

## Learning and Performance Effects of Practice

by William P. Berg, Philip N. Lundin

*Practice can have both performance (i.e., temporary) and learning (i.e., permanent) effects on sport performance. Coaches are primarily interested in employing those practice conditions which maximize the development of relatively permanent improvements in skill, that is, those that generate positive learning effects. Problems arise when coaches confuse performance effects for learning effects by assuming there is a strong positive correlation between performance in practice and long-term retention of skill. In fact, it is frequently the case that practice methods which produce less than optimal performance during practice, nonetheless result in superior learning. In this article we attempt to make clear the distinction between learning and performance effects of practice, as well as to illustrate how track and field coaches can benefit from understanding the distinction.*

### ABSTRACT

### I. Introduction

**T**he primary purpose of sport practice is to improve an athlete's capability to perform in competition. There are many contributors to effective performance in competition, and one of these is motor learning. Motor learning is defined as "a set of processes associated with practice or experience leading to relatively permanent changes in the capability for skill performance" (Schmidt, 1991, p. 153). Improved performance does not, by itself, constitute learning. Rather, improved performance simply indicates that learning has occurred, and then only if the performance improvement endures. Critical to understanding motor learning and its manifestations is appreciating the distinction between learning and performance. The purpose of this article is to elucidate this distinction, and to illustrate how track and field coaches can benefit from understanding the learning and performance effects of practice.

There are several aspects of the aforementioned definition of motor learning which require elaboration. First, although many factors contribute to an improved capability for skill performance, motor learning only concerns those related to practice or experience. For example, it is obvious that physical growth alone can bring about improvement in sport performance, especially among youth. However, this improvement is not considered the product of learning because growth is not a practice variable (Schmidt, 1991). Motor learning only pertains to performance changes that occur as a result of practicing a motor skill.

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Second, because motor learning is a set of processes involving alterations in the central nervous system, it is not directly observable. Although the processes of motor learning are not observable, the product is. That is, alterations in the central nervous system resulting from practice lead to improved skill performance. Consequently, evidence about motor learning processes can be obtained from tests of motor performance. If we observe improvement in performance resulting from practice, we generally presume that learning has occurred.

An important qualification must be added, however. In order for a change in skill performance to be regarded as the result of motor learning, the change must be relatively permanent (Schmidt, 1991). It must persist. There are numerous practice variables that may influence performance, however, some of these produce effects that are relatively temporary.

For example, skill performance can be affected by arousal level, warm-up, fatigue, etc. These factors primarily influence performance for the moment, with their effects quickly disappearing. Of course, to maximize coaching effectiveness, it is important for coaches to understand which variables affect performance temporarily (called performance variables) and which affect performance in a relatively permanent way (called learning variables).

It warrants highlighting that although motor learning results in relatively permanent changes in the capability for skill performance, the changes need not be beneficial. Learning can be negative - as in acquiring a bad habit. Naturally, coaches customarily strive to foster learning that is positive, where practice results in an improved capability for skill performance that becomes a permanent part of the athlete's make-up, and is available at some future time when the skill is required.

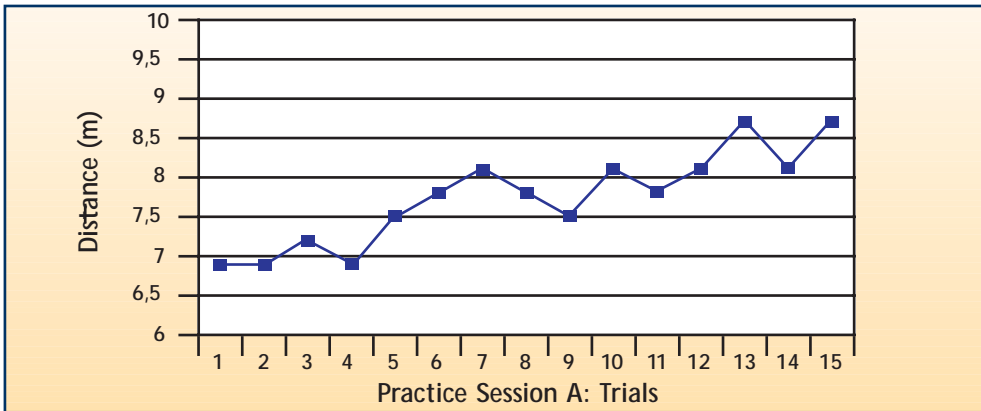


Figure 1: Hypothetical power throw performance by a shot putter over 15 trials in a practice session (A).

