

Bios Instert Notes .

Motor Control, Learning + Development

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Section K

IMPLICATIONS FOR PRACTICE (2008).

Taylor + Francis.

Key Notes

Whole-task practice

Complex motor skills presented as an entire unit.

Part-task practice

Complex motor skills presented and practiced in parts.

Massed practice

A practice session in which the amount of practice time in a trial is greater than the amount of rest between trials.

Distributed practice

A practice session in which the amount of rest between trials is equal to or greater than the amount of time spent practicing.

Variability of practice

Practicing a skill in a variety of movement contexts.

Contextual interference

Interference which results from practicing variations of a skill within the context of a practice situation.

Blocked practice

A type of practice in which skills are practiced repetitively and independently of each other.

Random practice

A type of practice in which skills are practiced together in an unstructured order.

Related topics

Measurement in motor control (C)
Theories of motor learning (H)

Stages of motor learning (I)
Motor development (M)

When coaching, teaching, or during rehabilitation we are generally attempting to improve performance. In previous sections we have considered theories of learning, stages of learning, how we control movements, and theories of control. All the information in these sections, and indeed in the ones that follow, have implications for coaching, teaching, and rehabilitation.

When learning a skill it must be remembered that practice in one context must often be transferred and repeated in another context. For example, the tennis player needs to perform successfully in practice matches and the competitive environment. In addition, performers have to successfully execute a variety of different actions; the tennis player has to be able to serve, volley, lob and return the ball using a forehand or backhand drive. All of these actions require a great deal of skill, and thus coaches have to be able to establish practice conditions that lead to the greatest probability of successful performances in all situations with all actions. Equally the patient relearning to walk may cope very well in the clinical setting but eventually they will have to walk in an environment that is much less controlled, such as the street. In light of this, a good coach, teacher or therapist will often ask themselves questions like: How should I structure my practice session to optimize learning? How should a particular skill be practiced? The

following section discusses the learning environment and considers how skill learning can be maximized with particular reference to practice.

Whether we are talking about football, cricket, tennis or any other movement skill such as relearning to walk, all skilled performances have something in common; they have come about through effective practicing of the skill. In the world of movement science, we are always searching for practice methods that allow for optimal performance. A very young child quickly learns to kick a ball and make it go roughly in the direction he or she wants it to. However, to bend a ball around a wall, the way David Beckham can, requires a great deal of skill and practice. It is our job as coaches and/or therapists to find the right type of practice, and schedule practice so that it does not become too boring and so that each child, athlete or patient is able to give their 'best' performance.

**Task analysis:
breaking the
task down into
its component
parts**

One question that to date has been difficult for researchers to answer is whether it is better for the learner to practice the movement pattern in parts until each part has been perfected, or practice the movement pattern as a whole from the beginning. In the early 1960s Naylor and Briggs hypothesized that the organization and complexity characteristics of a skill could provide the basis for a decision to use whole or part practice. Task complexity (which is different from task difficulty) is directly related to task difficulty and/or the number of elements of the task, and subsequently the amount of information processing placed on the subject. For example, serving a tennis or volley ball are both tasks that are high in complexity, as is driving a car. Tasks that are low in complexity are skills such as throwing a dart or picking up a glass.

Organization was defined by Naylor and Briggs (1963) in terms of the inter-relationship between the elements or parts of the task; more organized tasks are characterized by high interdependencies of the component. Tasks that rely very much on how one component is performed for the others to be successful have a high degree of organization. A good example of a task that has a high degree of organization is the triple jump. On the other hand, tasks that comprise many parts that are rather independent are considered to be low in organization, for example a dance routine.

Based upon Naylor and Briggs, assessing both the complexity of a task and the organization of a skill should help the coach or therapist to decide whether to use part or whole practice. The *whole method* involves learning the particular skill as a whole rather than trying to break it down into subroutines. In general, movement skills that are not too complex and that are highly organized in terms of their constituent parts are more suited to whole-task practice methods. For example, relatively simple skills such as catching a ball are best learned in this way. Many skills are very complex and even skills that might appear relatively simple, such as throwing the discus, will still appear very complex to novices. When teaching these, the coach should not present all aspects of the skill for practice. The learner would probably be overwhelmed by the quantity of information provided, and consequently would probably not be able to take in all of it. The *part method* is thought to be better for the more complex skills, or those that take longer to perform, e.g. a gymnastics routine. The whole skill is broken down into components that can be learned independently, and then they are recombined to form the whole skill. For example, footballers need to be able to run, dodge, jump, stop and turn, as well as kick a ball. They also need to learn how to control the ball with their feet, knees, chests, head and even their hands if they are a goalkeeper. These skills are generally performed as a combined

whole while on the football pitch, but are often practiced on their own. Park *et al.* (2004) conducted an interesting study that examined the difference between whole and part practice of a 16-step movement sequence. Participants produced a right arm lever movement to target locations that were presented in sequence. The part group practiced the first eight sequences for one day and all 16 on the second day. The whole-practice group practiced all elements for both days. On the third day a retention and transfer task was performed, see Fig. 1 for the results. The results showed no difference between part and whole practice in terms of learning the task. Part practice, however, resulted in better transfer in terms of performing the last eight elements (sequence B) but not for sequence A (the first eight elements). The authors state that this indicates that, compared to whole practice, part practice enables participants to eliminate parts of the movement without negatively influencing performance.

