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Original Article

The strength of schema depends on the amount of variation during variable practice

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Abstract:
Many studies have shown that the variable practice of a motor skill would facilitate its transfer to a new skill variation. Most of these studies, however, have tested this proposition under a limited amount of skill variation: generally three. We are interested in investigating if a more variable practice condition would enhance skill transfer. Therefore, this study aimed to investigate the effects of different amount of variation in variable practice in skill transfer. Undergraduate students (N=33) were randomly assigned to three groups: Constant practice; Variable practice with 3 variations; and Variable practice with 5 variations. Participants transported a tennis balls among six containers in a predefined sequence and target time. In acquisition phase, participants performed 30 trials with knowledge of results after every trial. In the transfer test, 10 trials were performed with the same sequence as in acquisition phase and a new target time, without knowledge of results. Results showed that most varied practice condition showed lower errors than the constant practice condition in transfer test. Moreover, differences among variable practice with different numbers of variations were not observed. Thus, variability of practice hypothesis was partially supported by the results of this study, since higher amounts of variations also led to a better transfer than constant practice. However, no advantages were found for the most variable practice condition when compared to the less variable condition in variable practice. New studies that investigate more complex skills and different amounts of variation in variable practice should be carried out in order to further investigate this specific issue of the variability of practice.
Key Words*:* Variability of practice, practice schedule, Schema Theory, amount of variation.

Introduction

Schmidt's Schema Theory (1975) was proposed from previous theories and propositions in order to better explain how motor skills are learned and controlled (Keele, 1968; Adams, 1971). In addition, the author addressed limitations of previous theories such as the production of new movements. Several studies were conducted in order to test the assumptions of Schema Theory or used it as a theoretical background for research (Moxley, 1979; Johnson & Mccabe, 1982; Sherwood & Lee, 2003; Wulf & Shea, 2004; Lage, Vieira, Palhares, Ugrinowitsch & Benda, 2006).

According to Van Rossum (1990), among the various contributions derived from the Schema Theory and the numerous studies that have proposed to test it, the variability of practice hypothesis can be highlighted. There are basically two types of Practice schedules: constant practice, which consists of practicing only one skill during a practice session; and variable practice, which consists of practicing more than one skill during a practice session (Shea & Kohl, 1990). Therefore, according to the variability of practice hypothesis, the variable practice of a motor skill would facilitate the transfer of learning to a new variation of this skill (Moxley, 1979).

The main constructs that support this proposition are Generalized Motor Programs (GMP) and the Schemes. Based on the proposition of Schmidt (1975), a single GMP would be responsible for controlling a class of similar skills, or variations of the same skill. The generalization of the GMP to movements never before produced would take place through sets of abstract rules called schemes, which would be strengthened from the experience of previous movements (Shapiro & Schmidt, 1982). Such schemes relate the result of actions of an individual with the selected parameters in each new trial. Then, in every trial specifications, such as total force, total time and the movement amplitude (muscular grouping - effector independence) are added to the GMP, according to the initial conditions. These specifications are produced before each trial (Schmidt, 1975).

When a movement is carried out, some information is abstracted from this movement and stored in the schemes: a) initial conditions; b) response specifications; c) sensory outcomes; and d) the response outcomes (Schmidt, 1975). A greater variation in the number of practiced skills, and hence an increase in motor experience

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by the learner would lead to a strengthening of the schemas and thus to an increase in the motor system competence to successfully carry out the execution of a new variation of the skill. In other words, new specifications are based on the already formed schemes (Moxley, 1979; Schmidt, 1975; Shapiro & Schmidt, 1982; Lage, Ugrinowitsch, Apolinário-Souza, Vieira, Albuquerque, & Benda, 2015).

As one of the possibilities to test the scheme theory, the hypothesis of variability of practice received much attention of researchers in previous decades (Johnson & Maccabe, 1982; Lee, Magill & Weeks, 1985; Van Rossum, 1990; Marinovic & Freudenheim, 2001). The results of these studies, however, are conflicting. In some conducted studies, variability of practice hypothesis was confirmed (Moxley, 1979; Lee, Magill & Weeks, 1985; Bicalho et al., 2019), while other studies, however, resulted in partial confirmation or even they denied the variability of practice hypothesis (Cummings & Caprarola, 1986; Marinovic & Freudenheim, 2001; Breslin, Hodges, Steenson & Williams, 2012). Such inconsistency in the literature indicates that these investigations have been carried out in different ways, and points out the need to keep investigating and further develop the variability of practice propositions.