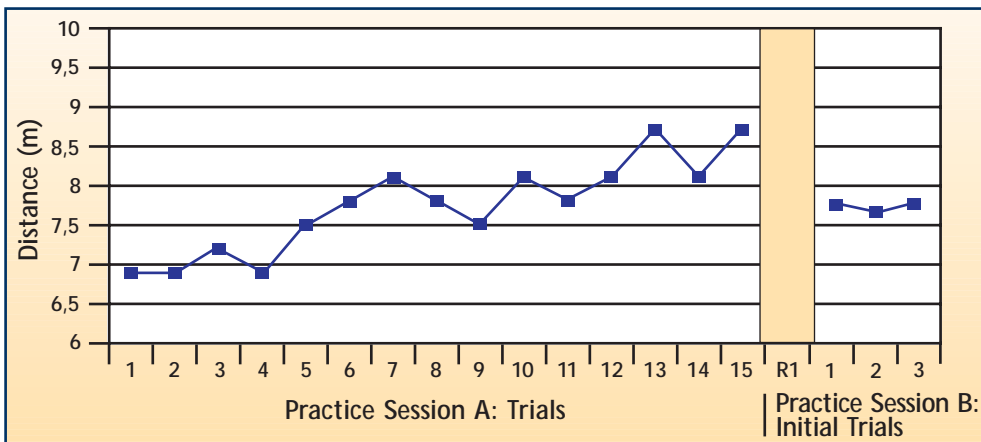


Figure 2: Hypothetical power throw performance by a shot putter over 15 trials in practice Session A, and the first 3 trials of Session B. (RI = one week retention interval)

## II. Evaluating the Learning and Performance Effects of Practice

Evaluating both the learning (permanent) and performance (temporary) effects of practice involves similar principles. The most common way to evaluate progress during practice is to periodically measure performance. For example, a coach working with a novice shot putter who is performing power throws (i.e., half throws) during a practice session (Session A) could measure throw distance to evaluate progress during the session (see Figure 1). If throw distance increases over the course of the practice session, the coach could conclude that practice was having a positive effect on throw performance. However, the coach could not conclude from this data alone that practice was also having a positive effect on learning. Only if all or a portion of the shot putter's improvement during practice Session A was retained in a relatively permanent way, would the coach be able to conclude that learning had occurred. For example, if one week following practice Session A the shot putter again performed power throws for distance (Session B), and his or her initial throws were superior to those from the beginning of Session A, then the coach could infer that learning had occurred during Session A (see Figure 2). On the other hand, if the shot putter's initial performance during Session B was similar to that at the beginning of Session A, the coach could conclude that while practice Session A had a positive effect on performance during practice, it had no effect on learning.

Although this example is oversimplified, the point is clear. Momentary improvement in performance does not necessarily reflect learning. Learning is best assessed by testing performance following a period of time in which no practice has occurred. This time period without practice is called a retention interval, and it has two fundamental purposes. The first purpose of a retention interval is to test the permanence of any skill improvement resulting from practice. The second purpose of a retention interval is to allow any temporary effects of practice to dissipate, so they do not interfere with the assessment of learning. For example, if the coach in our example tested the shot

putter on power throw performance several hours following practice Session A, as opposed to waiting an entire week, evaluation of learning could be compromised for two reasons. First, maintenance of a performance level for several hours would not constitute a relatively permanent change, and thus not reflect learning. Second, there might be temporary effects generated by practice Session A such as fatigue (usually negative) or motivation (usually positive) which may not have had time to dissipate completely. For instance, if tested immediately following Session A, the shot putter might be fatigued and thus fail to perform up to his or her capability. In this case, fatigue could mask learning that had actually occurred. The appropriate length of a retention interval depends on several factors including the amount of practice (the greater the amount of practice - the longer the retention interval), the developmental status of the athlete, among others. In short, learning is best assessed using a retention interval that is long enough to both permit any temporary effects of practice to dissipate, and to reflect the permanence of changes, if any, in skill performance.

