Gradual increment on practice variability: effects on structure learning and skill parametrization

CDD. 20.ed. 152.3

http://dx.doi.org/10.1590/1807-55092016000300781

Marcelo Silva JANUÁRIO*
Herbert UGRINOWITSCH*
Guilherme Menezes LAGE*
Márcio VIEIRA*
Rodolfo Novellino BENDA*

*Escola de Educação Física, Fisioterapia e Terapia Ocupacional, Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brasil.

Abstract

Traditionally, on the learning of motor skill practice has been scheduled in constant, blocked, serial or random fashion. A superiority of variable over constant practice has been suggested as well as random and serial practices over blocked practice. Recently a specificity of the type of practice has been observed: constant practice helps the formation of a movement structure, especially in the early learning, and the variable practice improves parameterization. This study investigated different practice schedules and their combinations in a sequence that provides a gradual increment of variability (constant, blocked, and random) in the acquisition of motor skills. Participants were divided into four groups (n = 10): CCC (constant), BBB (blocked), RRR (random) and CBR (constant-blocked-random). The experiment consisted of an acquisition phase and a transfer test. In the acquisition phase the task comprised pressing a numeric keyboard in a given sequence (2, 8, 6, 4) with the index finger, with fixed relative timing among presses (22.2%, 44.4% and 33.3%) and specific total times (700, 900 and 1100 ms) determined by the experimental design. The test results showed a superiority of CBR and RRR groups in the absolute error measure, of CCC and BBB groups in the relative error measure, and CCC, BBB and CBR groups in the variability of relative error measure. These results evidence the practice schedules that provided smaller variability led to the learning of a movement structure, whereas the ones that provided greater variability culminated in the improvement in parameterization.

Key Words: Practice schedules; Practice combination; Movement structure; Parameterization.

Introduction

The quality and speed of motor learning can be improved by factors frequently addressed in the process of teaching and learning of motor skills. Among such factors we can mention the knowledge of results[1], modelling and demostration[2], goal-setting[2], in addition to practice, which has been acknowledged as one of the most influential factors[3]. Practice has a key role in the acquisition of skilled behavior, which displays as remarkable features consistency and flexibility[4]. A feature of this practice is that it should not be a mere repetition of a specific solution to a problem, but the repetition of the process of solving motor problems[5-6] which leads the learner to the selection of the most appropriate responses to each motor problem.

In this process, the way the practice is scheduled influences the acquisition of motor skills[7-12]. Practice has been scheduled in constant, blocked, serial and random fashion[3, 10-11]. A varied practice schedule has been regarded as more effective as constant practice[13-15], as random and serial practice have been acknowledged as more effective than blocked practice in the learning of motor skills[10, 16-18]. Conversely, contrasting results have been found, challenging the superiority of the varied practice over constant practice and the advantage of random and serial practice over blocked practice[19-24]. As a result of such controversy, the combination of constant and varied practice was employed[7-8, 20] with favorable results on the acquisition of motor skills, particularly in the initial stages of learning. Such occurrence can be explained by the repetition of practice conditions which results in the acquisition of a more consistent motor skill relative to blocked, serial and random practices[7-8, 20-21, 24]. A feature of those studies is the introduction of associations between the effects of different practice schedules and their outcomes, as structural characteristics and parameters of the learned motor skill.

Lai and Shea[20] have shown superiority of constant practice in the learning of relative timing, a measure used to infer the formation of a cognitive structure or a skill structure related to the motor skill. Additionally, the absolute timing measure has been employed to evaluate the improvement of motor skill parameter specification and performance accuracy. Furthermore, Shea et al.[21] revealed an advantage of constant and blocked practice over random and serial practice schedules in the formation of the skill structure. Conversely, serial and random practice groups have shown superior motor skill parameter specification. These results indicate that practice schedules that provide greater consistency in a trial-by-trial basis, i.e. constant and blocked practice, favor the formation of a skill structure, whereas those who set greater variability from one trial to another, that is, the serial and random practice schedules, support the specification of parameters in motor skills.

Considering the preceding evidence, few studies investigated the combination of different practice schedules, aiming to find which one would result in concurrent improvement of both motor skill structure and parameter specification, which represents a more proficient learning[7-8]. The results of these studies have shown that the combination of constant practice followed by random or blocked practice led to superior performance in relative and absolute timing in retention and transfer tests. These findings suggest a hierarchy in which initial constant practice gives greater emphasis to the formation of a skill structure, and subsequently varied practice improves the capability of skill parameterization of the learner[7-8]. In other words, the practice should combine schedules that initially provide greater consistency from trial to trial with subsequent practice schedules which generate greater variability[7-8, 21, 25]. However, few studies have investigated the combination of practice schedules in the acquisition of motor skills[26-27]. There are few studies that combine constant, blocked and random practice in the same schedule, although such combination could assist in the learning process as the intertrial variability is increased in along with the learning of the practiced skill[26].