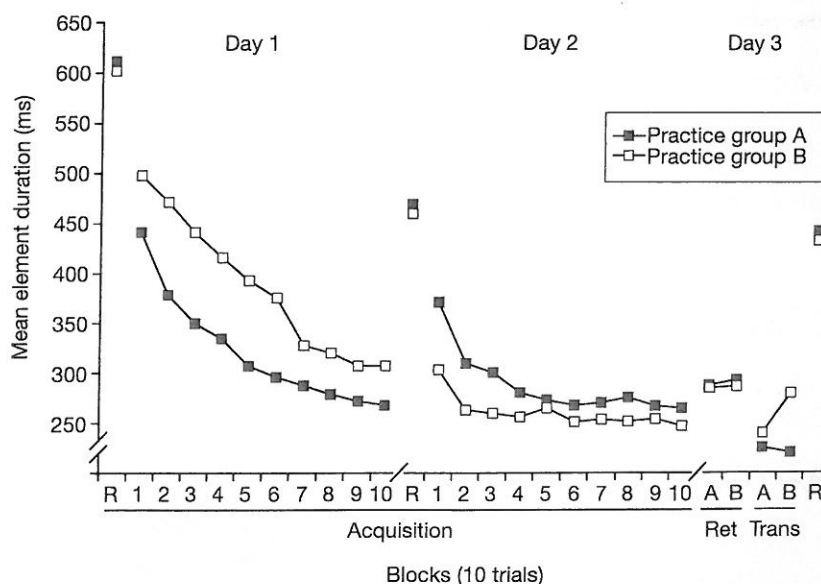


Fig. 1. Whole and part practice data during acquisition, retention, and transfer. Ret, retention; Trans, transfer. Adapted from Park *et al.* (2004).

When using part practice there is a need to devise subunits of skill, and decide how they should be practiced for maximum transfer to the whole skill. A starting point is to break the task to be learnt down into its component parts. This can take a number of forms and the task, context, and the level of expertise of the learner must be taken into account. Therefore, a number of facts have to be considered and evaluated. If, for example, we decide that the triple jump should be practiced in parts, there are still many questions to be answered. The performer can practice the hop, skip and jump separately; however, does the performer devote the same amount of time to the hop as the skip and the jump? Can the parts be practiced in the reverse order, e.g. the jump, the skip and then the hop? Does the coach recommend practicing the skip and jump together? In addition to this, what adaptations might be made to the context, can this be done in a gymnasium rather than the sand pit?

Wightman and Lintern (1985) suggested three methods of part practice that may be used depending upon the nature of the skill and the capabilities of the

learner. These are simplification, segmentation and fraternization. *Segmentation* involves portioning a task into components along temporal or spatial dimensions; each of the parts is then combined with other parts, leading to the performance of the entire task. Prior to the practice of the task the size of the components is decided upon, depending upon the performer's capabilities. This is often called a *progressive-parts method*. Using this method, the triple jumper would learn the hop first, then skip, then the hop and the skip, then jump, then the hop, skip and jump. *Simplification* refers to the modification of movements to the basics of the skill within a particular environment.

The third method of part practice involves *fraternization* of the skill. This involves the dismantling of the coordination of a skill into several parts. In general, when a task is high in organization, a whole-practice approach would be better suited. However, skills can be often high in organization but benefit from a part-practice method (Fig. 2). For example, in skills where both arms are required to do something very different, it may be better to practice each arm separately before performing with the arms together.

There are a number of methods that can be employed to make the skill or parts of the skill less difficult and to enable learning to progress (Box 1). When breaking the task into its component parts, the teacher, coach or therapist can manipulate a number of aspects of the learning environment and this applies to both the sport and clinical setting.

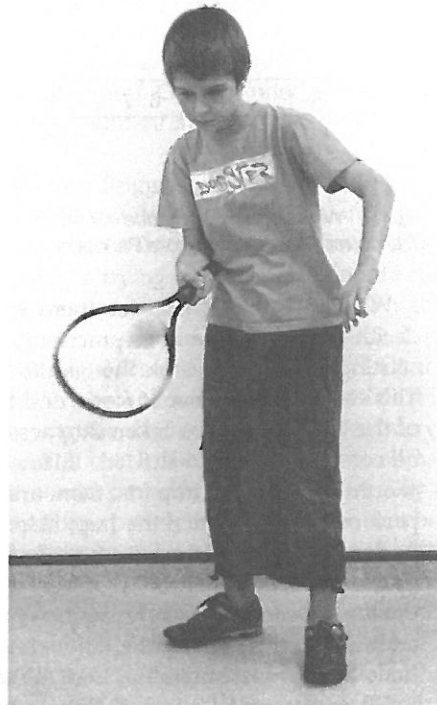


Fig. 2. Skills can be broken down into component parts.

Box 1. Adaptations that can be made to assist learning. Adapted from Utley et al. (2001)

Adaptations to organizational arrangements

- Physical aspects of the classroom/gym/sports hall/pitch etc
- Organization of grouping within the year group, within the session
- Organization of support: before, during, and after the session.

Adaptations to teaching methods

- Use of a variety of teaching styles
- Extending their active learning/activity components
- Use of active learning strategies, self-evaluation
- Variable practice
- Attention to spoken explanations – clarity, pace, vocabulary
- Monitoring of performers' understanding, use of additional memory aids
- Regular feedback and meaningful praise
- Assessment and modification of written materials – readability, clarity, vocabulary
- Consistency
- Over-learning
- When applying sanctions ensuring that they do not have hidden rewards.

Adaptations to curricular tasks and activities

- Tailoring tasks to the performers' interests
- Modifications to equipment size, weight, height, color, texture, and sound
- Modifications to space (adjustments to size of space, use of cones to mark out zones, use of texture to mark out zones, use of walls to field the ball)
- Modifications to time (some performers may need more time to complete an activity, others should be stretched by reducing the time)
- Modifications to rules
- Use of a variety of resources and equipment
- Providing alternatives to or modifications of pupil responses.

