported by the findings of Simon and

Bjork (2001). They found that in a key-press task experiment, participants who performed blocked practice and had better acquisition trials were more optimistic during the retention trial than those who performed random practice; yet random practice participants had the best results on the retention trial. While self efficacy could not overcome the benefits of random practice, studies have found that it is an important variable for enhancing performance (James, 2000), which is why the current author suggest that it may contribute to the benefits of randomized blocks. This can be especially important for beginning athletes, whose motivation is primarily extrinsic in nature. Thorndike's second law, the law of effect, suggests that if a response is satisfying to a learner, they will be more likely to repeat it. This is why priori experiences are so important. In this context, it is vital that instructors provide an environment that is conducive to success for their athletes. For instance, in order to enhance the self efficacy of a team who is down, the coach may use a moderate level of contextual interference to enhance performance. Practical applications will be further discussed in the last article of this series.

More studies need to be performed on the effects of randomized blocks, but the current evidence suggests that randomized blocks may be just as beneficial as or even better for learning than random practice, while minimizing the acquisition decrements experienced from contextual interference. The benefit of randomized blocks may be profound. For instance, if an athlete is using squats and barbell shrugs, these two apparatuses may be far apart from each other in the gym, and walking back and forth among apparatuses may be inconvenient—not to mention, the athlete risks losing a machine to a gym moron! So performing very small blocks may be more logical in such situations.

Additional studies that need to be done are the combination of randomized techniques. For instance, using random imagery, physical practice, and modeling during a practice session. All three techniques have been shown to be beneficial, but the optimal combination of these techniques needs investigation.

## **Conclusion**

In summary, evidence strongly suggests that given an equal number of trials, distributed practice is superior for learning relative to massed practice, for both discrete and continuous tasks. An exception may be when transferring to massed practice, in which the athlete should implement a partially massed acquisition regimen.

Lastly, relative to random practice, blocked practice enhances performance and depresses learning, while random practice depresses performance and enhances learning. However, it may be best for novices practicing difficult tasks to perform blocked practice and later progress to random once a certain capacity to express a skill has been attained.

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