Regarding blocked practice, Shea et al.[21] found that this schedule alone favors the learning of a movement structure, whereas when combined with constant practice, Lage et al.[8] found benefits not only in the formation of a motor skill structure, but also in parameterization capability. Possibly these results can be explained considering the blocked practice introduces both the aforementioned predictability features as well as the contextual interference effect. Facing such evidence, the following questions arise: what are the effects of the combination of constant-blocked-random practice in the acquisition of motor skills? Can the blocked practice, in the central position of the continuum between the constant practice and variability with high contextual interference (random practice), contribute to the learning of the structure and parameterization of the motor skill practiced?

Therefore, the objective of this study was to investigate the effects of constant, blocked and random practice schedules, and their combination (constant-blocked-random) in the learning of motor skills. This study presents three hypotheses: 1) the constant and blocked practice groups will present better performance in the structure measure in the transfer test when compared to random practice group; 2) the random practice group will outperform the constant and blocked practice groups in the parameterization measure[20] in the transfer test; and 3) the group that practices in the constant-blocked-random sequence will present superior performance in the transfer test in the structural measure[20] when compared to the random practice group and in the parameterization measure[20] when compared to constant and blocked practice groups.

Method

Sample

Forty volunteers undergraduate students of both sexes, self-declared right-handed, aged M = 24.5 years, SD = +3.4 years with no experience in the employed task took part on the study. The study followed the standard ethical procedures and was approved by the University's Research Ethics Committee (ETIC 268-10).

Apparatus and task

The instrument employed was similar the one used by Lai and Shea[20], Lai et al.[7] and Lage et al.[8] in their studies. The apparatus was composed of a numeric keypad, a microcomputer and a software specially developed for task control and data storage. The task in the acquisition phase consisted of typing keys in a specific sequence (2, 8, 6, 4) on the numeric keypad with the index finger of the right hand, with set time-bound goals: relative timing between the keys (22.2%, 44.4% and 33.3% of total time); and absolute timing (700, 900 or 1100 ms) according to the experimental group. The task allows ascertaining the acquisition of a spatiotemporal movement pattern, with specific measures for structure formation (relative timing) and parameterization capability (absolute timing). In the transfer test, the absolute timing target was 1300 ms for all groups.

Experimental design

The experiment comprised an acquisition phase (90 practice trials) according to the assigned group schedule, and the transfer test (10 trials) carried out 24 hours after the acquisition phase. The volunteers were randomly distributed in four practice groups (n = 10): 1) constant (CCC); 2) blocked (BBB); 3) random (RRR) and 4) constant-blocked-random (CBR). The practice was varied with respect to time goals in absolute timing in random and blocked practice groups, with 700, 900 and 1100 ms total time goals, and 900 ms target in all practice trials in the constant practice group. Participants of the CBR group underwent 30 trials of constant practice, 30 trials of blocked practice and 30 trials of random practice in the acquisition phase, with an interval of three minutes after every 30 trials to change the software's task presentation sequence. Participants in the CCC, BBB and RRR also had a 3 minute break every 30 trials. The four practice groups received knowledge of results (KR) on the absolute time and relative timing in all trials of the acquisition phase (100%). The transfer test consisted of 10 practice trials in the same task with an absolute time goal of 1300 ms, different from the ones presented in the acquisition phase, without KR.

Procedures

Data collection was carried out individually in a specific room for the purpose. All participants gave written informed consent. Verbal instructions and a demonstration of the task were presented, followed by an explanation of the KR presented by the task software. After sitting comfortably in front of the computer, the participants set the video monitor and keyboard to their liking. Information about the target relative timing was displayed throughout the acquisition phase in the PC screen, and at the start of each trial information on the absolute target time was also displayed to participants. In the first experimental phase, the task consisted of performing a sequence of movements typing the numbers 2, 8, 6 and 4 of a standard computer numeric keypad, with absolute timing goal of 900 ms for the CCC group and 700, 900 and 1.100 ms for the BBB, RRR and CBR groups. The relative timing goal between each key press was 22.2% of the absolute time from the 2 to the 8 key, 44.4% of the absolute time from the 8 to the 6 key and 33.3% of the absolute timing from the 6 to the 4 key. After a "go" message displayed on the computer screen by the task software, the participant typed the aforementioned number sequence. Finally, the KR was provided on the screen and encompassed the following information: absolute (total) time, percentage error in each of the three relative timings and the sum of the relative timing errors.

