THE ROLE OF MENTAL PRACTICE IN DECREASING FORGETTING AFTER PRACTICING A GYMNASTICS MOTOR SKILL

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Original article

Abstract
Parallel to processes of memory consolidation, forgetting is a functional mechanism that allows the maintenance of relevant information or learning in memory. Practice condition can affect the forgetting rate, favouring or not memory consolidation. Physical practice has been shown to be effective in decreasing forgetting, but the role of mental practice is not known yet. Thus, in this study, we aimed to investigate the role of mental practice in the forgetting rate of a motor skill. Twenty-four participants with the mean age of 26.13 years (± 3.04) of both genders were divided into three groups: (a) mental practice group (MG); physical practice group (PG) which practised the handstand skill either mentally or physically, respectively, and (c) control group (CG) that did not practice the skill. Results showed no difference between the forgetting rate of MG and PG. Also, they had forgetting rates lower than CG. Thus, it is suggested that mental practice is as effective as physical practice to decrease the forgetting rate of motor skills, favouring the maintenance of the movement representation in memory. Possibly, physical and mental practice conditions share mechanisms that slow down forgetting processes.

Keywords: *handstand skill, mental practice, forgetfulness, memory consolidation, cognitive processes.*

INTRODUCTION

Memory is one of the key elements involved in motor performance, learning, and control (Robertson, 2012). Working-memory (WM) is involved in the process of storing and manipulating information during a given task (Diamond, 2013), playing a decisive role in mechanisms of error detection and correction (Seidler, Bo, & Anguera, 2012). The greater rate of improvement in motor performance at the beginning of practice typically observed in motor learning, as opposed to the rate of improvement at the end of the practice period, is entailed by trial-to-trial adjustments in motor command that aim to reduce the discrepancy between the performed and the desired behaviour (Smith, Ghazizadeh, & Shadmehr, 2006). WM participates in the updating of motor plans through mechanisms of error detection (Seidler et al., 2012). Throughout practice both the errors and the WM influence decrease, and the participation of cognitive processes associated with learning consolidation increases (Smith et al., 2006). Although the encoding and adaptation of long-term memory (LTM) influence learning since the beginning of practice, this process is paramount for motor learning consolidation not only at the final stages of practice, but especially after acquisition (Robertson, Pascual-Leone, & Miall, 2004). Through more stable memories, the learner is capable of maintaining her performance similar to the performance reached at the end of the last practice session, even after a period without practice (Mosha & Robertson, 2016; Robertson, 2012).

The long-term reverberation of the information acquired during practice is crucial for the LTM consolidation, since forgetting processes act in an adaptive fashion in which only relevant information is retained long-term (Schacter, 1999). The first empiric evidence on forgetting processes was shown at the end of the 19th century with studies by Ebbinghaus (Murre & Dros, 2015). One of his best scientific contributions pertains to the forgetting curve, wherein it was shown that the largest forgetting rate occurs only moments after learning (Murre & Dros, 2015). Considering the pieces of evidence provided by Ebbinghaus` groundbreaking experiments, the Decay Theory suggests that forgetting is entailed by decayed activation of memory traits (Ricker, Vergauwe, & Cowan, 2016). According to this theory, the weakening of memory traits is faster after its encoding and, if this trait was not strengthened enough, it gets lost over time (Brown, 1958).

Other than time, practice is one of the factors that can contribute to increasing or diminishing forgetting (Robertson et al., 2004). Different practice conditions may increase or diminish the rate of forgetting. For instance, the suppression of sensory receptors that participates in the coding of mental representation may increase the rate of forgetting (Ventura de Oliveira et al., 2019). Conversely, increasing the quantity of practice slows the rate of forgetting, entailing distinct levels of motor consolidation (Lage et al., 2017).

Practice conditions with explicit movement are usually known as physical practice, while those that do not include movement are called mental practice (Gomes et al., 2014; Millard, Mahoney, & Wardrop, 2001; Wulf, Horstmann, & Choi, 1995). Studies often see physical practice as superior to mental practice, while the latter, to a lesser extent, leads to better performance and learning than conditions with no practice (Toth, Neill, Hayes, Moran, & Campbell, 2020). One of the explanations for the benefits of mental practice is related to the cognitive processes underlying it, which are similar to those of physical practice (Munzert & Zentgraf, 2009). Considering this similarity, it is reasonable to expect a similar rate of forgetting between these two practice conditions during motor memory consolidation. Nevertheless, to the best of our knowledge, the forgetting rate of these two practice conditions has never been investigated in the literature. In line with the idea that mental practice may be an important factor to aid the consolidation of motor learning, we investigated the rate of forgetting in mental and physical practice of a sports skill. We hypothesized that mental and physical practice would show a similar rate of forgetting, and a lower rate than the no-practice condition.

