Original Article (short paper)

Constant-blocked practice: variation of parameters improves motor skill acquisition

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Abstract — Aims: The purpose of this study was to investigate the effects of the combination of constant and variable practice when both, motor program and parameters on absolute and relative dimensions of a task, are manipulated. **Method:** Twenty undergraduate students, aged between 19 and 24 years, participated in this study. Two groups practiced the task of pressing four keys of a numeric keyboard with total and relative times specified under constant conditions in the first part of the acquisition phase and under block conditions in the second part when one group varied parameters and another varied motor programs. **Results:** Both groups improved parameters and motor program measures during the acquisition phase. In the retention test, the parameters variation resulted in higher accuracy on motor program measure than variation of motor programs. **Conclusion:** Both combinations improve parameters and motor program accuracy. Moreover, the maintenance of GMP during the variation phase contributes to strengthening it.

Keywords: motor learning, generalized motor program, parameters, practice schedule

Introduction

There is a considerable interest in the effects of practice schedules in the learning of a motor skill. Practice schedules have been the most investigated subject in the area of Motor Learning in the last decades[1]. Initially, investigations were carried out manipulating variable practice[2], under the perspective of the contextual interference effect (CIE), which is defined as the degree of interference created by the practice of two or more skills within the same session[2,3]. Variable practice can be organized in a blocked (AAABBBCCC), serial (ABCABCABC) and random fashion (ACBABCBAC), the assumption being that high interference (i.e., serial and random practice) is better than low interference (i.e., blocked practice)[4,5].

At that time, studies addressed neither what is manipulated nor what is learned during practice. This question came to light when Magill and Hall[3] proposed that the CIE would occur when practice varied generalized motors programs (GMPs), but not when the parameters were varied. Sekiya and Magill[6]; Sekiya, Magill and Anderson[7]; Sekiya, Magill, Sidaway and Anderson[8] showed that in both cases, variable practice improves learning parameters[6,7,8]. Since variable practice improves learning parameters, the idea that followed was that constant practice could improve the learning of the GMPs. According to Lai and Shea[9]; Lai, Shea, Wulf and Wright[10]; Shea, Lai, Wright, Immink and Black[11], constant practice leads to GMP learning because the trial-to-trial response stability from constant practice improves the formation of the GMP. On the other hand, the trial-to-trial response instability resultant from variable practice favors the identification of differences on variations of the skill[6,8,10], improving learning parameters. The instability created by variations of practice tends to provide more possibilities of the response variations, which throughout practice would improve the capacity of differentiation among them. These results suggest that combining constant and variable practice might favor the learning of both GMP and parameters, respectively[10].

Other studies[11,12,13] showed that, besides constant practice, blocked practice would also improve the GMP learning, assuming that there was repetition of the task during blocked practice. A stable environment would also lead to GMP learning. Moreover, the interference caused by variation between blocks might also improve parameters learning. So, this practice schedule might lead to learning either GMP or parameters.

Consequently, some studies have combined the constant practice in the first half of the session followed by variable practice in the same session of practice, which has led to GMP and parameters learning[10,14]. More specifically, Lage, Alves, Oliveira, Palhares, Ugrinowitsch and Benda[14] found that blocked practice in the second half of practice improved the parameters of the skill, probably due to the movement structure (i.e., GMP) learned on the first part of acquisition phase. These studies have manipulated the total time (i.e., parameters), which favored the GMP learning and the differentiation between the variations of the task. Nevertheless, it is necessary to manipulate the relative time (i.e., GMP) in the variable practice to observe the effects over the GMP learned during the constant practice.

Furthermore, the purpose of this study was to investigate the combination of constant-blocked practices with variations of GMP and parameters, to illustrate their effects on GMP and parameters learning. It was expected that after learning the GMP with constant practice, the variation of parameters in the second half of the session would be more beneficial to GMP learning than variation of programs.