Statistical procedures

Data were organized in 10 blocks of trials, comprehending nine blocks of the acquisition phase (block 1 through block 9) and the transfer test block (TT). The results were analyzed concerning relative error (skill's structural measure) and absolute error (parameter and performance accuracy measure) in the acquisition phase and transfer test. The standard deviation of each subject between trials in these measures was selected as a measure of variability.

To analyze the groups' behavior over the blocks of trials in the acquisition phase a two-way ANOVA (4 groups x 9 blocks) with repeated measures on the second factor was performed, and the inter-group analysis in the transfer test was evaluated with a one one-way ANOVA (4 groups). The LSD post hoc test was employed to locate the differences when necessary. Alpha was set at 5%.

Results

Relative Error (RE)

Acquisition

Almost all groups showed error reduction throughout practice, except for the RRR group, which maintained error in high levels (FIGURE 1). Nevertheless, the statistical analysis revealed no significant difference between groups [F(3, 36) = 2.13, p = 0.114] nor interaction between groups and blocks [F(24, 288) = 1.03, p = 0.425]. Nonetheless, a difference between blocks was detected [F(8, 288) = 2.39, p = 0.017], which was located by the LSD test between the first and the last blocks of trials (p < 0.05).

Transfer test

The statistical analyses showed significant differences between groups [F(3, 36) = 3.03, p = 0.041], while the LSD test revealed smaller error of CCC e BBB groups relative to RRR group (p < 0.05).

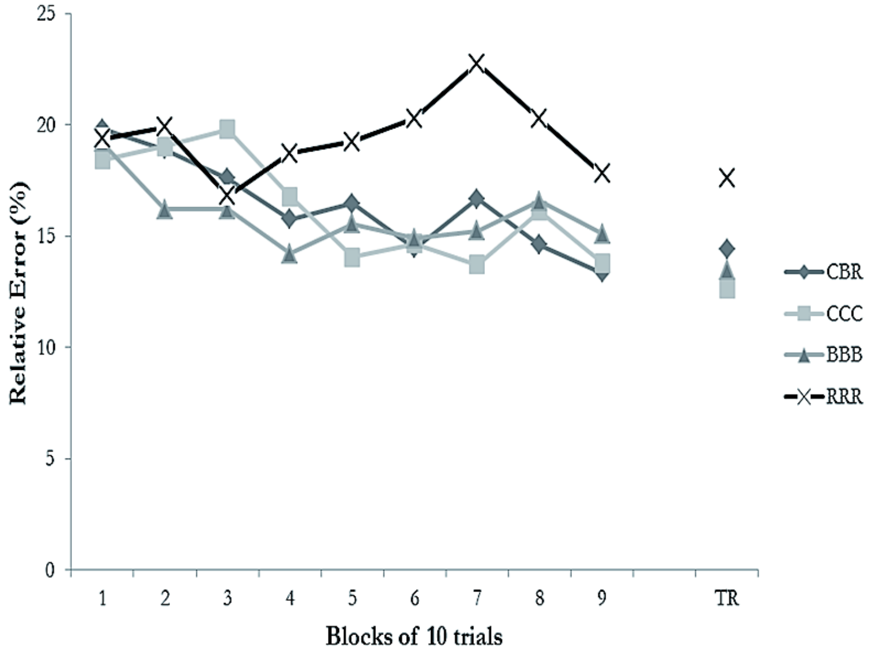

FIGURE 1 - Mean relative error in acquisition phase and transfer test.

Absolute Error (AE)

Acquisition

The groups showed a reduction in error throughout practice (FIGURE 2). Statistical analysis revealed no significant interaction between groups and blocks [F(24, 288) = 1.18, p = 0.258]. Differences were also found for the blocks factor [F(8, 288) = 6.24, p = 0.0001], and the LSD test showed higher error in the first relative to the last block of trials (p<0.05). A difference between groups was also detected [F(3, 36) = 3.39, p = 0.028], while the LSD test revealed the CCC group showed smaller error than BBB and RRR groups.

Transfer test

Statistical analysis indicated a significant difference between groups [F(3, 36) = 3.31, p = 0.031], and the LSD test unveiled lower error for CBR and RRR groups relative to CCC group.

