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Review article. How to design the practice to optimize motor performance and learning?: A literature review. Vol. IV, Issue. 3; p. 587-603, september 2018. A Coruña. Spain ISSN 2386-8333

How to design the practice to optimize motor performance and learning?: A literature review

¿Cómo diseñar la práctica para optimizar el desempeño y aprendizaje motor?. Una revisión de literatura

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Abstract

This manuscript presents a literature review of five types of practice commonly used: practice variability, performance, composition, and distribution, and contextual interference; and how these can influence the motor skill´s performance or learning process. This summary allows professionals in human movement sciences and related careers to take decisions when designing the work session.

Key words
Education; sports performance; motor skill.

Resumen

Este manuscrito presenta una síntesis de literatura de cinco tipos de práctica más utilizados: variabilidad de la práctica, ejecución de la práctica, composición de la práctica, frecuencia de la práctica e interferencia contextual; y como estas pueden incidir en el desempeño o el proceso de aprendizaje de una destreza motriz. Este resumen permite a profesionales en ciencias del movimiento humano y carreras afines, la toma de decisiones en el momento de diseñar la sesión de trabajo.

Palabras clave
Educación; rendimiento deportivo; destreza motriz.

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Introduction

The challenge of the human movement science professional is to achieve that people learn a motor skill. The field of Motor Learning studies, the process of acquiring motor skills and the factors associated with practice or experience that leads to a relatively permanent change, in the ability of the person to skillfully complete a motor skill (Magill & Anderson, 2013; Schmidt & Wrisberg, 2008). Multiple factors that can influence the performance and learning of a motor skill have been studied. Precisely, the practice has been considered an essential factor in the process of learning a motor skill (Coughlan, Williams, McRobert, & Ford, 2014; Fairbrother, 2010), it is even mentioned, that it is a condition without which motor learning cannot be achieved (Corrêa, Walter, Torriani-Pasin, Barros, & Tani, 2014). Therefore, it is important to determine under what type of practice learners improve the performance of the motor skill in an acquisition, retention or transfer test (Matsouka, Trigonis, Simakis, Chavenetidis, & Kioumomourjoglou, 2010; Shea & Wright, 1997). A key point to enhance motor learning is to design the practice efficiently (Coughlan et al., 2014; Davids, Button, & Bennett, 2008).

In order to examine the effect of different types of practice, various techniques of designing practice experiences have been explored to achieve efficient learning (Fairbrother, 2010). The practice sessions are designed by manipulating variables related to the number of elements, the order of them, how to perform them, the amount of rest, among others (Davids et al., 2008; Fairbrother, 2010; Magill & Anderson, 2013). Therefore, how to design the practice of a motor skill to optimize performance and learning? The conditions of the practice and their respective types must be taken into account. Also, is necessary to know that the effectiveness of the practice may be conditioned by other characteristics (e.g. the level of skill of the learner, the complexity, and organization of the task, the time available in the session, the absence or presence of augmented feedback). Therefore, the purpose of this literature review was to present a synthesis of five practice conditions and how these can influence the performance or learning process of a motor skill. Table 1 presents the taxonomy of the different conditions with their respective types of practice, analyzed in this review.

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Table 1. Characteristics of different practice conditions.

Practice Condition	Type of practice	Definition
Practice performance	Physical	It is the motor performance of the movement, where all the body parts required are physically involved.
	Mental	Muscular activation as a result of visualizing or imagining the skill in the mind, without taking it to the physical performance.
Variability in the sequence of the practice	Variable	Practice two or more skills, or variants of the same skill, under different conditions, in context, distance, time, space or duration.
	Constant	Practicing the same skill or variation of that skill always in one condition, whether in context, distance, time, space or duration
Practice composition	Whole	Practice the skill in a complete way.
	Part	Practice the skill fractionally, for example, by parts and each part separately
Practice frequency	Distribution	It involves the practice of a skill with more resting time between sessions (in 1 week period) or intermittent periods of work or trials (throughout a working session).
	Massive	Involves the practice of a skill with less resting time between sessions (in 1 week period) or continuous periods of work or trials (throughout a working session)
Contextual Interference (method to organize the practice variability)	Blocked	Rehearsal of the same skill, or variation of the same skill, repeatedly before practicing another skill, or variation
	Random	Rehearsal of different skills, or variations of the same skill, randomly ordered, avoiding consecutive repetitions of a skill, or variation
	Serial	It involves a combination of the practice in block and random. For example, the repetition of blocks that were built randomly.