Conditions of practice

... practice, when properly undertaken, does not consist of repeating the means of solution of a motor problem time after time, but is the process of solving this problem again and again by techniques which we changed and perfected from repetition to repetition. ... Practice is a particular type of repetition without repetition. (Bernstein, 1967)

After breaking down the skill as appropriate (*Fig. 2*), the next question is how the skill should be practiced. As coaches and therapists we need to decide how many activities should be practiced each session and how much time should be devoted to each activity. The belief that the more you practice the better might not be correct, and a balance has to be struck between quantity and quality. One of the major issues for the coach, teacher and therapist is how to space or distribute practice for optimal learning. *Massed practice* is where the skill is practiced repeatedly over a long period of time. Skills tend to be learned better this way, though

fatigue and boredom can cause some problems. More experienced performers and athletes tend to respond better to this type of practice. *Distributed practice* is where the sessions are short, spread out over time with rest periods or changes of activity interspersed with the main practice. This is a good way to offset boredom, but there is a danger that the skills may not be acquired as well as with massed practice. This technique is probably best for younger players or those new to the sport. *Variable practice*, as the name suggests is a mixture of both types. Depending on the skill level and experience of the individual, one or other or both types of practice might be employed by the coach. For part of the performance massed practice might be best, but for others, distributed practice favored. Variety is always useful in training sessions as it will reduce tedium and keep people motivated. A number of research studies have been conducted to determine which practice schedule leads to better performance and learning. It must be remembered that performance and learning are different, and that retention and transfer also need to be considered (see Section H). When reviewing studies that look at the benefits of practice it must be remembered that there is conflicting evidence as to which type of practice is best.

Massed practice

During massed practice the time spent active or actually practicing the skill is greater than the time spent resting. Massed practice will involve fewer blocks of practice but the blocks will be more intensive and the performer will repeat the action many times within the block of practice. During massed practice the performer will have very short or no periods of rest. The benefits or negatives of massed practice will very much depend upon the nature of the skill to be practiced. For skills that are relatively discrete such as a tennis shot, short massed practice which involves short rest periods may work very well. A table tennis player, as seen in the Fig. 3, may well benefit from massed practice of a particular shot, such as a smash. However, for better learning it may well be best to spread practice over a number of days or weeks. Therefore massed practice may work well for practice in a particular session, but massed practice sessions over time may not be beneficial. Vearrier *et al.* (2005) found that intensive massed practice worked well for retraining balance post-stroke, therefore its is important to consider the individual, the task, and the context when planning practice.

The following points should be considered:

- for more continuous skills such as learning to ride a bike, practice should be short and with plenty of rest
- for more discrete skills such as a tennis shot, massed practice with short rests may be best
- more frequent learning sessions will assist learning and retention; practicing a skill once a month may not work well
- trying to rush skill learning by over-massing practice will not work well
- practice sessions should not be so long that fatigue becomes a factor
- There is some crossover in the use of the term massed and distributed practice, and the next section and Research Highlight are also relevant to the information on massed practice.

Distribution of practice

When planning practice, regardless of whether this is in the sporting, educational or rehabilitation context, the frequency of practice and the length of

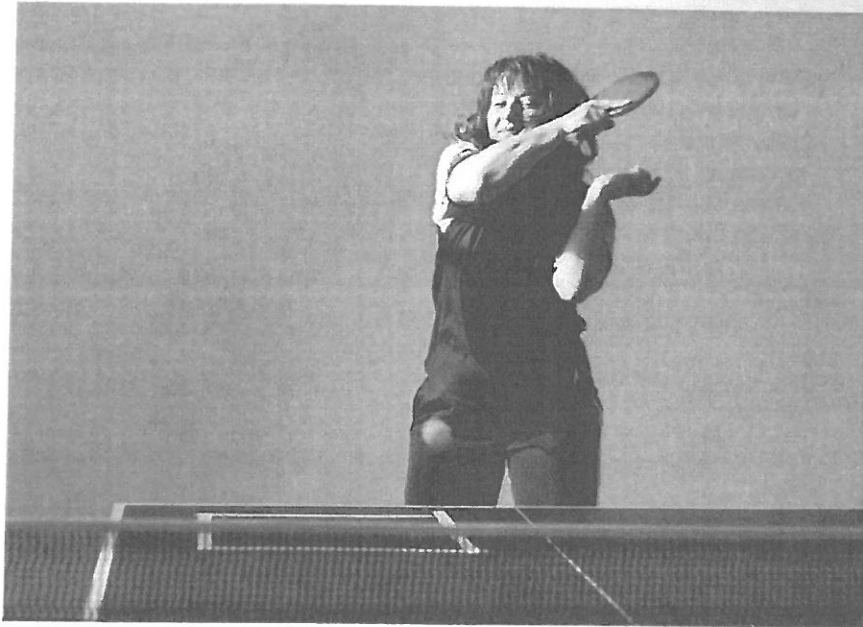


Fig. 3. Massed practice of a forehand smash.

recovery has to be decided. Over the years there has been a range of research that has explored the distribution of practice. Researchers have considered how massed, distributed, random and blocked practice influence performance, learning, retention and transfer. We have reviewed a few studies here, but there are many and, as with other areas of research, the findings present a contrasting picture of what is best 'practice'. As you will see from the few studies reviewed here, one of the main causes of a lack of consensus is the range and variety of tasks, contexts and participants involved in these studies. This at times makes comparisons difficult. Studies have also manipulated rest periods so that the period of practice is longer than the period of rest. In distributed practice, however, the period of rest is often equal to or less than the work period. Bourne and Archer (1956) conducted a study looking at the benefits of rest when learning a rotary pursuit task. They concluded that the longer the rest period the better the performance. Other research has supported this work, with Baddeley and Longman (1978) examining the best way to train postal workers on a keyboard task. The aim was to achieve a typing speed of 80 key strokes per minute. The participants were divided into four groups with varying practice schedules. One group had one hour's training once a day for 12 weeks. Another had one hour's training twice a day for 6 weeks, a third two hours' training once a day for 6 weeks, and the final group two hours' training twice a day for 3 weeks. There was therefore a variety of ways in which practice took place, from more-distributed to more-massed practice. The results showed that distributed practice was by far the best, and after a 9-month retention test the group that had the most massed practice performed worse, with little difference between the other groups.