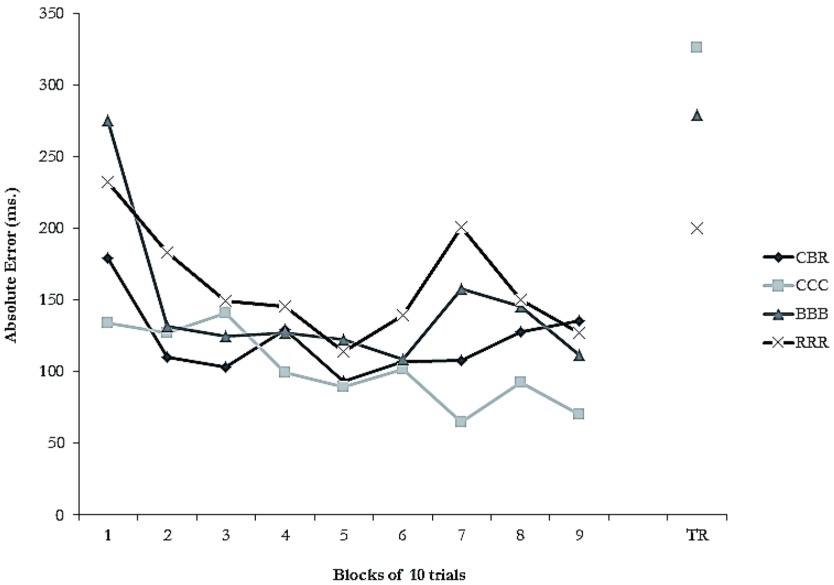

FIGURE 2 - Mean absolute error in acquisition phase and transfer test.

Relative error standard deviation

Acquisition

Groups showed reduction in relative error variability from the beginning to the end of the practice phase (FIGURE 3). Notwithstanding, the statistical analysis revealed no significant differences for blocks [F(8, 288) = 1.66, p = 0.1], nor interaction between groups and blocks [F(24, 288) = 0.55, p = 0.9]. A difference between groups was found [F(3, 36) = 13.38, p = 0.001], and the LSD test revealed that the RRR group displayed greater error variability in relation to CCC, BBB e CBR groups (p < 0.05).

Transfer test

The analysis unveiled significant differences between groups [F(3, 36) = 3.44, p = 0.027], and the LSD test shown lesser error variability of CCC, BBB e CBR groups compared to RRR group.

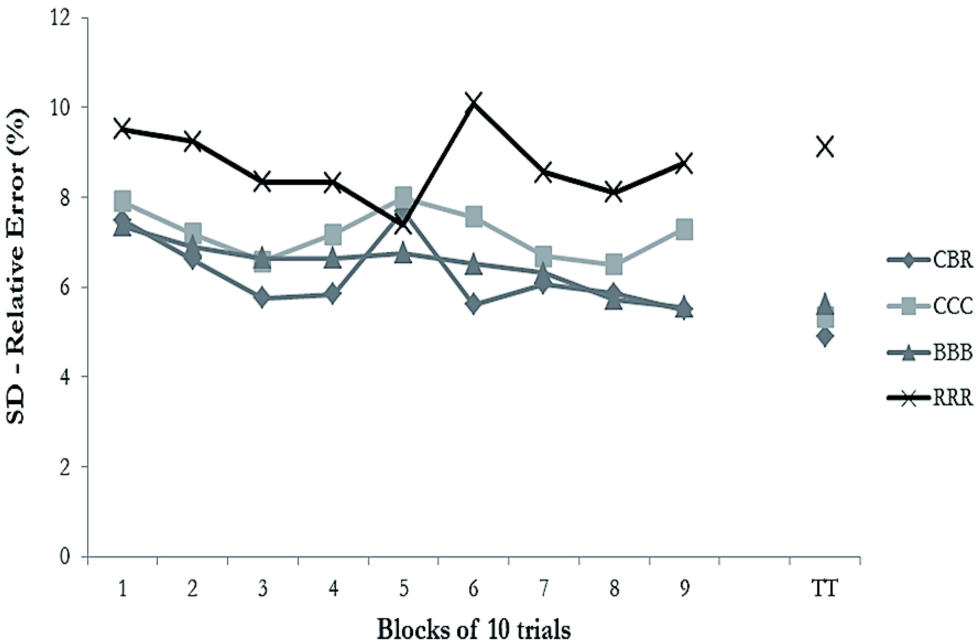

FIGURE 3 - Mean of the standard deviation of the relative error in acquisition phase and transfer test.

Absolute error standard deviation

Acquisition

Groups showed reduction in absolute error variability with practice (FIGURE 4). The statistical analysis revealed no differences between groups [F(3, 36) = 3.33, p = 0.09] neither interaction between groups and blocks [F(24, 288) = 0.45, p = 0.99]. Nonetheless, a significant difference was found between blocks [F(8, 288) = 4.86, p = 0.0001], and the LSD test showed greater variability of the first relative to the last block of trials (p < 0.05).

Transfer test

No differences between groups were found [F(3, 36) = 2.66, p = 0.063] (FIGURE 4).