Source: Own elaboration

Methods

This research is a literature review, that focus on five practice conditions generally used in the field of Motor Learning. The following databases were used: Academic Search Premier, Education Research Complete, ERIC, Fuente Academica, MedicLatina, MEDLINE, Academic Search Complete, SocINDEX with Full Text), SportDiscus, Scopus, Jstor, PubMed, and

PsycINFO. Keywords used: motor learning, motor skills acquisition, mental and physical practice, constant practice, variable practice, practice variability, whole and part practice, massive practice, practice distribution, blocked practice, serial practice and random practice. These keywords were used adding the systematic review and meta-analysis. Also, reliable textbooks in de area were used.

When a meta-analysis of one topic was found, it was selected as a relevant study to present the results. The most recent studies of the type of practice were selected as well. Textbooks were used to identify the definitions of practices and to identify hypotheses explaining the effectiveness of each practice.

Results

The following information was obtained from the studies found. For each type of practice, the definition and a practical example are presented. In addition, when applied, the hypothesis explaining the effectiveness of the type of practice are presented. Finally, the results of recent research on the topic are presented.

Practice Performance: physical practice or mental practice

The mental practice involves practicing the skill in the mind, imagining or visualizing it, with the absence of movement of the parts of the body (Magill & Anderson, 2013), for example, close your eyes and imagine making a forward roll. While the physical practice is the motor performance of the movement to learn, where it is evident the movement of the parts of the body involved, for example, to do a forward roll.

There are three hypotheses that underlie why mental practice is effective. The *Brain Activity Hypothesis* which proposes that the brain activity present during the mental practice is similar to the one presented during the performance of the physical practice. The *Neuromuscular Hypothesis*, unlike the previous, this hypothesis postulates that the mental practice activates nerve connections from the brain to the muscle, as they have found electrical activity in the muscles involved in the skill during mental practice. The third hypothesis called *Cognitive Hypothesis* indicates that the mental practice allows the person to understand the requirements of the movement to develop a strategy of movement without risk of fatigue or injury. This last hypothesis is related to the first learning stage that implies high cognitive demand, suggesting that the mental practice helps the trainee to answer questions related to the movement without the pressure and demand that implies the physical practice (Magill & Anderson, 2013).

Comparing the performance of a group of beginner's athletes (24 years), it was found that performing physical practice or combination of physical and mental (regardless of order) enhanced learning, while not performing any practice or perform only mental practice does not bring benefits. In the retention and transfer test, it was found that the physical practice group and the physical and mental practice groups presented greater performance than the mental practice groups and the control (Gomes et al., 2014).

In a meta-analysis, it was examined if the mental practice encourages performance in motor skills; the authors conclude that the mental practice influences the motor performance and that it is better than not to perform any practice at all (ES=0.48). The analysis of moderating variables in the study indicated that skills with a high cognitive component benefit more from mental practice (ES=1.44), than motor skills (ES=0.43) or strength skills (ES=0.20) (Feltz & Landers, 1983). In addition, another meta-analysis also indicated that mental practice is effective in improving motor performance (*d*=0.527), however, is less effective than physical practice. In this study, the analysis of moderator variables indicated that mental practice is more effective when the skill has a high cognitive requirement. On the contrary, mental practice loses effectiveness when the time to perform the retention test increases. It was found that the level of skill of the participants (experts and beginners) and duration of practice, do not moderate the effect of mental practice (Driskell, Copper, & Moran, 1994).