METHODS

Twenty-four undergraduates in physical education (12 female and 12 male), with the mean (M) age of 26.13 years (standard deviation [SD] = 3.04) participated in this study. As a prerequisite for participation in the experiment, the individuals had to be able to raise their legs at a 90º angle while both hands were touching the ground (Rohleder & Vogt, 2018). Volunteers could not have previous systematic experience with the handstand movement or with mental practice. They also did not report any pathology that could restrict their movements. The selected volunteers were informed of the purpose of the study and asked for their written informed consent to participate in this study. The experiment was reviewed and approved by the local Ethics Committee (Universidade Estadual de Minas Gerais - CAAE 97208818.3.0000.5093).

Data collection was conducted in a university laboratory, with standard luminosity and windows properly covered by curtains. To perform the kinematic analysis of handstand, we used a video camera (Nikon, D-750 Sigma - lens 17-50 mm) with a 60 Hz frame rate and the Kinovea software (v.0.8.15) to process the data.

Volunteers were marked on the right side of their bodies with red adhesive tape in a plus (+) shape in the following locations: lateral condyle (knee), greater trochanter (hip), humeral head (shoulder), ulna's styloid process (hand), and temporal bone (head). After the placement of landmarks, the volunteers received the following instructions: “To perform the handstand skill, you must remove your feet from the ground, while maintaining support with your hands, and straighten your arms, legs, and spine as much as possible. You must touch the ground with fingers extended, and place the hands apart, at the shoulder width. The legs must remain upright and side-to-side with one another, while the head must remain aligned with the body”. Further, an image of the ideal execution of the task was shown to each participant, and a video of an ideal execution pattern (performed by a professional) was reproduced twice. After these initial procedures, participants performed three pre-test trials, which were filmed for posterior analysis. Participants were allowed to start each trial after the “prepare and go” command was given by the experimenter.

After the pre-test, participants were randomly assigned and counterbalanced by sex in three groups: mental practice group (MG), physical practice group (PG), and control group (CG). The practice phase of MG consisted of imagining the task. Before starting mental practice, participants comfortably sat down on a chair facing a desk and holding a pen with their left-hand. Fifteen trials were performed mentally, and participants were required to signalize the end of each trial by touching the far end of the pen on the desk. The PG physically performed 15 trials of the handstand skill after the pre-test. 30 seconds of rest were provided to participants in-between trials, and each trial started after the “prepare and go” command given by the experimenter. Participants in the CG played T-Rex Game on the offline Google Chrome browser for 10 minutes after the pre-test (a time similar to the time spent by participants in the MG and PG groups). This procedure was adopted to avoid any unwanted mental practice by participants of the CG.

Ten minutes after the end of the practice session, a post-test was performed. Similarly to the pre-test, all participants performed three trials of the motor task, which started after the command “prepare and go” was given by the experimenter. The trials were recorded for posterior analysis.

For video analysis, three angles were defined on Kinovea (Figure 1): (i) Angle between the lateral condyle and greater trochanter (angle 1); (ii) Angle between the greater trochanter and ulna's styloid process (angle 2); (iii) Angle between the greater trochanter and temporal bone (angle 3). The reference values were: angle 1 = 200º, angle 2 = 164º, and angle 3 = 159º. The reference values were extracted from the analysis of a gymnastics athlete with more than 10 years of experience and participation in international artistic gymnastics competitions.