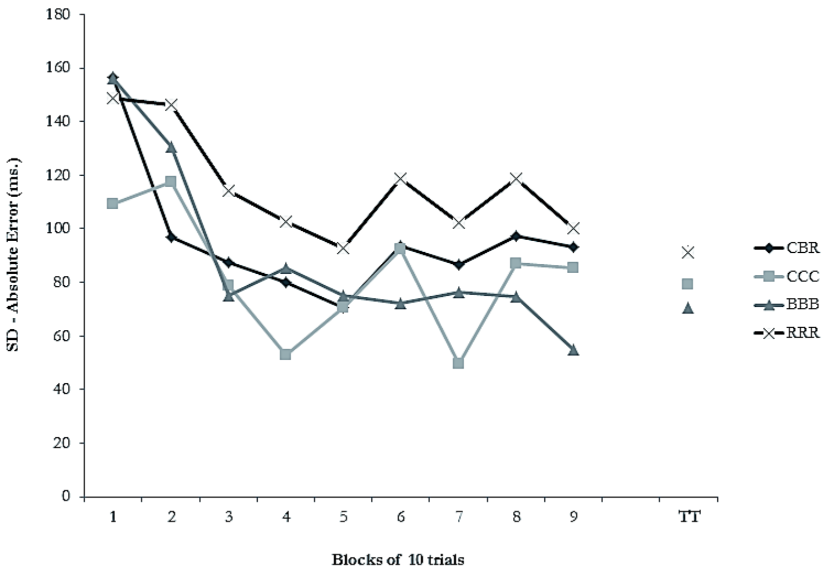

FIGURE 4 - Mean of the standard deviation of the absolute error in acquisition phase and transfer test.

Discussion

The current study aimed to investigate the effects of constant, blocked and random practice schedules, and the gradual increase in the intertrial variability of practice (constant-blocked-random combination), in the learning of motor skills. The results demonstrated that the organization of practice affects both the learning of the skill structure and its parameterization.

The first hypothesis tested was that groups of constant practice and in blocks would show better learning of the skill structure (relative timing measure). Results confirmed the hypothesis, as the practice schedules that enforced a more consistent response in the acquisition phase led to better performance in the skill structure measure during the test. In the relative error measure, the CCC and BBB groups performed with a lower error than the RRR group. Those results support the findings of Shea et al.[21] in which CCC e BBB groups also showed superior performance in the relative error measure. Lai and Shea[20] also found in their study a better performance of the constant practice group in the relative error measure in testing, when compared to the varied practice group. The authors concluded the formation of a movement skill structure (in their rationale the generalized motor program) was achieved due to factors that benefit the response stability during the acquisition the motor skill. Lage et al.[8] argues that the opportunity to remain steady during the practice trials, afforded by some practice conditions, may favor the acquisition of a movement structure. Therefore, these practice conditions allow the learner to direct attention to the relative timing structure during practice.

In the present study, the constant and blocked practice groups, compared to the random practice group, had opportunity to direct attention to the relative timing structure. This ensues due to the absence of parameter variation in the constant group, allowing the participants to focus their attention in relative timing during practice. The superior performance of blocked practice in the relative timing measure can be explained by the smaller parameter variation in that practice condition, which allows the learners to direct attention to the relative dimensions of the task. The present study results, altogether with Lai and Shea[20] and Shea et al.[21] studies, suggest the constant and blocked practice conditions promote greater stability in response execution over the acquisition of motor skills compared to random practice conditions, leading to the learning of the movement skill structure. Hence the results of the current study are in line with the notion that factors that increase consistency during practice promote the learning of a movement skill structure[20-21].

Our second hypothesis predicted that the random practice group would present superior performance in the parameterization measure compared to CCC and BBB groups (absolute time and performance accuracy). The results partially confirm the hypothesis, since the RRR group exhibited superior performance in the absolute error measure in the test only when compared to the CCC group. These results are in accordance with Shea et al.[21] study, in which random practice, affording greater response variability during acquisition, conducted to a more efficient learning of the capacity of specifying parameters than constant practice. A possible explanation for the superior performance of the RRR group regarding the absolute error is the effective contribution of the contextual interference effect present in this practice schedule. The current results demonstrate the effect of the contextual interference effect in the absolute error measure, since the CCC group was statistically more precise in acquisition compared to RRR group. In the transfer test the RRR group was more accurate than CCC group, supporting the effect of the contextual interference.

Concerning the explanation of the contextual interference effect generated by the varied practice schedules, two hypothesis have been proposed: the elaboration hypothesis, stated by Shea and Morgan[10] and Shea and Zimny[18], which suggests the high contextual interference leads to a better elaboration of the memory representation over the skill variation features. During high contextual interference practice, the learner is compelled to vary the processing strategies, resulting in the formation of a stronger memory trace, less environmentally dependent of the initial practice conditions. As stated by Corrêa[28], the contextual interference effect generates numerous and varied memory processes, resulting in two types of skill representation in memory. The first one features a greater distinction, due to the comparisons made by the learner during task execution. The second results from the greater elaboration following the different strategies of codification brought about by this kind of practice. Those events lead to a more meaningful memorization process, tentatively more lasting and probably easier to remember when performing the same task at a later time.