Studies investigating the variability of practice hypothesis varied in many ways, from the kind of sample, task type and practice schedules. Despite these distinctions, the quantity of variable practice typically remained fixed at three distinct tasks (or parameters). Exceptions were the studies of Goodwin, Grimes, Eckerson & Gordon (1998), and Lage et al. (2006), in which the quantity of parameters was manipulated, five and three variations were used in both studies, beyond constant practice, as well as practice schedule. Although Lage et al. (2006) did not test the variability of practice hypothesis, Goodwin et al. (1998) show that groups with three and five different parameters presented superior performance than constant practice in transfer test. In general, they confirm the variability of practice hypothesis. Apart from them, most studies have investigated this subject comparing a group of constant practice with a single group of variable practice, usually with three variations of a single skill (Van Rossum, 1990; Lelis-Torres, Ugrinowitsch, Apolinário-Souza Benda & Lage, 2017; Bicalho et al., 2019). However, the experimental design that consists of a group of constant practice and a single variable practice group with three variations does not allow a deep understanding of the importance of different quantities of variable practice to the transfer to a novel skill.

The motor scheme is strengthened when varied experiences are practiced, which forms a complex set of abstract rules, resulting in greater flexibility of motor responses. According to Schmidt (1975, p. 245) “one important prediction is that increasing either the amount or the variability of such previous experiences lead to increased schema strength. These predictions suggest a test of the schema notion in terms of transfer of learning”. In the same way, Moxley (1979, p.65) suggests that “a learner with sufficiently varied experience ought to be able to generate a response which, while being in a familiar movement class, is not one which has been done before”. In both cases, transfer of learning depends on a varied experience that is reached through variable practice. We question here if three different parameters are enough to deliver a varied experience or even to strengthen a motor schema responsible for transfer of learning. If a motor schema were strengthened by a varied experience, then a condition with more quantity of variation would be able to enhance transfer of learning.

Then, the present study investigated the effects of different quantity of variation in the variable practice in transfer of learning. We hypothesized that constant practice would be inferior only to higher number of variations of the skill, which would be the only condition to strengthen motor schemes.

Material & methods

Participants

Thirty-three undergraduate students (M age = 22.06 yrs, SD = 2.49) of both sexes (11 men, 22 women) were recruited to volunteer in this study. The participants had no prior experience with the experimental task, and they were asked to read and sign an informed consent form before beginning the experiment. This study was approved by the Institutional Review Board of the University (CAAE 26143113.6.0000.5149), and it was conducted according to the ethical guidelines issued by the Declaration of Helsinki.

Apparatus and Task

The apparatus consisted of a wooden platform (100 cm in length, 66 cm in width, and 10 cm in height) with six containers (12.5 cm diameter, 5 cm deep) numbered from 1 to 6 (arranged in two lines: 1 to 3 in the far and 4 to 6 in the near of participant). A separate wooden recipient with a LED was used to cue participants regarding the beginning of each trial (control station). This control station was made of one container and a LED that turned on and provided a visual stimulus for participants to start the task.

The participant was asked to stand directly in front of the apparatus. The participant held the ball in the first container of the sequence and payed attention to the control station, where the cueing LED was to be fired. As soon as the LED turned on, the participant performed a specific sequence of movement on a specific target time (Fig. 1). A specific software to measure and store data was developed. The task consisted of transporting one tennis ball in a specified sequence starting in container 4, within a time constraint.