Method

Participants

Twenty undergraduate students (n = 10), aged between 19 and 24 (Mean 21.12 ± 1.96), self-declared right-handed, and inexperienced in the task, participated of this study. All volunteers were informed about the objectives of the experiment and the procedures were approved by the Local Ethics Committee (CAAE: 32953214.3.0000.5149).

Task and apparatus

The task consisted of pressing, with the index finger of the right hand, four keys in a specific sequence (2, 8, 6 and 4) on the numeric keypad of a computer with color screen. This task intended to verify the achievement of temporal pattern with specific parameters and GMP. The task consisted of performing the sequence with total times of 700 ms, 900 ms or 1100 ms and relative times of 22.2%, 44.4% and 33.3%; 44.4%, 33.3% and 22.2% or 33.3%, 22.2% and 44.4%. The relative times were divided into segments, of which segment 1 corresponded to pressing keys 2 to 8; segment 2 corresponded to pressing keys 8 to 6; and segment 3 corresponded to pressing keys 6 to 4.

Procedures and experimental design

The experiment was performed in two days: the acquisition phase occurred in a single session practice on the first day and retention, occurred 24h after the acquisition phase, on the second day. On the first day, standard instructions about the task were provided. The participants were positioned comfortably in front of the computer to initiate the experiment. They were asked to be as accurate as possible in both relative and absolute time. The participants were counterbalanced by sex into experimental groups, constant-blocks with manipulation of parameters (PG) and constant-blocks with manipulation of motor program (MPG).

During the acquisition phase, the participants performed 60 trials of constant practice and 60 trials of blocked practice. During constant practice, both groups practiced with the absolute time of 900 ms and relative times of 22.2%, 44.4% and 33.3%. During the blocked practice, the PG repeated the relative time practiced in the constant practice and varied three absolute times (700 ms, 900 ms or 1100 ms). The MPG repeated the absolute time practiced in the constant practice and varied three relative times (22.2%, 44.4% and 33.3% 44.4% 33.3%; and 22.2% or 33.3%, 22.2% and 44.4%). After every trial, participants received knowledge of results (KR) about the ratio of each segment and the constant time error.

The retention test, performed 24 hours after the acquisition phase, consisted of 10 trials with the same conditions as the constant practice, but without KR. The inter-trial interval was 6 seconds. After the first part of the acquisition phase (with constant practice), there was one minute of interval so that changes in the software could be made.

Statistical Analysis

The data analysis was performed over the relative error (RE), the absolute error (AE) and the coefficient of variation (CV) of both. This last analysis was adopted as a variability measure, while the RE was used to assess the accuracy of GMP learning and the AE was used to assess the accuracy of parameterization. The Shapiro-Wilks test indicated that the data are normal ($p > .05$), therefore the data analyses were carried out by a two-way ANOVA (2 groups x 12 blocks) with repeated measures in the second factor for the acquisition phase. The comparison between both groups on the retention test was carried out by a Student's t-test. When necessary, the Tukey's post hoc was adopted for pair comparisons. We used the STATISTICA statistical package 10.0, and the significance value adopted was 5% for all the analyses.

Results

Relative error

Figure 1 shows data about relative error. The analysis of the acquisition phase identified significant effect for blocks ($F(11, 198) = 4.37$, $p = 0.0001$, $\eta^2 = 0.19$). The Tukey post hoc test detected that the relative error accuracy of both groups increased from the first to the last block of the acquisition phase ($p < 0.05$). The analysis also identified that PG was more accurate than MPG ($F(1, 18) = 4.90$, $p = 0.03$, $\eta^2 = 0.21$). No significant interaction between blocks and groups ($F(11, 198) = 1.20$, $p = 0.28$, $\eta^2 = 0.06$) was found. In the retention test, the Student's t test identified that the PG had higher accuracy than MPG ($t(df = 18) = -2.92$, $p = 0.009$).