Other studies have found similar results to Baddeley and Longman, and distributed practice would appear to be better than massed practice. Savion

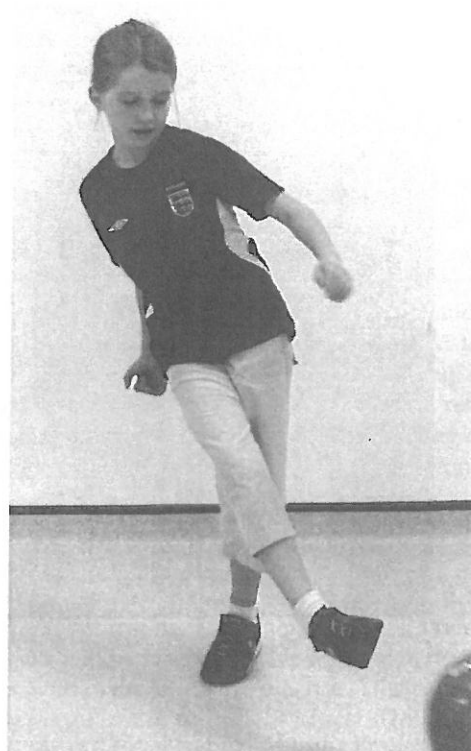


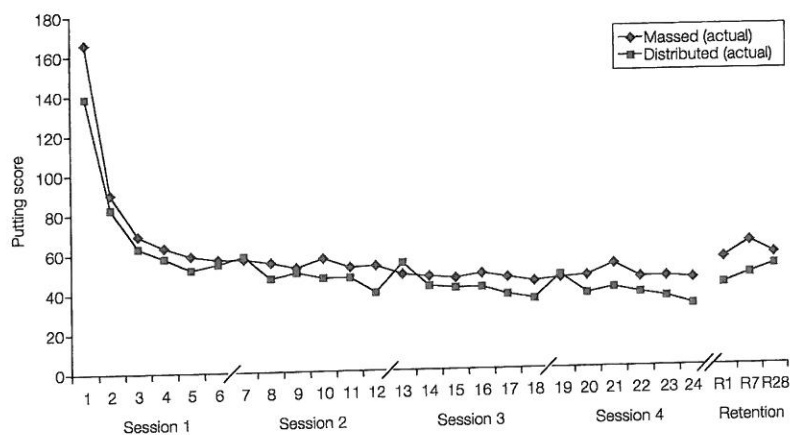
Fig. 4. Skills can be acquired using a variety of practice schedules.

Lemieux and Penhume (2005) looked at the effects of amount of practice and length of delay on the learning and retention of a timed motor sequence task. Participants were assigned to a varied-practice condition or a varied-delay condition. In the varied-practice condition, participants received either 1, 3, or 6 weeks of practice followed by a 4-week delay recall. In the varied-delay condition, participants received three blocks of practice followed by a varied delay of 3 days or 2, 4, or 8 weeks. The amount of practice did not affect learning or retention, but distribution of practice did affect learning and retention. Savion Lemieux and Penhume conclude that delay may well allow for consolidation of learning. Vearrier *et al.* (2005) conducted a study in which the purpose was to test if intensive massed-practice intervention (participants practiced 6 hours per day for 2 consecutive weeks) could significantly improve balance function post-stroke. The ability of the subjects to recover from a balance perturbation improved during training, and further still during the maintenance phase, ending 3 months post-intervention. Intensive massed practice of standard physical therapy produced significant results in balance retraining with patients post-stroke. Studies of this nature are of particular interest as they advance our knowledge of how best to rehabilitate patients post-injury in a variety of conditions.

Although there is conflicting evidence, it would appear that massed practice does not produce as positive results as distributed practice, especially in terms of retention and transfer. It may well be that massed practice causes fatigue and does not allow the learner time to evaluate, reflect or make appropriate

Research Highlight: Dail and Christina (2004)

An interesting study that examined putting in golf was conducted by Dail and Christina (2004). Participants included 90 novice golfers with a mean age of 22.3 years. They were randomly divided into two groups: a massed-practice and a distributed-practice group. The task was to attempt to hole a putt or get as close as possible from a distance of 370 cm. The number of correct putts or distance from the hole was recorded. Each group completed 240 acquisition putts, with the massed group completing them in one session. The distributed group practiced 60 putts per day for 4 days. The results indicated that the distributed-practice group outperformed the massed-practice group during both acquisition and retention (60 putts). The figure below shows the results, including the retention test which took place on three occasions (1 day, 7 days, and 28 days later (R1, R7, R28)).



Reproduced with permission from Dail and Christina (2004).

cognitive associations. Another form of practice that is popular and that is well researched is variable practice.

Variable practice

A consistent characteristic of motor learning theories is that practice variability is beneficial to skill acquisition. For example, Schmidt's schema theory (Schmidt, 1975) states that practicing variations of a movement (variable practice) will be of benefit when the movement must later be recalled (retention) or when producing a novel form of movement (transfer). Schmidt's schema theory predicts that practicing a variety of different ways to perform a motor skill during a practice session provides the learner with an opportunity to apply different parameters to a movement skill and develop their generalized motor program (see Section H). Recall schema is therefore strengthened by variable practice. Thus, a goalkeeper may practice stopping the ball from different distances, different heights and different trajectories and different set pieces, such as a penalty kick, corner or indirect free kick. He or she may also use balls of different sizes or the goals may be adjusted in size (Box 1).