Another explanation that aims to explain the superiority of high contextual interference practices is the forgetting or reconstruction hypothesis, proposed by Lee and Magill[16] and Lee et al.[17] The authors hypothesize that the interference generated by high contextual interference practice schedules results in greater variability between trials and thus might result in forgetfulness of the action plan, leading the learner to be driven to reconstruct the action plan at every trial. Such process wouldn't take place in constant practice, since the learner may use the same action plan on consecutive trials. Consequently, the action plan reconstruction process can account for the learning gains. According to Lee and Magill[16] the partial or complete forgetfulness that leads to the reconstruction of the action plan at every trial results in the strengthening of the active processes, which allows for a more effective learning.

When comparing the performance of BBB and RRR groups in the absolute error measure, the results did not show a typical contextual interference effect. In particular, the RRR group did not show superior performance in testing compared to BBB group. A possible explanation for the absence of a significant difference between blocked and random groups is the moderate contextual interference present in the former practice schedule. In blocked practice, unlike constant practice, there also is a change in task after a number of trials. Thus, the learners were led to vary the processing strategies, even if in a lesser extent than the CBA and AAA groups. At any rate, the variation introduced in blocked practice induced learners to reach similar performance to the random practice group.

The findings suggest that the intermediate level of practice variability in blocked practice prompted this practice schedule to attain the learning of a movement structure and did not differ from the random practice group as the most efficient in learning to specify task parameters.

Regarding the third hypothesis, the CBR group did not surpass the RRR group in relative timing performance. This result indicates the CBR group reached intermediate levels of learning, being comparable to CCC and BBB groups. One possible explanation is that the CBR group was not subject to the same level of stability of CCC and BBB groups in the acquisition phase. Porter and Magill[27] conducted a study that showed that the combined group practice that initiated practice in a blocked schedule, followed by serial and random practice, showed superior performance in absolute error in the transfer test when compared to a random practice group. However, this group, which also provided a gradual increase in the variability of practice, did not show superior performance when compared to the blocked practice group in the transfer test. We stress that in the present study the combined practice group was composed of the constant, blocked and random practice schedules, whereas in the study by Porter and Magill[27], the combined practice group was constituted by blocked, serial and random practice schedules. Despite the combined practice group in this study starting in a schedule that allows for greater consistency during the acquisition, this did not favor the relative timing performance. The current results suggest that it may be necessary to provide additional consistency during acquisition trials.

Regarding the absolute error measure, CBR and RRR groups showed better performance than the CCC group in the transfer test, indicating that these groups reached a more efficient learning parameter specification of the task. Moreover, there was no significant difference between the BBB group and the CBR and RRR groups, indicating that the BBB group showed an intermediate performance in absolute time. An explanation for the performance of CBR and RRR groups in absolute error is the effective contribution of the contextual interference effect in these practice schedules.

Notwithstanding, the results also suggest that the combination of constant-blocked-random practices, in which there is a gradual increase in the practice variability, resulted in a similar level of variability as the random practice group. Contrary to what was expected the CBR group did not show the expected performance in the relative timing measure. A possible explanation is the presence of random practice at the end of the acquisition. The random practice resulted in increased variability in response execution in the final phase of acquisition, leading to a reduction of the level of stability in the CBR group. Another factor that may have contributed to the learning of the response parameter specification in the CBR group was the effect of contextual interference present in blocked practice. It seems that this effect, albeit low, added to the high contextual interference effect in this random practice, contributed to the learning of the response parameter specification. Furthermore, results suggest that this quantity of constant practice in the combination group was not enough for individuals to reach the learning of a movement structure; constant practice was performed in only 33% of trials.

Results of the present study also suggest that intermediate levels of practice variability, present in blocked practice, may lead to the learning of a movement task structure. The current results support the "challenge point" hypothesis[29]. According to this hypothesis, the contextual interference level can influence the functional difficulty of the task. According to the authors, a low contextual interference practice schedule reduces the functional difficulty of the task, which facilitates learning for beginners in the task. The blocked practice, which features low contextual interference, reduced the task's functional level of difficulty, allowing beginners to reach the learning of a movement structure. On the other hand, the CBR group allowed learners to become more skilled during practice. This is due to the group starting with a practice schedule that reduced the functional level of difficulty of the task, and then allowed learners to benefit from the contextual interference effect present in blocked and random practice to learn how to specify the parameters of task response. As stated by Guadagnoli et al.[30] experienced learners benefit from random practice, while inexperienced learners benefit from blocked practice.