Absolute error

Figure 2 shows data about absolute error. The analysis of the acquisition phase identified significant effect for blocks ($F(11, 198) = 2.96$, $p = 0.001$, $\eta^2 = 0.14$). The Tukey post hoc test detected that the absolute error accuracy increased from the first to the last block of the acquisition phase for both groups ($p < 0.05$). No differences between groups ($F(1,18) = 0.51$, $p = 0.48$, $\eta^2 = 0.02$) nor interaction between blocks and groups ($F(11, 198) = 0.58$, $p = 0.84$, $\eta^2 = 0.03$) were identified. In the retention test, the Student's t test did not identify differences between the groups ($t(df = 18) = 0.24$, $p = 0.8$).

Coefficient of variation of the relative error

Figure 3 shows data about the coefficient of variation of relative error. The analysis of the acquisition phase identified significant effects for groups ($F(1, 18) = 6.62$, $p = 0.01$, $\eta^2 = 0.26$). The Tukey post-hoc test indicated that MPG was more consistent than PG ($p = 0.01$). No significant effect was found for blocks ($F(11, 198) = 1.10$, $p = 0.36$, $\eta^2 = 0.05$) nor was there significant interaction between group and blocks ($F(11, 198) = 1.72$, $p = 0.06$, $\eta^2 = 0.08$). In the retention test, the Student's t test did not identify any effect between the groups ($t(df = 18) = 0.25$, $p = 0.8$).

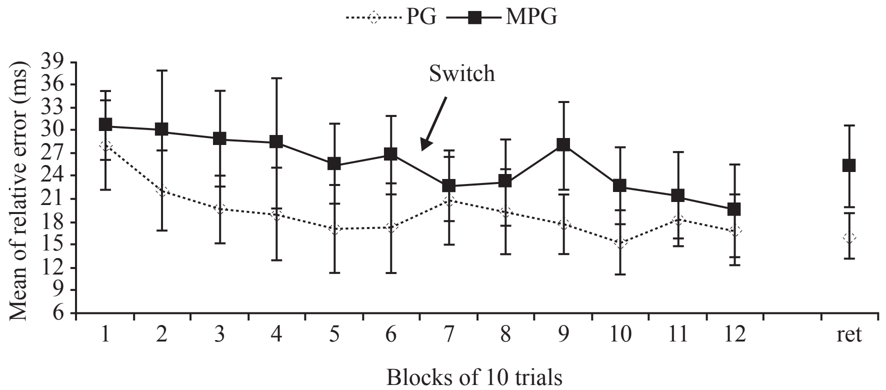

Figure 1. Mean of relative error in the acquisition phase and in the retention test. The vertical bars denote the confidence interval in 95%

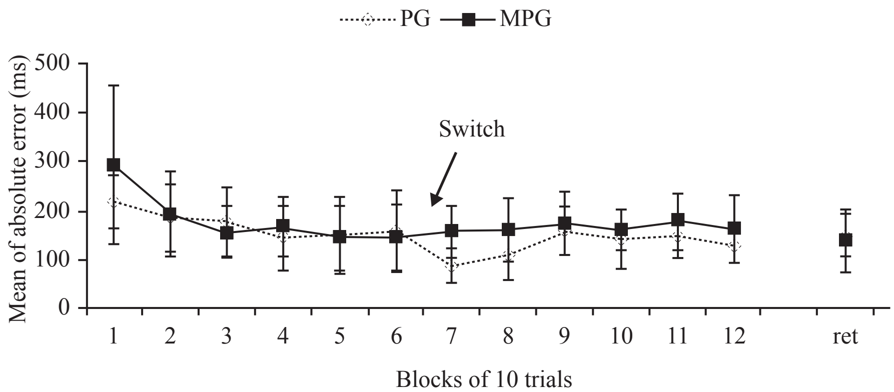

Figure 2. Mean of absolute error in the acquisition phase and in the retention test. The vertical bars denote the confidence interval in 95%.