In Section I, Gentile's (2000) two-stage theory of motor learning was introduced, and it is generally agreed that two guiding principles emerge from this

model. The first is that although Gentile (2000) emphasized the need during practice for the learner to experience a variety of regulatory and non-regulatory context conditions, she also states that variable practice should not really be introduced until the learner has established an appropriate coordination pattern for the task at hand. In light of this, consistent practice may be more beneficial for the learner at this stage. Secondly, the type of variability that should be introduced will differ with respect to the type of skill being learned and the environment in which it will be ultimately performed.

A number of researchers have considered how variability of practice influences learning and retention. Much of the research has been conducted to test predictions about schema theory. Over the years the range of tasks to be learnt has varied from discrete to continuous, and from few to many degrees of freedom to be controlled. Shea and Kohl (1991) looked at comparisons between variable-practice conditions in order to consider the influence this had on retention. Participants were split into three groups and trained on a task that involved being able to precisely exert a given force on a stress gauge. One group practiced only on the criterion force (criterion only) while another other group practiced at four different forces as well as the criterion force (criterion and variable). The final group practiced the criterion task and completed additional spaced practices of the criterion task (criterion-criterion). The results indicated (Fig. 5) that the groups that practiced exclusively at the target force initially acquired the skill faster. However, when tested later, the criterion-varied group had retained their skill much better compared to the other groups. Variability of practice therefore benefited skill retention.

From the 1970s to the present day, there has been a variety of studies examining variable practice and its influence on skill acquisition and retention. These studies cover a massive range of tasks, contexts, and individuals. McCracken and Stelmach (1977) found that when learning to knock over a barrier with the

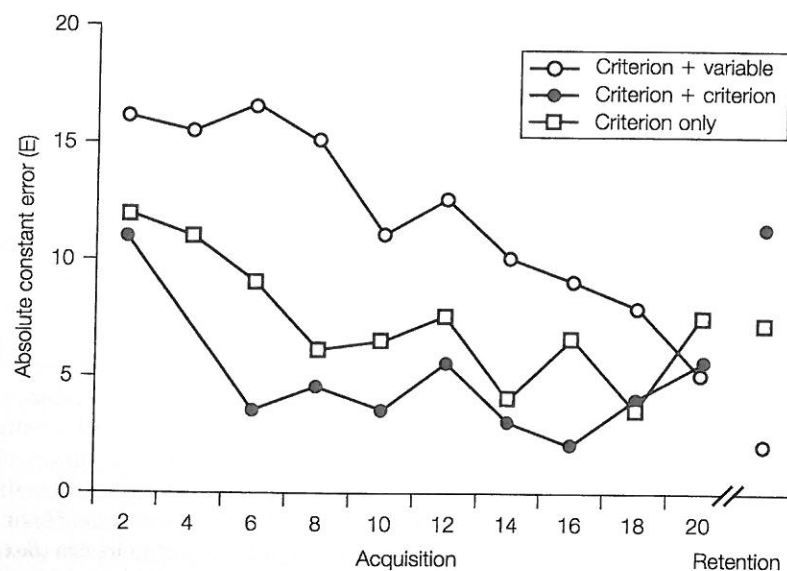


Fig. 5. The benefits of variable practice on retention. Adapted from Shea and Kohl (1991).

hand in a set time, the variable group outperformed the constant group. As with Shea and Kohl (1991) they found that during two retention periods the variable group outperformed the constant group even though they had not during the acquisition period. Recent studies have looked at more complex tasks. Granda-Vera and Montilla (2003) looked at practice schedule, acquisition, retention and transfer when 6-year-old children performed a throwing task. They found that participants in the variable practice group showed better performance than the blocked group in acquisition, retention and transfer. Douvis (2005) also found that variable practice produced better practice results when using variable practice in learning a forehand in tennis. Heitman *et al.* (2005) looked at the effect of specific versus variable practice on a pursuit rotor task. The variable group practiced at varying speeds and the specific practice group performed 30 trials at 45 rpm on day one, and on day two all groups performed 15 trials at 45 rpm and 15 trials at 75 rpm. It was found that the specific group had higher retention scores and the variable group had high transfer scores. The authors conclude that this reflects the influence of context on continuous motor skills.

Williams and Hodges (2005), in a paper examining practice and skill acquisition in football, presented an interesting diagram showing the relationship between variable practice, contextual interference, and practice activity (Fig. 6). It is this relationship that is of interest to coaches, teachers, and clinicians and in the next part of this section we will explore this.

Implementing practice variability: contextual interference

Having established that practice variability enhances learning, we must now further consider how a teacher, coach or therapist should organize the practice session. One way to do this which is particularly popular is to apply the phenomenon known as *contextual interference* (CI). CI is a functional interference