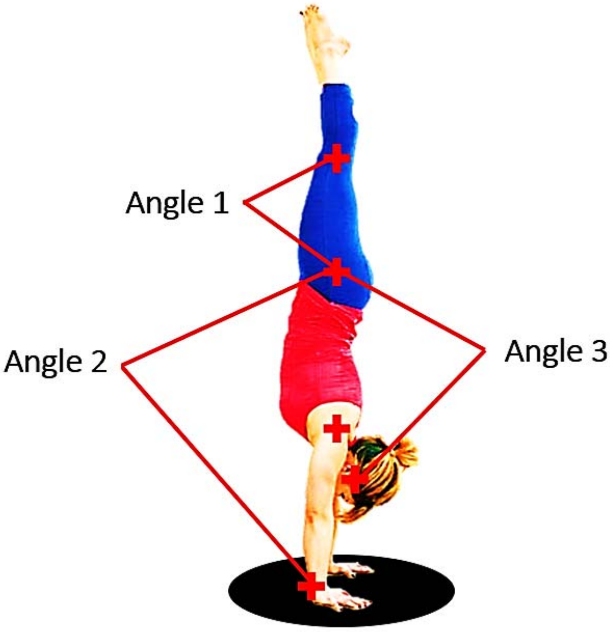

Figure 1. Angles analysed.

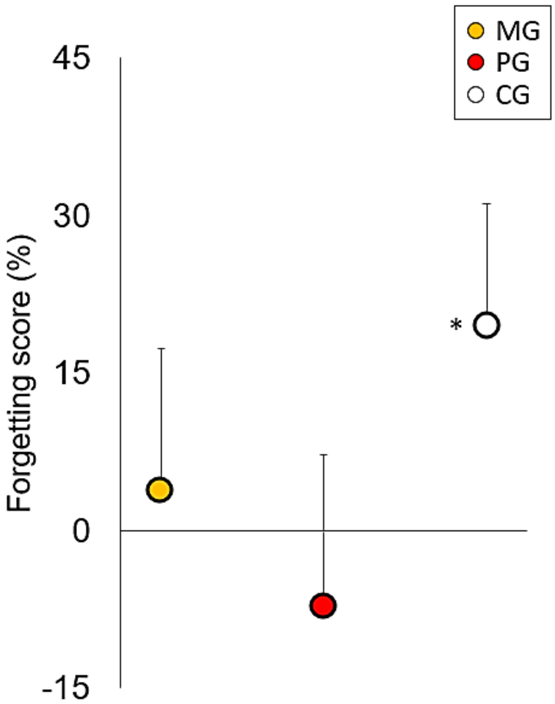

Figure 2. Mean and standard deviation of the groups' forgetting score.
MG = mental practice group; PG = physical practice group; CG = control group; * = indicates a significant difference from the other groups

Performance error was computed as the difference between the actual angles and the angle criteria:

$$Performance\ error = [|(Angle\ criterion^{i} - Actual\ angle^{i})| + |(Angle\ criterion^{ii} - Actual\ angle^{ii})| + |(Angle\ criterion^{iii} - Actual\ angle^{iii})|].$$

A forgetting score was calculated as follows:

$$Forgetting\ score = [(post\text{-}test - pre\text{-}test)*100]/pre\text{-}test.$$

Smaller numbers indicate less forgetting from pre- to post-test (Lee & Fisher, 2019).

One-way ANOVAs and post hoc Fisher LSD tests were used to compare groups. Effect sizes were calculated using eta-squared (η^2). An alpha level of .05 was set for all inferential statistics.

RESULTS

Descriptive statistics are presented in Figure 2. The inferential analysis detected a significant effect of groups [$F(2, 21) = 7.16$, $p < .01$, $\eta^2 = .40$]. Post hoc analysis indicated that the forgetting rate was greater in CG than in MG ($p = .02$) and PG ($p < .01$). No difference was found between MG and PG ($p = .33$).

DISCUSSION

In this study, we investigated the effects of mental practice in the forgetting rate of a motor skill. Our results support our hypothesis that a similar forgetting rate between mental and physical practice would be found, with both practice conditions showing a smaller forgetting rate than the no-practice condition. The lower rate of forgetting of the MG compared to the CG suggests that mental practice is capable of slowing down the forgetting process after the implicit practice of a movement. Also, the similar forgetting rate of the MG and PG groups support the idea of shared underlying cognitive processes between mental and physical practice (Munzert & Zentgraf, 2009).

Studies showing the existence of unconscious implicit muscle movements during mental practice provided the first pieces of evidence of similarity between physical and mental practice (Hale, 1982; Jacobson, 1930). By using electromyography, Jacodson (1930) and Hale (1982) showed that thinking about a movement of elbow extension led to increased neuromuscular activity of the biceps brachii. This muscle activity of the same muscles involved in physical practice, although in smaller magnitudes, suggested that the benefits of mental practice are related to neuromuscular changes that favour future physical movement.