According to the evidence raised it can be concluded that as a strategy during the practice, it is recommended to use the mental practice in combination with the physical practice. This combination strengthens learning, especially on cognitive skills. It also helps to reduce fatigue during practice and avoid injury.

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Variability in the sequence of practice: variable practice or constant practice

Constant practice or also known as specific practice, as its name implies, involves performing only a skill or a variation of the skill (e.g. without changing the distance, time, space and duration of the skill) and working without changes in the context (e.g. always in the same place with the same conditions). Some examples related are: the amount of skills, is to practice a single skill in one session, for example, to jump in one place; as for the number of variations, in a constant practice there are not variations it will be the same exercise in the distance, as in time, and space. Finally, in terms of changes in context or environment, in this type of practice it will be done on the same surface, for example: sand.

On the contrary, variable practice implies a learning environment where multiple tasks or variations of the same task are performed or work in multiple contexts (Matsouka et al., 2010). An example of the amount of skills is to practice the movement of throwing and jumping in the same session; as for the number of variations of the same skill, an example is to practice in one session the following types of throwing: overarm throw, underarm throw, or another type of throw. Finally, in terms of changes in context or environment the practice of the vertical jump can be done on different surfaces: sand, cement, soil, among others.

Therefore, the variability in the sequence is obtained by manipulating different aspects between them: the amount of skills, variations of the same skill, or changes in the environment of performance (Magill & Anderson, 2013).

Constant practice is supported by the *practice specificity hypothesis*. This hypothesis raises that motor skills are specific and learn only by performing the skill itself, and making even a small change to the skill implies learning a new skill (Magill & Anderson, 2013; Shea & Wright, 1997). Therefore this hypothesis proposes that the condition of the practice should be identical to the task that one wants to learn (Shea & Wright, 1997); since the constant practice enhances the movement representation (Czyż & Moss, 2016). For example, to learn to throw a free throw in basketball you should practice only the free throw under the specific conditions of the skill. However, this hypothesis has received little support from the scientific evidence (Shea & Wright, 1997).

Alternatively, it has been proposed the *practice variability hypothesis*, which explains the benefits of practicing multiple variations (but similar) of the skill that one wants to learn (Shea & Wright, 1997). It is suggested that variability strengthens motor learning as it promotes flexibility and adaptation of movement representation (Czyż & Moss, 2016; Leving, Vegter, de Groot, & van der Woude, 2016). It also provides a varied collection of movements from where you can then choose and adapt it to different skills and environments, improving the capacity to respond, this hypothesis is supported by the performance in retention and/or transfer tests (Ranganathan & Newell, 2013).

In general, evidence suggests that variable practice is more effective than constant practice in learning motor skills (James & Conatser, 2014; Moreno & Ordoño, 2015; Yan, Thomas, & Thomas, 1998). However, constant practice tends to be more effective under certain conditions (Moreno & Ordoño, 2015; Ranganathan & Newell, 2013), such as when you want to reduce the variability of performing in a very specific skill (e.g. the basketball free shot) (Ranganathan & Newell, 2013).

In order to establish the impact of these types of practice, in beginners and expert participants (24 years), the performance in free shoot in basketball was assessed in four groups: constant-expert, variable-expert, constant-beginner and variable-beginner. The results indicated that the type of practice did not influence the performance of the expert players in the acquisition test (there was no difference between types of practice). However, the variable practice affected negatively beginner's players, in transfer tests. To what authors conclude that variable practice is not recommended for beginners players (Taheri, Fazeli, & Poureghbali, 2017).

In the learning of a simple motor hand rotation task, it was found that the practice with high variability was more effective than a practice with low variability. The results indicated that the high variability group presented a better performance in the retention test compared to the low variability group; however, no difference was found in the acquisition measurement (James & Conatser, 2014).