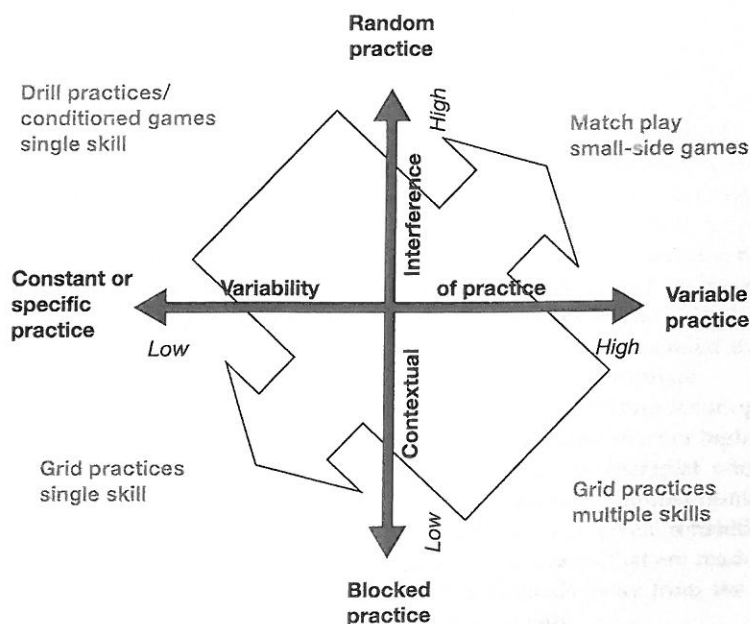


Fig. 6. The relationship between variable practice, contextual interference and practice activity in football. Reproduced with permission from Williams and Hodges (2005).

introduced in practice which results in several movements being practiced, and refers to the learning effectiveness of random vs. blocked practice.

Low CI results in the performer practicing only one skill in the practice session – *blocked practice*. For example, when learning to play hockey, the player may practice shooting for 10 minutes, passing and receiving the ball for 10 minutes and then spend their final 10 minutes practicing dribbling. Although blocked practice schedules assist individuals in initial decision making and performance enhancement, when interference is introduced to simulate real-world conditions, there is a substantial erosion of learning. In stark contrast, a high degree of CI can occur when a learner practices several different but related skills in the same practice session – *random practice*. If we consider the performer learning to play hockey again, in the same 30-minute session the players may practice shooting, passing and receiving and dribbling for five consecutive attempts, and the order in which the skills are practiced is changed throughout the session. Under conditions where the environment is dynamic and the individual is required to adapt to variations in the surroundings, random practice schedules are superior to blocked practice sessions for retention of motor skills. A third type of practice, *serial practice*, would see the player practicing dribbling, passing, receiving and the shooting in five consecutive trials, but with the order in which the skills are practiced kept the same throughout. These different kinds of practice are not unique to teaching in physical education, it is also characteristic of, for example, a therapy session in which the patient is learning to use their wheelchair, in that the patient will have to practice this skill on a variety of different surfaces.

Interest in CI can be traced back to Battig's (1966) work in the area of verbal learning. Battig (1966) proposed that 'intertask facilitation is produced by intratask interference' (p.227) (intertask facilitation being the capacity to transfer and perform between different tasks). This was in direct contrast to predominant methods of conceptualizing the role of interference in learning and memory at the time.

Shea and Morgan (1979) showed that the CI effect as observed by Battig was applicable to the motor skill acquisition in a study which saw participants move their arms as quickly as possible through three different three-segment patterns. In response to a stimulus light, the participants picked up a ball with their right hand and knocked over a series of freely moveable wooden barriers and then brought the ball to a final resting position. Some participants were instructed to use blocked practice (low CI) and some participants used random practice (high CI). Participants in the blocked-practice group practiced task A 18 times followed by task B and task C 18 times each. The random-practice group practiced each task 18 times but the order of presentation was random (e.g. ABCB-CABAC). Shea and Morgan's (1979) data showed that although the participants in the blocked-practice group had a better performance, they did not have better retention and transfer of the skill.

Since 1979, substantial laboratory-based research on CI has been conducted (Magill and Hall, 1990; Brady, 1998). However, several researchers have questioned the utility of laboratory-based research, claiming that it lacked ecological validity to real-world environments. Despite Del Rey's (1989) notion that the laboratory tasks that had been selected were chosen because their processing demands were similar to those required in sports, many of the tasks used to investigate the CI effect were simple and involved minimal degrees of freedom, which by their very nature resulted in rapid gains in skill. To validate the

theoretical notion of CI, researchers began translating the concept into instructional procedures that applied to the practitioner, and tested them out with real-world sporting activities.

To date, researchers have found some evidence for the effect of contextual interference on the acquisition of sport skills. Goode and Magill (1986) followed by Wrisberg and Lui (1991), showed that practicing badminton serves with high or low CI did not elicit a difference between the two groups in acquisition, but that during retention and transfer differences between the two groups were apparent. This, however, was limited to the performance on the short serve. In addition, these studies did not demonstrate as Battig predicted, that blocked practice would cause superior performance during acquisition.

Strong support for the CI effect has been demonstrated by Hall *et al.* (1994). These workers randomly assigned 30 baseball players to either a control group or a group that performed blocked or random practice. The random and blocked groups received two additional batting-practice sessions each week for 6 weeks, while the control group received no additional practice. The extra sessions consisted of 45 pitches, 15 fastballs, 15 curveballs, and 15 change-up pitches. The blocked group received all 15 of one type, then 15 of the next type, and finally 15 of the last type of pitch, in a blocked fashion. In contrast the random group received these pitches in a random order. Pretest analysis showed no significant differences between the groups. However, when the transfer test results were examined the random group performed with reliably higher scores than the blocked group, who performed better than the control group. When comparing the pretest to the random transfer test, the random group improved 56.7%, the blocked group 24.8%, and the control group only 6.2%, superbly demonstrating the CI effect.

Smith and Davies (1995) examined the effect of contextual interference on the learning of the Pawlata roll in a kayak. This study was motivated by the fact that at the time many instructors in Britain were advocating learning the Pawlata roll in one direction only to a criterion of accuracy, thereafter transferring to the opposite direction. However, Smith and Davies (1995) suggest that skill retention would be better served by practicing on alternate sides and therefore proving contextual interference. In light of this, Smith and Davies conducted a study in which 16 undergraduate students with no kayaking experience were randomly allocated to either a low-CI group or a high-CI group, which practiced the skill on alternate sides. Analysis of the data showed that the high CI group was quicker to achieve successful performance in retention (full roll) and transfer (half roll) tests, regardless of the direction of the roll, one week later. In addition, and perhaps more surprisingly, the high-CI group also acquired the skill more quickly than the blocked-practice group. Overall, these data showed the recommended training methods at the time for learning the Pawlata roll were not appropriate.