The results of the present study may also be supported by the hypothesis of "desirable difficulties" proposed by Bjork[31-32]. It seems that the intermediate levels of practice variability experienced by the BBB group provided a desirable level of difficulty for learners. According to the author, the desirable difficulty refers to the practice conditions that lead to the learner's engagement in a process of effort during practice that allows the achievement of good performance in retention and transfer.

Referring to CBR group, we conclude that this combination resulted in high levels of response variability during skill acquisition, resulting in a more efficient learning in specifying task parameters.

As previously discussed, blocked practice together with the random practice contributed to the increase of the response variability during acquisition. Thus, if the benefit of the blocked practice was directed to increased variability, then the amount of constant practice may have been insufficient to promote the learning of a movement structure.

Importantly, these findings indicate that novice learners can benefit from a practice schedule that promotes greater response consistency during acquisition to the learning of a movement structure and afterwards a practice schedule that provides greater response variability for learning the parameter specification. Regarding the combined practice group, we suggest further studies to be carried out varying the amount of practice that provides greater response stability and those that provide greater response variability.

Resumo

Aumento gradual da variabilidade de prática: efeito na aprendizagem da estrutura e na parametrização da habilidade

Tradicionalmente, na aprendizagem de habilidades motoras a prática tem sido estruturada de forma constante, em blocos, seriada ou aleatória. Tem sido proposta a superioridade da prática variada sobre a prática constante bem como da prática aleatória e seriada sobre a prática em blocos. Atualmente tem sido observada uma especificidade do tipo de prática: a prática constante auxilia na formação de uma estrutura de movimento, especialmente no início da aprendizagem e a prática variada na melhora da parametrização. O presente estudo investigou diferentes regimes de prática e a sua combinação numa sequência que fornece um aumento gradual de variabilidade (constante, blocos e aleatório) na aquisição de habilidades motoras. A amostra foi distribuída em quatro grupos (n = 10): CCC (constante), BBB (blocos), AAA (aleatório) e CBA (constante-blocos-aleatório). O experimento foi dividido em fase de aquisição e teste de transferência. Na fase de aquisição a tarefa foi pressionar teclas numéricas do teclado de um computador em uma sequência (2, 8, 6, 4) com o dedo indicador, com tempo relativo entre os componentes especificado (22,2%, 44,4% e 33,3%) e com os seguintes tempos totais (700, 900 e 1100 ms) estabelecidos conforme o delineamento experimental. Os resultados do teste demonstraram superioridade dos grupos CBA e AAA na medida de erro absoluto, dos grupos CCC e BBB na medida de erro relativo e dos grupos CCC, BBB e CBA na medida de variabilidade de erro relativo. Tais resultados demonstram que os regimes de prática que forneceram menor variabilidade conduziram ao aprendizado de uma estrutura de movimento, enquanto que as que forneceram maior variabilidade resultaram na melhora da capacidade de parametrização.

Palavras-chave: Estrutura de prática; Combinação de prática; Estrutura de movimento; Parametrização.

References

1. Benda RN. Sobre a natureza da aprendizagem motora: mudança e estabilidade. Rev Bras Educ Fís Esporte. 2006;20:43-5.
2. Magill RA. Aprendizagem motora: conceitos e aplicações. São Paulo: Edgard Blucher; 2000.
3. Schmidt RA, Wrisberg CA. Aprendizagem e performance motora. Porto Alegre: Artmed; 2001.
4. Lage GM. Efeito de diferentes estruturas de prática na aprendizagem de habilidades motoras [dissertação]. Belo Horizonte (MG): Universidade Federal de Minas Gerais, Escola de Educação Física, Fisioterapia e Terapia Ocupacional; 2005.
5. Bernstein NA. The co-ordination and regulation of movements. Oxford: Pergamon; 1967.
6. Tani G. Crianças e movimento: o conceito de prática na aquisição de habilidades motoras. In: Krebs RJ, Copetti F, Beltrame TS, Ustra M, organizadores. Perspectivas para o desenvolvimento infantil. Santa Maria: Edições SIEC; 1999. p.57-64.
7. Lai Q, Shea CH, Wulf G, Wright DL. Optimizing generalized motor program and parameter learning. Res Q Exerc Sport. 2000;71:10-24.