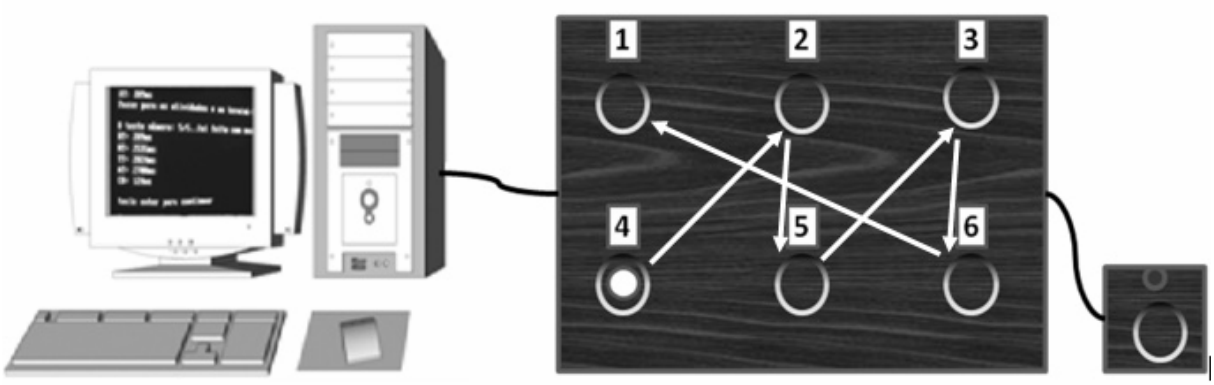

Fig.1. Apparatus diagram.

Experimental Design

Participants were randomly assigned to one of three groups (n = 11): 1) Constant practice (Ct); 2) Variable practice with 3 variations (V3) and 3) Variable practice with 5 variations (V5). The experiment consisted of two phases: acquisition and transfer test. During acquisition phase participants performed 30 trials of a serial positioning task with time constraint. A tennis ball had to be transported among six containers in a predetermined sequence (4→2→5→3→6→1, Fig. 1). Ct participants performed these trials with 2,700 msec. as target time. V3 participants performed with 2,700; 3,300 and 3,900 msec. as target times. V5 participants performed with 2,700; 3,000; 3,300; 3,600 and 3,900 msec. as target times. For variable practice schedules (V3 and V5) trials were organized in a pseudo-random manner (so that no target time would be repeated for more than two consecutive practice trials), thus characterizing this practice organization as a random schedule. Participants received terminal knowledge of results (KR) on every trial, with pre and post-KR intervals set to 3 seconds. Transfer test was performed 15 minutes after acquisition phase, and participants were informed that the target time was set to 4,200 msec. and that KR would not be provided.

Procedures

Data collection was performed individually in a specific room. Participants stood up in front of the apparatus and received verbal instruction and demonstration about the task. For variable practice participants, at the beginning of each trial was provided information regarding the target time to be carried out in the trial, through an 8 x 11 cm. card that was affixed to the center of the platform with the possible target times according to each experimental condition. At the signal "ready", the individual positioned itself in front of the platform in order to view the cueing LED, and as soon as it turned on the participant started the tennis ball transport among containers, in the predetermined sequence, with the preferred hand in accordance with the target time provided by the experimenter before each trial. New instruction about the change of target time was provided before the transfer test.

Data analysis

Data were organized into six blocks of five trials during the acquisition phase and two blocks of five trials in the transfer test. The effects of the dependent variable were assessed as performance accuracy (absolute error – difference between target time and performance time), performance direction (constant error – positive or negative value according to the error direction), and performance consistency (variable error – standard deviation of constant error).

A 3 (Groups) × 6 (Blocks) ANOVA with repeated measures on blocks was performed for the acquisition phase, and a 3 (Groups) × 2 (Blocks) ANOVA with repeated measures on blocks was performed for the transfer test. The post hoc Tukey test was used as the pair-wise comparison of means. Effect sizes were calculated with partial eta-squared (η_p^2). Normality of the data was assessed by the Shapiro-Wilks test, and homoscedasticity was evaluated with the Levene test. A significance level of $p < .05$ was used.

Results

Absolute Error

The ANOVA performed for the acquisition phase showed significant effects for groups [$F_{2, 27} = 15.18$, $p < .001$, $\eta p^2 = .52$]. The Tukey post hoc test indicated that Ct showed smaller errors in this phase than V3 and V5 ($p < .001$). A significant effect was also reported for blocks [$F_{5, 135} = 16.43$, $p < .001$, $\eta p^2 = .37$], and a post hoc test indicated that the first block of trials showed significantly higher errors than other blocks ($p < .01$), indicating that error decreased over the acquisition phase. A significant interaction was also reported [$F_{10, 135} = 2.14$, $p = .025$, $\eta p^2 = .13$]. The post hoc test indicated that the first block of trials of Ct showed significantly higher errors than the other blocks of the same group ($p < .05$). The first block of trials of V3 also showed significantly higher errors than blocks 4, 5 and 6 of the same group ($p < .001$). See Figure 2.