There is remarkable consistency in the motor learning literature favoring high CI. However, there is limited research that has examined the effect of high CI on the relearning of activities of daily living. Given that the therapist often has limited time with a patient, as well as the fact that there is a limited number of tasks and task variations that can be experienced in a given rehabilitation setting, practice sessions that promote retention of the gains that are made with the therapist and that facilitate transfer to other contexts away from the clinic are highly desirable.

Weeks *et al.* (2003) examined the role of variability in practice structure when learning to use upper-extremity prosthesis. The purpose of the study was to

examine the acquisition, retention, and transfer of selected prehension skills under conditions of low and high CI to establish the most effective practice context for patients. As an adequately sized population of recent upper-extremity amputees was not available for the study, the training was given to able-bodied participants who wore a simulator that mimicked actual upper-extremity prosthesis in form and function. Forty-eight participants were randomly distributed into two groups for skill-acquisition training: those who practiced three different prehension tasks with the simulator in a random practice order or those who practiced the three tasks with the simulator under a blocked-practice order. During acquisition, the groups practiced the three tasks on two consecutive days. On the third day, two different tests of learning were administered: a retention test on the tasks practiced in acquisition, and an inter-task transfer test on three tasks similar to those practiced in acquisition. Analyses of data showed that both the random and blocked groups showed significant improvements in initiation time and movement time to perform each task across the two days of acquisition. Thus, regardless of degree of 'randomness' inherent in the schedule, practice did indeed promote functional use of the prosthesis. In addition, both practice schedules were equally effective for promoting skill retention. However, during the intertask transfer phase of the study, the random-acquisition group demonstrated significantly greater proficiency in performing the new tasks than the blocked-acquisition group. Weeks *et al.* (2003) suggest that their data show that persons learning to use upper-extremity prostheses may be better able to transfer skill to new prehension tasks by practicing under random-practice conditions. Further studies like that performed by Weeks *et al.* (2003) are required to validate the concept of CI for rehabilitation, and this will add to the ever-increasing pool of resources for therapists to draw on while practicing evidence-based medicine.

The influence of expertise, task complexity, and contextual interference was examined by Ollis *et al.* (2005). Novice and experienced knot tiers took part in the study in which they practiced tying knots that were simple and complex.

After establishing baseline-knot tying abilities the novice group and the expert group practiced in three experimental conditions, low CI, moderate CI, and high CI. The results of this experiment can be seen in Fig. 7. It was found that high levels of CI scheduling enhance learning for novices even when practicing a complex task, and also that CI benefits are more apparent as the learners engage in tasks with high transfer distality. The authors conclude that complexity and experience influence the CI training effect in motor situations that have high contextual meaning.

Theoretical explanations

Despite the fact that it seems that the CI effect is equally applicable in both the laboratory and the applied setting, there is still considerable debate surrounding the accepted explanation for the CI effect. Current theoretical explanations include the *elaboration hypothesis* (Shea and Zimmy, 1983; 1988) and the *action-plan reconstruction hypothesis* (Lee and Magill, 1985). However, both rely heavily on the role of cognitive effort or the more effortful processing engendered by random practice schedules; and the deficient or decreased processing resulting from blocked schedule (Albaret and Thon, 1998; Brady, 1998; Immink and Wright, 1998).

The elaboration hypothesis (Shea and Zimmy, 1983; 1988) is based upon the levels-of-processing framework of memory (see Section J) and relies heavily on

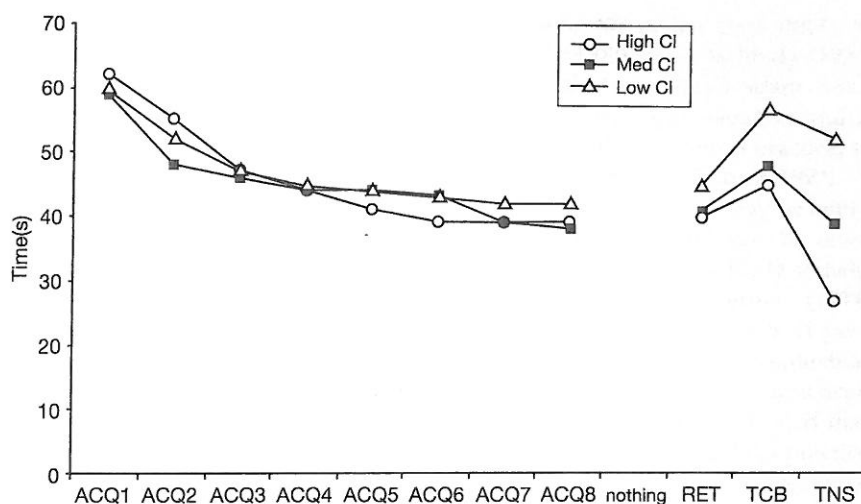


Fig. 7. Time taken to tie (a) simple-knots group (novice) and (b) complex-knot group (experts) in varying contextual-interference situations. ACQ, acquisition; RET, retention; TCB, transfer complex and blindfold; TNS, transfer normal and sighted. Reproduced with permission from Ollis et al. (2005).

the notion of intratask and intertask processing and their use by the learner during practice. In blocked practice, learners primarily use intratask processing or within-task analysis, since only one task resides in the working memory. However, random practice encourages the learner to engage in both intra- and intertask processing since multiple tasks reside in the working memory. Shea and Morgan (1979) suggested that random practice works by actively engaging the learner in the learning process, by forcing them to try out a number of different strategies to complete the motor task. The majority of these skill variations are held in the working memory (see Section J), allowing the performer to compare each variation, to see what is similar or dissimilar and what works or does not work. Consequently, there is further elaboration of the memory representations of the skill variations that a learner is practicing. In the end these variations become distinct from each other and they can then be used when the environmental and task constraints dictate it. Therefore, according to the elaboration view of CI, random practice leads to a more enriched representation, whereas a more impoverished encoding results under blocked conditions.