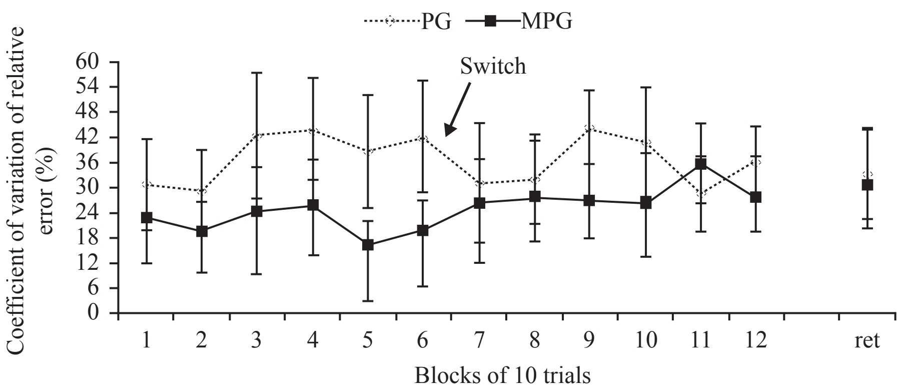

Figure 3. Coefficient of variation of the relative error in the acquisition phase and in the retention test. The vertical bars denote the confidence interval in 95%.

Coefficient of variation of absolute error

Figure 4 shows data about coefficient of variation of absolute error. The analysis of the acquisition phase identified significant effects for blocks ($F(11,198) = 3.03$, $p = 0.0001$, $\eta^2 = 0.14$). The Tukey post-hoc test detected that the second block was more consistent than the ninth and eleventh blocks and that the sixth block was more consistent than the ninth and eleventh blocks ($p < 0.05$). No difference between groups ($F(1,18) = 0.20$, $p = 0.65$, $\eta^2 = 0.01$) was identified, nor was there significant interaction between blocks and groups ($F(11, 198) = 1.11$, $p = 0.35$, $\eta^2 = 0.05$). In the retention test, the Student's t test did not identify any difference between the groups ($t(df = 18) = -1.01$, $p = 0.32$).

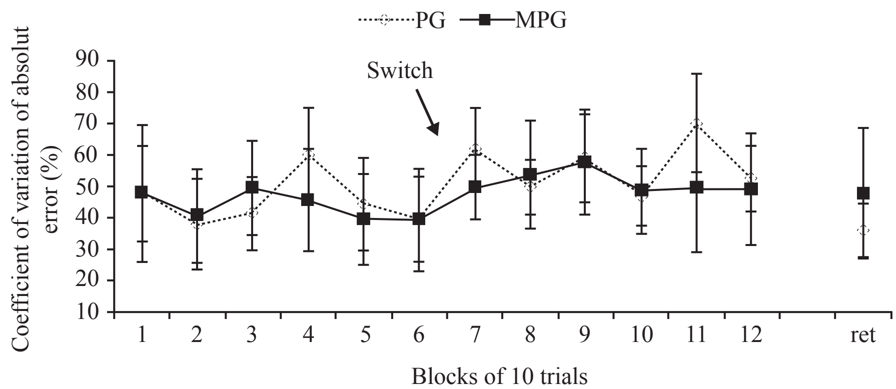

Figure 4. Coefficient of variation of the absolute error in the acquisition phase and in the retention test. The vertical bars denote the confidence interval in 95%.

Discussion

Previous studies have observed the effectiveness of combining constant-varied practice manipulating parameters of the task[10,14]. Constant practice improved the GMP learning and variable practice improved the parameters learning. However, these studies have not manipulated the GMP during variable practice. This study tested the combination of constant-variable practice and manipulated both GMP and parameters during variable practice in the second half of the learning phase. For such analysis, this study adopted a sequential pressing task manipulating the total and relative time. The hypothesis of the authors of this study was that, after constant practice, the variation of parameters would be more beneficial than GMP variations. The results of relative error confirmed this hypothesis. What follows is a discussion of both accuracy performance measures, the relative error and the absolute error, representing GMP and parameters learning, respectively, and the performance consistency of both measures.