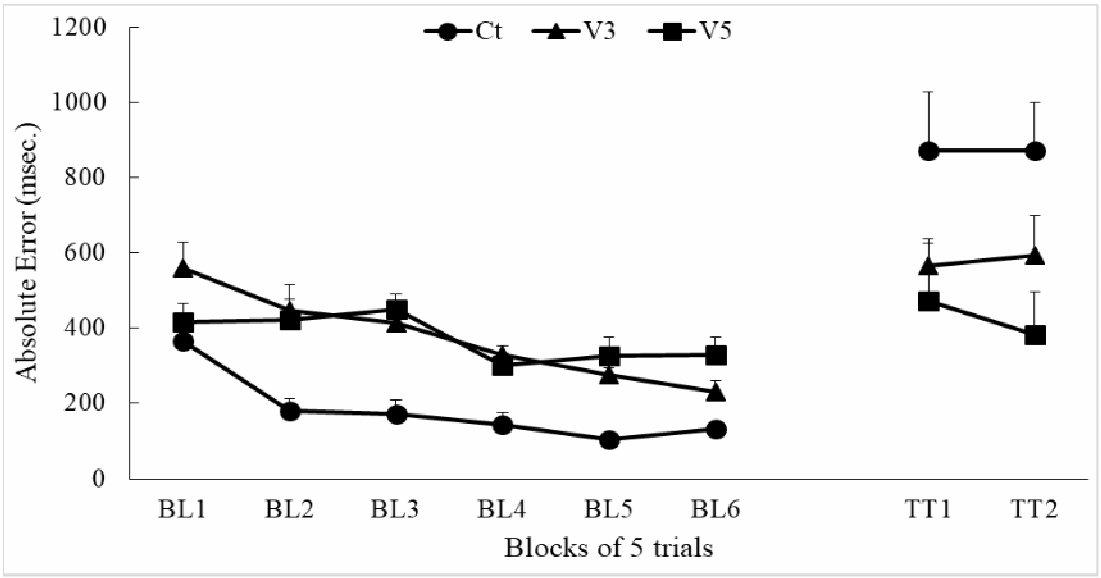

Fig.2. Mean of absolute error in acquisition phase and in transfer test. Vertical bars represents standard error values.

The ANOVA performed for the transfer test showed a significant group effect [F2, 27 = 4.39, p = .022, ηp^2 = .24]. The post hoc test indicated that V5 was more accurate than Ct (p < .019). There were no statistically significant effects for blocks [F1, 27 = .08, p = .77, ηp^2 = .003] or interaction [F2, 27 = .23, p = .79, ηp^2 = .01].

Constant Error

The ANOVA performed for the acquisition phase showed significant effects for groups [F2, 27 = .25, p = .011, ηp^2 = .28]. The post hoc test indicated that Ct was significantly more accurate than V3 (p < .01). A significant interaction was also reported [F10, 135 = 2.89, p = .002, ηp^2 = .17]. The post hoc test indicated that Ct first block was different from the first block of V3 (p < .02) and V5 (p < .001). No significant effect for blocks was found [F5, 135 = 1.31, p = .26, ηp^2 = .04]. See Figure 3.