## III. Learning Variables and Performance Variables

Critically important for evaluating learning in athletics is the notion of learning versus performance effects. Practice can have two distinct kinds of influences on performance - one that is relatively permanent (due to learning), and one that is only temporary (Schmidt, 1991). Coaches are primarily interested in employing those practice conditions which maximize the development of relatively permanent improvements in skill. These practice conditions are referred to as *learning variables*. Many practice conditions have important temporary effects as well, and these conditions are called *performance variables*. Like learning variables, performance variables can be positive or negative. For example, simple encouragement by a coach might at that moment energize an athlete to elevate their performance, and thus function as a positive performance variable. On the other hand, practice can generate moderate to severe physical fatigue which can worsen

performance while it is present, thus constituting a negative performance variable.

The most important learning variable is practice itself. Both the amount and quality of practice are important. Greater amounts of practice are associated with superior learning. The quality of practice refers to its effectiveness. Certain practice methods have a stronger positive effect on learning than others. A second important learning variable in feedback, be it intrinsic (available as a natural consequence of performing an action), or augmented (such as that provided by a coach). Feedback about movement errors is one of the most important aspects of the learning environment. Without it, athletes may have little understanding of how to correct their errors.

Naturally, practice and feedback are performance variables as well. After all, a coach wouldn't expect learning to occur in the absence of any momentary improvement in performance. However, momentary improvement is not evidence of learning. Coaches may assume that the best way to optimize learning is to optimize performance during practice. Unfortunately, fostering motor learning is not always this straightforward. Sometimes, practice methods which produce less than optimal performance during practice nonetheless result in superior learning. Likewise, practice methods that facilitate optimal performance during practice sometimes result in less than optimal learning.

As an example, random practice has been shown to be a stronger positive learning variable than it is a positive performance variable. Random practice is a practice sequence in which individuals perform a number of different tasks in no particular order, thus minimizing consecutive repetitions of any single task (Schmidt & Wrisberg, 2000). Conversely, blocked practice is a practice sequence in which individuals repeatedly rehearse the same task (Schmidt & Wrisberg, 2000). Blocked practice is typical of many drills in track and field where a task is repeated over and over. On the surface, blocked practice appears to make sense in that it allows learners to concentrate on one task at a time and refine it. However, research on the performance and learning effects of blocked and ran-

dom practice appear to contradict conventional wisdom.

Shea and Morgan (1979) and others have shown that blocked practice leads to better practice performance than random practice, but that random practice produces superior learning. These findings raise questions about traditional viewpoints that learning is maximized by conditions that make learners most effective in practice. Indeed, in track and field practice is often blocked, presumably because it is easier for a coach to organize and/or because it results in effective performance. Research suggests, however, that when learning is the goal, random practice should be the method of choice.

As an analogy, consider the case of a child learning multiplication (after Cuddy & Jacoby, 1982). If a child is asked  $4 \times 8 =$ , he or she will solve the problem and answer "32". If a child is repeatedly asked  $4 \times 8 =$  (blocked practice), he or she will repeatedly answer "32". However, under blocked practice the child will solve the problem only once (on trial 1), and thereafter he or she will simply recall the answer and respond accordingly. If on the other hand a child is asked a variety of multiplication problems in succession, such as  $4 \times 8 =$ ,  $3 \times 6 =$ ,  $5 \times 3 =$ ,  $2 \times 9 =$  and  $4 \times 8 =$  (random practice), he or she will solve  $4 \times 8 =$  (on trial 1) and then solve three different problems before again being asked  $4 \times 8 =$ . Under random practice, solving different problems may cause the learner to forget the answer to  $4 \times 8 =$  by the time this problem is presented a second time. In this case the learner is forced to solve  $4 \times 8 =$  again. It is this problem solving which is apparently beneficial to learning. Although blocked practice is less likely to produce an error during practice, random practice is more likely to engage the processes of learning.