In relation to the consistency of the absolute error during the acquisition phase, the first blocks were more consistent than final blocks. More specifically, they were more consistent than the blocks were there occurred changes in the task. This result was expected since the learners needed to make some modifications to perform the tasks and reach the new goal. However, in the retention test, the consistency measures show no effects when GMP or parameters were manipulated after the constant practice.

Although the manipulation of the motor program during the acquisition phase showed higher consistency than the parameter manipulation, there was no difference in the retention test, similar to the results of absolute error. It is possible that during the acquisition phase, the changes of motor program increased the interference too much, making the organization of the inter-trials changes impossible. Consequently, the relative error was high, but without changes. This difficulty of planning the changes of the motor program from trial to trial may have contributed to the fact that no difference in the learning test was found.

Previous studies about combination also did not find any difference in consistency measures in the tests[10,14]. Thus, it is possible that the practice schedules have less influence over the consistency than that of the performance accuracy.

During the acquisition phase, the relative error analysis showed that the manipulation of both, GMP and parameters, improved the GMP accuracy. Furthermore, the absolute error also diminished in both conditions; that is, the parameters accuracy increased. However, during the retention test, the manipulation of parameters resulted in higher GMP accuracy than the GMP manipulation, while the parameterization showed similar accuracy between all conditions.

The results are explained by the stability created during constant practice and the instability created with variations from blocked practice; further they corroborate with Lai and Shea[10] and Lage, Alves, Oliveira, Palhares, Ugrinowitsch and Benda[14]. On the other hand, the results are opposite to previous studies[11,13] showing that blocked practice favors the GMP learning. Probably because these studies did not manipulate the combination of practice, disregarding the proposition of Summers[15] and Roth[16] of initially learning the structure of movement to further develop the capacity of parametrization. This study therefore indicates that the constant practice performed in the beginning of the acquisition phase must have provided enough stability for GMP learning. Looking at the sixth block of the acquisition phase on relative time (i.e., the last block of constant practice), it can be seen that both groups had similar performance. Thus, is possible to say that the constant practice in the first half of the sessions of practice provided the same condition to both groups. This condition enabled the parameters learning with the variation from blocked practice**.**

These findings extend those that manipulated only parameters[10,14,17] because the GMP during the variation phase was also manipulated. As previously mentioned, the manipulation of parameters resulted in higher GMP accuracy than GMP manipulation. The explanation might be because the GMP was maintained throughout the variable practice. According to Shea, Lai, Wright, Immink and Black[11], the type of variation influences the GMP learning since the variation of only the absolute aspects of the skill results in constant practice of the GMP. In this study, when the parameters were manipulated, the GMP remained unaltered. Then, practicing the same GMP during the variable practice seems to contribute to strengthening it**.** Another explanation might be related to the amount of trials. It seems that for learning new tasks or new structures (i.e., relative time), larger changes in the organization of action are required than for learning new parameters. Therefore, it might be necessary to include a higher number of trials to achieve the goal. The amount of practice performed in this study seems to not be enough for the new relative times be learned, which were reflected in relative error results in the retention test.

On the other hand, there was no difference in the absolute error analysis, indicating that what is varied does not seem influence the parameters accuracy. Sekiya, Magill, Sidaway and Anderson[8] have showed that manipulating either GMP or parameters led to the learning of parameters. However, it would be interesting to test if the effects found in relation to parameters accuracy would be replicated in transfer tests, which would require adaptation of the GMP and parameters. Finally, the comparison of simple and complex motor tasks have shown different results [18], indicating the necessity of testing the same question with complex motor skills.

In conclusion, the stability of GMP during the acquisition phase (i.e., blocked practice) improves accuracy of the GMP. However, other studies about combination practice should be performed with complex motor tasks in order to gain a better understanding about the motor skill learning processes.

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Manuscript received on April 29, 2017

Manuscript accepted on July 12, 2017