In a meta-analysis, it was found that variable practice has a small and significant effect on the performance of transfer tests in children (*ES*=0.28; $IC_{95\%} = \pm 0.17$). In addition, it was identified that the advantage of variable practice on the constant is lower in young children (3-5 years) than in older children (9-11 years), therefore, the variable practice benefits more children between 9 and 11 years of age, than younger children. They also determined that there is a greater benefit of variable practice in ballistic-type skills and complex skills (Yan et al., 1998).

Taking into consideration the evidence presented, it can be concluded that using the variable practice enhances the performance and learning of the motor skills, rather than the constant practice. However, it is recommended to use constant practice when you want to improve the performance of a very specific skill and in participants in a beginner stage.

Skill Composition: Whole-practice or part-practice

The whole practice involves carrying out the skill completely in every attempt, from the beginning to the end, for example, in the skill of swimming in freestyle, the practice would involve performing the movement of arms, legs and breathing all at the same time. In part practice, the skill is separated into simpler units and each part is practiced separately before performing the whole skill; continuing with the previous example, when you are teaching freestyle in swimming, you would practice the movement of the legs alone, the movement of the arms alone, and then the breath alone; finally, when each one is mastered, the three parts are practiced together, performing the complete style.

There are three different methods for part practice: fragmentation, simplification, and segmentation (Fontana, Furtado Jr, Mazzardo, & Gallagher, 2009; Schmidt & Wrisberg, 2008). The method of fragmentation involves performing the practice of the upper and lower extremities separately or performing the activity with one side of the body and then with the other side, when each part is dominated separately are practiced together (Magill & Anderson, 2013). An example of this method is the one indicated above with the freestyle in swimming practiced by parts.

With the segmentation method (or progressive method), by separating the skill in subunits, first the first subunit is practiced, then the second is practiced; once both are dominated, they are practiced together; then the third subunit is practiced and then this is joined with the previous, and so on, until you perform the skill completely (Magill & Anderson, 2013). An example is a dance routine, where you first learn two groups of steps, and put them together, after practicing the third group of steps, you put together with the previous two, and so on.

Simplification is a method where the difficulty is reduced for one or more parts of the skill, with the objective of facilitating the complete performance of the skill (Magill & Anderson, 2013; Shea & Wright, 1997). Different ways in which a skill can be simplified are identified: reducing the difficulty of the object, for example, performing the skill of batting with a static ball "baseball tee", and then start increasing the difficulty until reaching a real situation. In a study conducted to evaluate the effect of these two types of practice on the learning of motor skills (sequence of movements), in university students, did not report difference between the two types of practice in the retention test. However, it was found that performing whole practice enhanced performance in the transfer test, compared to the part practice (Park, Wilde, & Shea, 2004). In children, the effect of the type of practice in learning juggling skills was analyzed. No difference was found between practice in the retention or transfer test. However, the younger children (6 and 9 years old) presented greater benefit of the part practice, while the oldest children (10 years) presented a greater benefit of the whole practice (Chan, Luo, Yan, Cai, & Peng, 2015).

Fontana et al. (2009) found, in the meta-analysis performed, that both methods are equally effective in the acquisition and retention of the skill. In detail, in acquisition and retention, it was found that practicing the skill by parts presents a better result than in complete form, when the skills are in series with a low organization, while performing the complete practice is better when the skill is in series and with a high organization. In the retention, continuous skills benefit more by practicing them in a complete way (Fontana et al., 2009).

In conclusion, it is suggested to use the part practice when the skill is of high complexity and identify subunits that are not highly related. The whole practice is recommended when the skill present low complexity and the subunits are highly related, however, the simplification method can be applied to facilitate the learning.