In other words, blocked practice is considered a stronger positive performance variable than random practice, whereas random practice is considered a stronger positive learning variable than blocked practice. If random practice reliably results in superior learning, are there any situations in which a coach would choose to use blocked practice instead? The answer is yes - blocked practice would be used whenever immediate performance is more

important than skill retention. There are several situations in which this would be the case. First, when introducing a new skill to an athlete, the goal is for them to be able to perform it well enough to engage in multiple rehearsal trials, and thus practice should be performed in a blocked fashion. Blocked practice permits the athlete to focus on the novel task and correct the large errors which frequently accompany initial performance of a task. Second, initial practice of a skill should not be overly discouraging for a learner. Blocked practice has greater potential to maximize initial success, and therefore confidence, than random practice does. Other reasons blocked practice might be preferred over random practice include: (a) to maximize safety when practicing dangerous tasks, (b) to stabilize performance prior to an important competition, (c) to test performance during practice, and (d) to maximize the orderliness of practice (e.g., when random practice is impractical). It is not that an athlete cannot learn using blocked practice - they can and do. The critical point is that the learning that occurs as a result of blocked practice will not be as extensive as that resulting from random practice.

Again, the purpose of our lengthy discussion of blocked and random practice is to illustrate how important it is for coaches to fully understand both the performance and learning effects of the practice methods they utilize - as these effects can be counterintuitive. As another example, it has been shown that compared with providing augmented feedback after every practice attempt, summarizing feedback after several trials (e.g., four) produces poorer performance during practice but better performance in the future (i.e., superior learning). The superior learning resulting from summary feedback is likely the result of greater attention paid by the learner to his or her intrinsic feedback on those trials when augmented feedback is withheld. In short, a coach who assumes that learning is always maximized by conditions that optimize performance during practice may not be promoting learning as effectively as he or she could.

Also important is a coach's understanding of and an ability to use positive performance variables, especially those which can be intro-

duced directly prior to or during a competition. Again, positive performance variables have a positive but temporary effect on performance, and can include warm-up, a motivational technique such as a pep talk, anxiety reducing techniques, among many others. For example, a coach observing a high jumper who is struggling during a competition could provide feedback to the athlete about inaccuracy in the approach run which may permit the athlete to make immediate modifications, thus elevating performance. In this situation, neither coach nor athlete is interested in the long-term (learning) effects of the coach's intervention. Rather, both are focussed on immediate performance improvement - whether it be transient or enduring is not a concern.

#### IV. Theory to Practice

How does a track and field coach make use of an understanding of the learning and performance effects of practice? Fundamentally, this is a matter of ensuring that practice methods chosen are consistent with the goal of practice. If the goal of practice is long-term retention, then the practice methods and instructional assistance should effectively promote long-term retention. Likewise, if the goal of practice is immediate performance improvement, then the practice methods and instructional assistance should be well-suited for this goal. More often than not, the goal of learning as much as possible in a practice session will conflict with the goal of performing as well as possible in a practice session. This is because the methods which best promote long-term retention often result in less than optimal performance during practice. A coach who appreciates this principle will be well-prepared to ensure that there is a high level of congruity between rehearsal techniques chosen for practice and the goal of practice. An example of the practical implications of understanding the learning and performance effects of practice is provided in the following case study.

#### **Case study: Practicing to be able to negotiate hurdles with either leg.**

Jim is an 18-year-old collegiate track athlete who's event is the 400 m hurdles. Jim has



three years experience running the event (300 m hurdles) in high school. He has always used his left leg exclusively as his lead leg. Jim's college coach, Ron, has convinced Jim that it would be advantageous to be able to negotiate hurdles leading with either the left or right leg. Ron explains that the capability to lead with either leg potentially enhances performance in at least two ways. First, being able to alternate one's lead leg makes it possible to negotiate hurdles using an even number of steps between hurdles (e.g., 14 or 16), as opposed to only using an odd number of steps. Second, being able to lead with either leg improves a hurdler's ability to adapt optimally when conditions interrupt his or her planned step pattern (hurdle rhythm). Factors which could cause such an interruption in hurdle rhythm include wind, striking a hurdle, fatigue, etc. How should Ron approach the task of training Jim to be able to lead with either the left or right leg?

First, Ron has to clearly define the ultimate goal, which is for Jim to be able to lead with either his left or right leg in a 400m hurdle race. Not only does Ron want Jim to be equally effective leading with either leg, he wants Jim to be equally comfortable with either leg. Via practice, Ron hopes to promote a permanent change in Jim's capability. This 'learning' will be manifested by effective performance in future competitions (and competition-specific practice sessions), including where circumstances force Jim to deviate from his preplanned hurdle rhythm. Conversely, if in future competitions Jim returns to favoring his left lead leg in situations when using his right lead leg would be preferable, this will be considered evidence that learning is not complete.