Lee and Magill (1985) proposed an alternative but not contradictory explanation for the CI effect – the action plan reconstruction hypothesis. Lee and Magill (1985) claimed that the elaboration hypothesis could not adequately account for the random group's acquisition performance deficits. According to Schneider *et al.* (1995), the retention benefit of random practice can be attributed to the extensive retrieval practice that occurs as a result of a continual interchange of task information in the working memory (see Section J) from trial to trial. Essentially, when learners are engaged in random practice they are required to regenerate an action plan, based upon information stored in the long-term memory store, on the next practice trial for that skill variation. This regeneration is thought to have occurred because the learner has partially or completely forgotten the action plan that she or he developed on the previous practice trial for that skill

variation (Lee and Magill, 1985). In contrast, the performer who engages in blocked practice can use the action plan that she or he developed on the previous trial.

The contextual interference effect: is there an exception to the rule?

An overview of CI research typically shows that acquisition performance is improved with repetitive blocked practice, while retention and transfer performance, perhaps the most important indicators of training effectiveness (Salas and Canon-Bowers, 2001), benefit from random-practice scheduling (Brady, 1998). Since the original demonstration of the CI effect in the motor domain (Shea and Morgan, 1979), this effect has been observed using a variety of subject populations (Del-Rey *et al.*, 1982; Edwards *et al.* 1986; Ollis *et al.* 2005; Keller *et al.* 2006) and environmental settings (Goode and Magill, 1986; Shea and Wright, 1991). Although it appears that there is a large amount of evidence that demonstrates the effectiveness of the CI effect, the data also show that it does not always apply to all motor learning situations (for a good review see Magill and Hall, 1990; Wulf and Shea, 2002). Brady (1998) cites many important factors that can influence the CI effect, such as amount of practice, cognitive effort, intrinsic interest and/or motivational processes, trait anxiety and/or self-efficacy. Some of these are discussed below.

Task-related characteristics

Magill and Hall (1990) suggested that the primary limiting factor for the CI effect was the task's characteristics. They noted that skills that require many variations that are controlled by different generalized motor programs would be affected more by high CI. More specifically, they suggested that practicing tasks controlled by different motor programs rather than the same one resulted in more interference and consequently more effortful processing. In contrast, tasks that are governed just by one motor program require more parameter (force or timing) modification. Unfortunately, this proposal has not been well supported by applied research, indeed, a near opposite trend is apparent with much of the data suggesting that high CI enhances learning tasks with similar movements.

Practicing more complex tasks under high interference conditions may prove too difficult for early learners to elicit CI effects. Research which has investigated the effects of CI on the learning of volleyball skills has produced equivocal results (French *et al.* 1990; Bortoli *et al.*, 1992) and Magill and Hall (1990) proposed that high CI may overwhelm novices in the early stages of skill acquisition and that learners need to be somewhat proficient before they can take advantage of random practice. This proposition was later supported by Hebert *et al.* (1996). Alternatively, more expert individuals may not find simple skills challenging enough even under random conditions. Research has shown that in general experienced learners benefit more than novices from high levels of CI scheduling (Guadagnoli and Lee, 2004; Magill and Hall, 1990) and that as task complexity increases, the relative benefit from increasing levels of CI should decrease (Albaret and Thon, 1998; Wulf and Shea, 2002).

Learner characteristics

Although predominantly an under-researched area, it has been suggested that learner characteristics (e.g. personality) may interact or mediate with the CI effect. For example, an individual's self-efficacy may dictate whether low or high CI is more appropriate for skill acquisition. Bandura (1997) coined the phrase

'self-efficacy' as the belief that an individual has in his or her own ability to execute a certain course of action or obtain a specific outcome. As Brady (1998) notes, it seems likely that highly efficacious individuals would adapt more readily to high-CI conditions. In contrast, as blocked practice accelerates acquisition, individuals with low efficacy may benefit more from this type of practice, as performance accomplishments are a potent source of efficacy (Bandura, 1997).

In line with Gentile (2000), research has suggested that children may be better suited to blocked rather than random practice. At first high CI may be more difficult for beginners and children, and blocked practice is more likely to help the learner establish the basic movement pattern. Jarus and Goverover (1999) investigated the varying conditions of contextual interference within 5–11 year olds who practiced the task of throwing beanbags under either low contextual interference (blocked practice), high contextual interference (random practice), or medium contextual interference (combined practice). Analysis indicated that only the 7-year-old subjects differed in their performance in the various practice groups. On the other hand, the 5 and 11 year olds did not differ in performance in the different practice groups. This suggested that developmental age may interact or mediate the effects of CI. Granda-Vera and Montilla (2003) also investigated the effects of CI in young children aged six years. Participants on a variable-practice schedule showed better performances than those on a blocked schedule, and the difference between the two groups was significant in the acquisition, retention and transfer phases. These results support the hypothesis that contextual interference enhances skill learning.

Conclusion

The role of practice in motor learning and retention remains an area of great interest for all those involved in designing practice. As we constantly strive to improve performance, improve rehabilitation and ensure we are more efficient, there will always be debate about what is the best to practice a skill. What is clear is that we must always consider the nature of the task, the individual, and the context in which the skill is both learnt and performed.

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