Practice frequency: Distributed practice or massive practice

The frequency of practice implies manipulating the intervals of practice and rest (Lee & Genovese, 1988; Shea & Wright, 1997). This manipulation can be done from a macro point of view, for example, the frequency of sessions in a week or from a micro point of view, as would be a frequency of trials in a session. This review focuses on the point of view of a practice session, so the important thing is to determine the balance between the amount of practice and rest during a session (Magill & Anderson, 2013).

When the index between the practice interval and the rest interval is greater than one, or the resting time is short, it is said that the practice is massive (Magill & Anderson, 2013; Shea & Wright, 1997). For example, in a session, the number of practice trials has a run time of five continuous minutes and the rest time is one minute between trials; the index is greater than one ($^5/_1$=5). On the other hand, the distributed practice is when the index between the interval of practice and rest interval is less than one, or the rest time is considered long. Perform one minute of practice and five minutes of rest, the index is less than one ($^1/_5$=0.2) (Magill & Anderson, 2013; Shea & Wright, 1997).

A study analyzed the effect of practice frequency on learning a pass in Australian football sport. After practicing the skill, it was found that in massive practice performance improved in the acquisition and in two retention tests performed ten minutes and two weeks later, respectively. While the players who performed distributed practice improved on the acquisition and the retention test at ten minutes only, however, they decreased their performance in the retention test after two weeks; therefore, they conclude that the massive practice in comparison with the distributed practice enhances learning in discrete skills. In addition, no difference was found between beginner or expert players, regardless of the type of practice performed (Panchuk, Spittle, Johnston, & Spittle, 2013).

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Contrary to the previous result, in a meta-analysis carried out on the topic, it was indicated that the distributed practice, improves more the performance in the acquisition (*ES*=0.91) and retention test (*ES*=0.49), in comparison to the massive practice. So it is recommended to perform distributed practice for the learning of a motor skills (Lee & Genovese, 1988). Another meta-analysis also found that performance improved when performing distributed practice compared to massive practice (*ES*=0.46). In addition, another research evidences that the nature of skill, the time interval between trials and the interaction between the two, significantly moderates the expected effect. Specifically, distributed practice is more effective in low-complexity skills and with smaller rest intervals between trials. In addition they found, that the distributed practice is better than the massive in both the measurement of acquisition (*ES*=0.45) and in the retention assessed in a 24-hour period (*ES*=0.51) (Donovan & Radosevich, 1999).

Taking into consideration the above evidence, it is recommended to use the distributed practice compared to the massive practice to optimize motor learning.

Context interference: blocked practice, random practice, or serial practice

Previously it was noted that when you have a variable practice, there are at least two skills, two variations of a skill, or two different contexts where to perform the practice. The literature review found several ways in which tasks can be ordered during practice, the three most common are: blocked, serial, or random. The difference between these practices is the order in which the trials are made, suggesting that the blocked practice produces low contextual interference and that the random practice promotes a high interference; so between these two types can arise different ways of ordering the practice, known as serial practice (Brady, 1998; Cheong, Lay, Grove, Medic, & Razman, 2012). In blocked practice, all trials of the task are first performed and once those trials are made, it starts to perform the trials of the second task, and so on. For example, in a practice session you are going to perform 20 trials of three variations of overarm throwing: throw at 5m of the target (a), at 10m (B) and at 15m (C). In this particular case, the variation of the skill is the distance from where it is going to be thrown depending on the target. Therefore, we practice the 20 trials of the throwing A, then the 20 trials of the B, and to finish the 20 trials of the C.

At the other end of the continuous of interference, when the practice session is organized using random practice, the order of the trials to be performed is alternating the order of the trials in a random order, however, it is suggested that no more than two trials of the same task are performed continuously (Brady, 1998). Following the example of the three ways to throw, for the random practice the order to perform the 20 trials of each distance in a random way, an example can be a trials of A, B, A, C, B, A, C, B... and so until completing the 20 trials of each skill. With regard to the serial practice, it is located in the continuum between the blocked and random practice (Magill & Anderson, 2013). In this case, you want to sort the trials in such a way that the task series is formed. With the three previous variations, a sequence of 2 trials of each distance is made randomly (B, A, C, A, C, B) and then repeat 10 times, to complete the 20 trials for each skill.