Although long-term retention of the capability to negotiate hurdles with either leg is the ultimate goal of practice, it is not the goal of the initial practice sessions. Initially, Ron will focus on promoting relatively swift improvement in Jim's ability to negotiate hurdles using his right leg as the lead leg, such that Jim can execute the skill well enough to perform multiple repetitions. Initially, Ron will allow Jim to perform numerous repetitions in a more or less blocked fashion. Blocked practice

is appropriate early in learning because it allows a learner to promptly make use of any available intrinsic and/or augmented feedback in order to diminish the sizable errors that usually accompany initial performance of a novel task. Naturally, Ron will also want to frequently provide Jim with augmented feedback about his hurdling technique, possibly as often as after each trial. An example of a rehearsal session early in learning would be:

- ◆ 3 x 4 x 5 hurdles at a uniform 11.5-12.5m spacing permitting a 5-step hurdle rhythm with the right leg as the lead leg. The coach provides frequent augmented feedback.

Because blocked practice and high frequency of augmented feedback are useful for promoting optimal performance in practice, these techniques are appropriate early in the learning process. However, once Jim demonstrates that he can effectively negotiate hurdles with the right leg as the lead leg and do so with a high degree of consistency, Ron will shift the practice sessions to a more random format by introducing the notion of alternating lead legs. For example:

- ◆ 3 x 4 x 5 hurdles at a uniform 15-16.5m spacing permitting a 6-step hurdle rhythm using alternating lead legs.

For greater randomization, Ron will require that Jim work on other skills (e.g., starts) in between each set of hurdle trials. Additionally, Ron will gradually reduce the relative frequency of augmented feedback until he offers it only at the end of each set of trials.

Later in the learning process, Ron will randomize practice to an even greater extent, rarely allowing Jim to perform the same task or task variation twice in succession. For example:

- ◆ 3 x 4 x 5 hurdles at an irregular spacing over 80m, negotiating the hurdle using the optimal lead leg (i.e., that which is least detrimental to rhythm and velocity). Ron will arbitrarily change the hurdle spacing by 1-2 m prior to each trial.

To further promote learning, Ron will have Jim practice in a variety of contexts including various lanes on the track, various weather conditions, various track surfaces, and various levels of fatigue.

As the goal of daily practice transforms from enhanced performance during initial practice sessions to enhanced learning thereafter, likewise the practice methods prescribed by Ron will change accordingly. Outside the initial practice sessions, however, will there ever be a time when the goal of practice is to enhance performance without concern for whether or not the enhancements will be permanently retained. The answer is yes. For example, prior to important competitions or during the period devoted to peak performance, Ron will return to employing positive performance variables in practice - with full knowledge that the practices may not promote long-term retention. At this point it is more important for Ron to help Jim stabilize his performance and gain confidence in his skill. An example of a rehearsal session late in learning would be:

- ◆ 2 x 2 x 7 hurdles at a .30m shorter than regulation spacing, using a 14-step hurdle rhythm (alternating lead legs). By shortening the hurdle spacing .30-.50m per hurdle, Jim is able to more readily repeatedly reproduce the hurdle rhythm of a race within a practice setting.

#### IV. Conclusion

In this article we have attempted to make clear the distinction between learning and performance effects of practice. In short, learning effects are relatively permanent and performance effects are temporary. Problems arise when coaches confuse performance effects for learning effects, that is, when they assume there is a one-to-one mapping between performance in practice and long-term retention of skill. In fact, it is often the case that practice methods which produce less than optimal performance during practice nonetheless result in superior learning (e.g., random practice). Likewise, practice methods that facilitate optimal performance during practice may result in less than optimal learning. Performance and learning effects can be separately evaluated by using retention tests, whereby athletes are tested after a period of time without practice (i.e., retention interval). Comparing performance on a retention test to one's ini-

tial performance on the task is an effective way to assess learning.

Understanding the distinction between the learning and performance effects of practice can benefit a track and field coach in at least three ways. First, the coach will be better able to measure both learning and performance, and thus can avoid confusing performance effects for learning effects. Second, the coach will be better prepared to ensure a high level of congruity between the goal of daily practice and the methods and instructional assistance chosen for practice. Finally, the coach may become more sensitive to ways in which an athlete's performance can be enhanced temporarily, such as would be desirable just prior to or during a competition. ■

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