Other possible links between mental and physical practice were suggested in the literature, such as the hypothesis of functional equivalence that proposes that mental and physical practice share memory representations, neural structures, and perception, planning and execution mechanisms (Moran, Guillot, Macintyre, & Collet, 2012). Among the shared brain areas are the premotor cortex, the supplementary motor cortex, the primary somatosensory area, cerebellum, and basal ganglia (Hardwick, Caspers, Eickhoff, & Swinnen, 2018). Studies presenting these neural correlations between physical and mental practice do not show a clear relation to memory formation or forgetting. However, the similarity between the brain areas involved in both practice conditions and the similar forgetting rate between the MP and PP groups suggests that motor memory strengthening and forgetting are also processes shared by these two practice conditions.

The superiority of mental practice over a no-practice condition is recurrently demonstrated in the literature (Toth et al., 2020), and our study also supports this premise. The smaller forgetting rate of the MG compared to the CG may be associated with a greater ability to protect a previous performance level from factors that interfere with forgetting processes. In this study, for instance, the time between the end of the practice session and the post-test is one of these factors. Considering that the greatest weakening of memory traits occurs immediately after its encoding, resting time is paramount for memory survival (Brown, 1958). A recent memory goes through a phase of instability of its neuronal representation, thus vulnerable to perturbations and interferences (Robertson et al., 2004). The early consolidation processes are responsible for the stability and robustness of the memory after a period of sleep (Diekelmann & Born, 2007, 2010). Mental practice likely acts as a protecting agent against the short-term effects of time on forgetting, as shown in the present study. Another study also investigated the effects of mental practice on the learning of a gymnastics skill (Šešum & Kajtna, 2018). It is important to highlight that during the mental practice condition in their study, a relaxation technique was applied, which is not usual in study designs investigating mental practice. Given the use of such relaxation technique, it is difficult to support the hypothesis that there are no benefits of mental practice in the learning of gymnastic skills, since relaxation may have interfered with the results by Šešum and Kajtna's (2018). It is also worth noticing that they did not investigate the rate of forgetting. If relaxation in conjunction with mental practice results in better memory consolidation, this additional effect could be observed in the rate of forgetting.

Even though our results suggest a relation between mental practice and decrease in forgetting, more evidence is needed to further our comprehension of the role of mental practice in motor memory consolidation. For instance, our single session design allows inferences about the early stages of memory consolidation, but not about the whole process of LTM formation. Future studies should investigate how the forgetting rate under a mental practice condition behaves with distinct intervals between the practice session and the post-test. We could expect that the forgetting curve, as a function of time, would follow the same features of the one under physical practice conditions, wherein the faster forgetting rate occurs immediately after acquisition (Murre & Dros, 2015). Additionally, future studies could investigate the interaction between mental practice and factors such as the quantity of practice and sleep duration. Since fewer practice trials and shorter sleep times maximize forgetting processes (Krause et al., 2017; Lage et al., 2017), the benefits of mental practice could be better observed under conditions with more trials or after a period of sleep. More than behavioral research, given the neural correlations found between mental and physical practice (Hardwick et al., 2018), studies investigating brain areas and cognitive processes related to LTM consolidation could help to explain the mechanisms underlying the decreased forgetting under mental practice. In addition to studying the effects of mental practice in LTM and forgetfulness, investigating the role of combined practice (physical + mental practice) in forgetting processes should be the next step, since this type of practice seems to produce increased benefits compared to physical or mental practice alone.

CONCLUSION

The results of this study suggest that mental practice of a gymnastics skill lessens forgetting rate compared to a no-practice condition. Also, the forgetting rates of mental practice and physical practice do not seem to differ from each other, suggesting that these two practice conditions share mechanisms that diminish forgetting, favouring LTM consolidation. Although incipient, our results broaden the possibilities of future studies, since the relation between mental practice and forgetting processes were not strongly investigated in the literature yet. In terms of practical implications, this study supports the use of mental practice to improve motor performance of gymnastics skills. Especially in cases in which physical practice is not an option, such as in injury conditions, mental practice can be a viable alternative to practice in order to acquire new motor skills.

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