8. Lage GM, Alves MAF, Oliveira FS, Palhares LR, Ugrinowitsch H, Benda RN. The combination of practice schedules: effects on relative and absolute dimensions of the task. J Hum Mov Stud. 2007;52:21-35.
9. Meira Junior CM, Tani G, Manoel EJ. A estrutura da prática variada em situações reais de ensino-aprendizagem. Rev Bras Cien Movimento. 2001;9:55-63.
10. Shea JB, Morgan RL. Contextual interference effects on the acquisition, retention and transferer of a motor skill. J Exp Psychol Hum Learn. 1979;5:179-87.
11. Magill RA, Hall KG. A review of the contextual interference effect in motor skill acquisition. Hum Mov Sci. 1990;9:241-89.
12. Ugrinowitsch H, Manoel EJ. Interferência contextual: manipulação de aspecto invariável e variável. Rev Paul Educ Fis. 1996;10:48-58.
13. Barreiros JMP. Variability of practice and contextual interference in children and adults. Mot Hum. 1992;8:5-15.
14. Margolis JF, Christina RW. A test of Schmidt's schema theory of discrete motor skill learning. Res Q Exerc Sport. 1981;52:474-83.
15. Moxley SE. Schema: the variability of practice hypotheses. J Mot Behav. 1979;11:65-70.
16. Lee TD, Magill RA. The locus of contextual interference in motor skill acquisition. J Exp Psychol learn. 1983;9:730-46.
17. Lee TD, Magill RA, Weeks DJ. Influence of practice schedule on testing schema theory predictions in adults. J Mot Behav. 1985;17:283-99.
18. Shea JB, Zimny ST. Context effects in memory and learning movement information. In: Magill RA, editor. Memory and control of action. Amsterdam: North Holland; 1983. p.345-66.
19. Kerr R. Practice variability: abstraction or interference. Percept Mot Skills. 1982;54:219-24.
20. Lai Q, Shea CH. Generalized motor program (GMP) learning: effects of frequency of knowledge of results and practice variability. J Mot Behav. 1998;30:51-9.
21. Shea CH, Lai Q, Wright DW, Immink M, Black C. Consistent and variable conditions: effects on relative and absolute timing. J Mot Behav. 2001;33:139-52.
22. Van Rossun JHA. Schmidt's schema theory: the empirical base of variability of practice hypothesis - a critical analysis. Hum Mov Sci. 1990;9:387-435.
23. Del Rey P, Whitehurst M, Wughalter E, Barnwell J. Contextual interference and experience in acquisition and transfer. Percept Mot Skills. 1983;57:241-2.
24. Corrêa UC, Ugrinowitsch H, Benda RN, Tani G. Effects of practice schedule on the adaptive process of motor learning. Rev Port Cien Desp. 2010;10:158-71.
25. Giuffrida CG, Shea JB, Fairbrother JT. Differential transfer benefits of increased practice for constant, blocked, and serial practice schedules. J Mot Behav. 2002;34:353-65.
26. Lage GM, Alves AF, Oliveira FS, Palhares LR, Ugrinowitsch H, Benda RN. O efeito da interferência contextual na aprendizagem motora: contribuições científicas após três décadas da publicação do primeiro artigo. Rev Bras Cienc Mov. 2011;19:107-19.
27. Porter JM, Magill RA. Systematically increasing contextual interference is beneficial for learning sport skills. J Sports Sci. 2010;28:1277-85.
28. Corrêa UC. Interferência contextual: contribuições à aprendizagem motora. In: Pellegrini AM, organizadora. Coletânea de estudos: comportamento motor I. São Paulo: Movimento; 1997. p.129-58.
29. Guardagnoli MA, Lee TD. Challenge point: a framework for conceptualizing the effects of various practice conditions in motor learning. J Mot Behav. 2004;36:212-24.
30. Guardagnoli MA, Holcomb WR, Weber TJ. The relationship between contextual interference effects and performance expertise on the learning of a putting task. J Hum Mov Stud. 1999;37:19-36.
31. Bjork RA. Memory and metamemory considerations in the training of humanbeigns. In: Metcalfe J, Shimamura A, editors. Metacognition: knowledge about knowing. Cambridge: MTT; 1994. p.185-205.
32. Bjork RA. Assessing our own competence: heuristics and illusions. In: Golper D, Koriat A, editors. Cognitive regulation of performance: interaction of theory and application. Cambridge: MTT; 1999. p.435-59. (Attention and performance, 17).

Acknowledgments

Authors tank to CNPq for its support.

ADDRESS
Marcelo Silva Januário
Escola de Educação Física, Fisioterapia e Terapia Ocupacional
Universidade Federal de Minas Gerais
Av. Pres. Antônio Carlos, 6627
31270-901 - Belo Horizonte - MG - BRASIL
e-mail: marcelojanuariotkd@yahoo.com.br

Submitted: 09/15/2013
1a. Review: 09/24/2013
2a. Review: 04/02/2015
Accepted: 05/13/2015