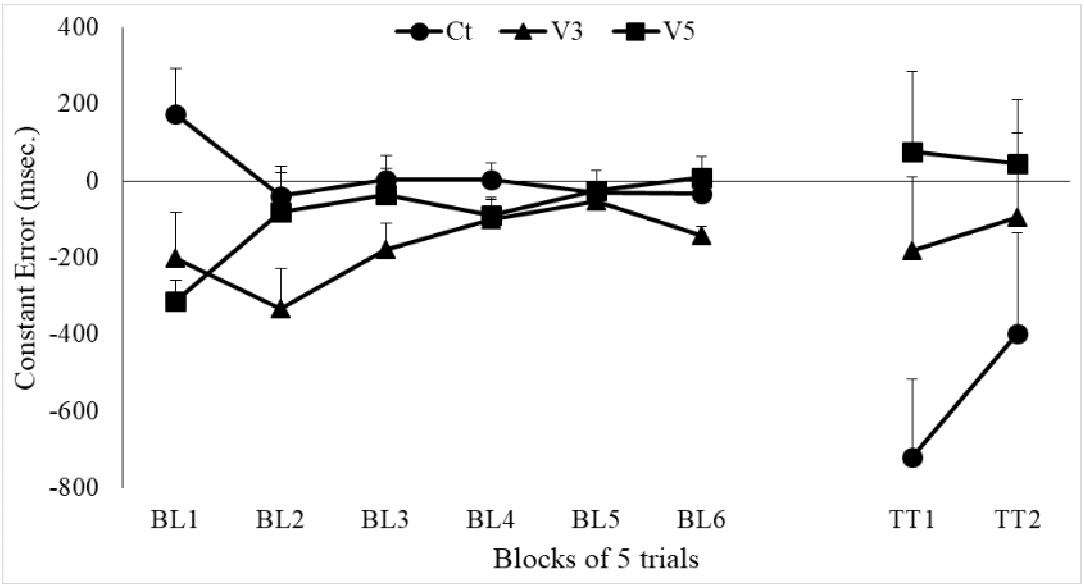

Fig.3. Mean of constant error in acquisition phase and transfer test. Vertical bars represents standard error values.

The ANOVA performed for the transfer test showed no significant effects for groups [F2, 27 = 2.60, p = .092 ηp^2 = .16], blocks [F1, 27 = 2.03, p = .165, ηp^2 = .07] or interaction [F2, 27 = 1.40, p = .26, ηp^2 = .09].

Variable Error

The ANOVA performed for the acquisition phase showed significant effects for groups [F2, 27 = 20.15, p < .001, ηp^2 = .59]. The post hoc test indicated that Ct was more consistent than V3 and V5 (p < .001). There was also a significant effect for blocks [F5, 135 = 10.37, p < .001, ηp^2 = .27]. The post hoc test indicated that the first block of trials was more variable than the others (p < .01), indicating that variability decreased over acquisition phase. No significant interaction was found [F10, 135 = 1.84, p = .057, ηp^2 = .12]. See Figure 4.

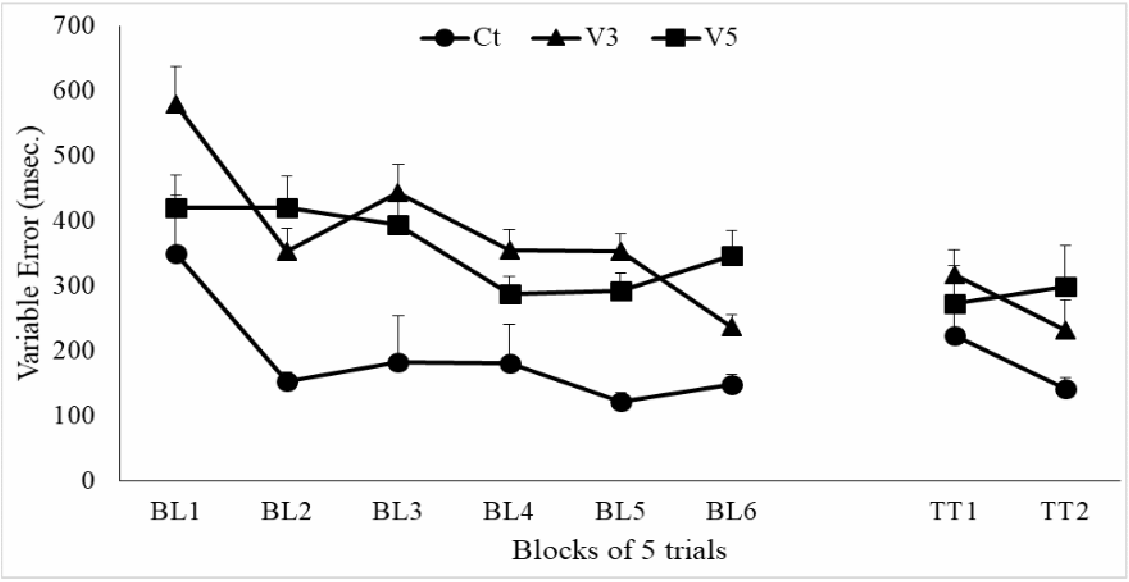

Fig.4. Mean of variable error in acquisition phase and transfer test. Vertical bars represents standard error values.

The ANOVA performed for the transfer test showed no significant effect for groups [F2, 27 = 1.75, p = .191, ηp^2 = .11]. A significant effect for blocks was reported [F1, 27 = 5.76, p = .023, ηp^2 = .17]. The post hoc test indicated that the second block of trials was less consistent than the first one (p < .02). There was also a significant interaction [F2, 27 = 3.42, p = .047, ηp^2 = .20]. The post hoc test failed to find those differences.