It has been shown that the order of practice produces an effect on learning, which has been called the Contextual Interference Effect (CIE). This effect exposes that the blocked practice presents a better performance with respect to the random practice when evaluating the performance in acquisition tests. However, in a retention and/or transfer test the random practice tends to present a better performance (Brady, 1998; Magill & Anderson, 2013). With regard to the serial practice, this tends to behave like the random practice (Cheong et al., 2012).

The CIE is supported by *the elaboration hypothesis* and *the action plan reconstruction hypothesis.* The elaboration hypothesis was proposed by Shea and Morgan in the year 1979 and state that people during random practice perform different variations of the same task, which helps to compare every trial stored in the memory, elaborating a more detailed representation of the skill, compared to blocked practice. In a similar way, Lee and Magill in the year 1985 propose that in performing the random practice, due to the high interference, people must rebuild in each trial the action plan of the skill, because the interference caused by the other of the skills, causes the person to forget what he or she previously performed, compared to the blocked practice where the person always uses the same action plan for consecutive trials (Lee & Simon, 2004; Magill & Anderson, 2013).

One study analyzed the effect of practice with different levels of interference in field hockey skills in university students and reported that different types of practice (blocked, random, serial) encourage performance in acquisition and learning. They also indicated that practice types are effective in beginner participants (Cheong et al., 2012). On the contrary, the random practice had better performance in retention tests than blocked practice group in learning a motor skill (Pauwels, Swinnen, & Beets, 2014).

In previous meta-analyses, it was concluded that both types of practice (random and blocked) improve performance in an acquisition test (Jiménez-Díaz, Salazar, & Morera-Castro, 2014, 2016) and that blocked practice presents better performance in relation to the group of random practice (Jiménez-Díaz et al., 2016; Mazzardo, 2004). While in the retention test the blocked practice tends to decrease its performance (Jiménez-Díaz et al., 2016; Mazzardo, 2004); while random practice and serial practice, on the contrary, tends to increase its performance (Jiménez-Díaz et al., 2016; Mazzardo, 2004). When comparing the types of practice in acquisition it was found that the blocked practice is significantly better than the random one in the acquisition (Jiménez-Díaz et al., 2016). In the retention test, the random practice is better than the blocked practice (Brady, 2004), while serial practice presents a small and non-significant effect when compared to block practice (Mazzardo, 2004). This same behavior is presented in the transfer test (Mazzardo, 2004).

In these meta-analyses was found that the number of trials, the age of the participants, the type of skill, and the type of study, are characteristics that influence the contextual interference effect (Jiménez-Díaz et al., 2014, 2016; Mazzardo, 2004). In conclusion, it is recommended to use random practice compared to blocked or serial practice for better long-term performance (learning). However, if a better short-term performance is desired, blocked practice is recommended. In addition, it should be taken into consideration, that when practicing in an out-of-laboratory environment, there is no significant difference between the types of practice.

Conclusions

The work of the professionals in the human movement science is to propitiate, in the most efficient, effective, and safe way, that people practice, and learn motor skills, tasks, and actions in a planned way.

There is no specific sequence that indicates in which order decisions should be taken for the elaboration of the practice, however, it is recommended to select first between mental or physical practice; second set the number of skills to practice in the session; third indicate the composition of the practice; fourth, decide on the frequency of the performance of each one of the attempts; and finally, if the type of practice is variable or constant. If it is variable, you must choose the level of interference of the desired context for the practice, blocked, serial or random.

If people have individual conditions such as temporary disability, an injury, it is important to take into account that decisions in the conditions of practices should be changed to the needs of that person, even if necessary they can be carried out in parallel or in a different order than the one previously exposed.

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