Dicussion

This study tested the variability of practice hypothesis in the transfer to a novel skill, raising the question of the role of the quantity of variation in a variable practice schedule. Based on Schmidt (1975) and Moxley (1979) propositions as well as Van Rossum (1990) revision, it was expected that more varied practice would be superior than constant practice in the transfer to a novel motor skills. Likewise, three different parameters may not be enough variability of practice in order to strengthen a motor schema. Results confirm this prediction, as only the variable practice with the higher number of variations showed better transfer to a new skill when compared to the constant practice.

In acquisition phase, variable practice conditions led to higher errors than the constant practice condition. This result was expected, because of the greater difficulty brought by the need to perform more than one task early in practice. It also is in line with previous findings that also detected higher errors in variable practice conditions in relation to constant practice conditions during acquisition phase (Lee, Magill & Weeks, 1985; Lage et al., 2006; Bicalho et al., 2019). In addition to higher absolute errors in acquisition phase, a greater variability of the variable practice conditions in relation to the constant practice condition was also reported. This higher variability associated with the variable practice was expected, since in this practice response specification parameters are systematically modified.

In the transfer test, in turn, only variable practice with a higher number of variations was superior to the constant practice. This better transfer to a novel skill supports the variability of practice hypothesis, since it was expected that the variable practice condition would be superior to the constant practice schedule (Moxley, 1979). This result is particularly aligned with the Van Rossum's findings, since the variable practice with only 3 variations did not lead to advantages in transferring what was learned to a novel task when compared to the constant practice condition. These results showed the expected effects of increasing the quantity of variations in variable practice for the transfer of motor skills. Thus, the greater flexibility demonstrated by the individuals of the variable practice condition with a higher number of variations was due to the strengthening of the learners schemes, brought by this increased quantity of variation.

Several studies were performed in order to test the predictions of the variability of practice hypothesis, and most of them failed in giving its empirical support; in other words, the role of variable practice is not as consistent as it was believed (Van Rossum, 1990). This fact is evidenced by reviews of literature that demonstrate the superiority of variable practice schedules over constant schedules was confirmed in less than half of the studies analyzed when the predictions of the variability of practice hypothesis was tested (Paroli & Tani, 2009). However, in most of these studies the experimental designs consisted of variable practice groups with usually three variations during skill acquisition, which may have been a decisive factor in the inconsistency of the found results. Practice conditions with such small quantity of variations could be insufficient to benefit the transfer to novel motor skills in adults, who probably has already well developed schemes for most tasks involving simple positioning or time (Moxley, 1979), thus requiring more variations in variable practice conditions, as shown in the present study.

From the variability of practice hypothesis assumptions, it is possible to predict that, as a function of the greater quantity of variability of the variable practice condition with five variations in relation to the other conditions, transfer to a novel task would be easily enhanced, as seen in the present study. It is important to note that more than performing and retaining different response specifications, individuals of variable practice group with more variations also stored information on the sensory consequences and different response results, according to parametric adjustments generated by this practice condition. The formation of strengthened general schemes, however, did not occur with such quality on the variable practice with a smaller quantity of variations condition, since it failed to overcome the constant practice condition in the transfer to a novel skill. Thus, our results supports the variability of practice hypothesis, in which is expected that variable practice would lead to a varied experience that leads to increased schema strength during the acquisition phase, thereby driving to a better transfer of learning (Schmidt, 1975; Moxley, 1979; Van Rossum, 1990; Lage et al., 2015; Lelis-Torres et al., 2017; Bicalho et al., 2019). The most important aspect to be discussed from the results of this study refers to the quantity of practice variation offered to learners so that they can benefit from the variable practice condition, since smaller quantity of variation were not as efficient as larger quantity of variation during acquisition in the transfer to a novel skill.

Conclusions

The findings of this study corroborate some of the propositions of the variability of practice hypothesis by Moxley (1979). According to this author, adults would have better well developed schemes for most tasks involving simple positioning or time, thus requiring variable practice with greater variations in order to benefit from it. As a solution to this problem was suggested the use of children as participants in the variability of practice hypothesis research (due to its lower motor experience), which resulted in several studies that confirmed the proposal, as revised by Van Rossum (1990). In this study we demonstrated that it is indeed possible to verify the benefits of the variable practice in adults through increasing the quantity of variation in variable practice.

Despite the reported advances, new studies that investigate the role of the quantity of variations in variable practice are still needed. Besides the use of more complex skills, other variable practice schedules should be used to better understand the effects of increasing the quantity of variation in the acquisition and transfer of motor skills.

Conflicts of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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