Original Article (full paper)

The effect of constant practice in transfer tests

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Abstract — Background: There is a consensus that repetition observed in constant practice produces minimal benefits to the transfer of learning. **Objective:** The purpose of this study was to investigate in 3 experiments the effects of constant practice in transfer contexts. **Methodology**: Participants were asked during acquisition phase, in all experiments, to press four keys sequentially with different requirements of absolute timing in a same relative timing structure. In the transfer tests, they were tested in a novel absolute timing criterion. **Results**: The results of experiment 1 and 2 showed that the relative timing structure was maintained only when the transfer required parameter scaling close to the parameter value practiced in acquisition. The transfer parameter that is far to the parameter practiced did not affect the movement parameterization. The result of experiment 3 showed that relative timing structure is disrupted in the transfer test when constant practice has high and low amount of practice. **Conclusion:** Some specific aspects interfere in the transfer test when constant practice is experienced.

Keywords: motor learning, practice organization, specificity of practice, transfer of learning

Introduction

Because the variability of practice hypothesis was predicted based on the schema theory[1], variable practice has been one of the most studied topics in motor learning[2-9]. According to the variability of practice hypothesis, skill variations, which are governed by the same generalized motor program (GMP), promote an enhanced capacity to successfully perform a novel skill's variation[6]. As one would expect, the typical method used to contrast the positive effects of the variable practice in transfer is to employ constant practice as a control condition.

The constant practice condition requires the execution of a unique criterion-based skill[10] and the sole possibility of variation is in the total number of trials. The low status ascribed to constant practice in transfer is based on the common sense observation that the primary characteristic of constant practice is repetition. However, a more detailed analysis of the type of repetitions observed in constant practice suggests that it is more related to repetition of the instruction rather than repetition of the process of movement control. The acquisition of a skill is an atypical form of repetition without repetition, that is, it does not consist of repeating the means of the solution to a motor problem, but rather repeating the process of solving the problem[11]. This type of analysis suggests that inherent variability is present in constant practice; hence, some level of transfer should be expected. Motor learning can be viewed as an interaction between the processing requirements of the conditions of practice and the processing requirements of the transfer test condition[12].

Two dependent measures to investigate the role of practice in learning have been used in studies whose theory of schema is the theoretical framework[13-22]. The first measure, the relative timing errors, inform on the learning process of the movement structure, or the GMP, which is characterized by a well-defined pattern of relative timing. The second, the absolute timing errors, is related to the learning of temporal parameter estimation. Together, these two measures provided new explanations regarding the role of practice schedules in the learning of skills[14]. Focusing only on the effects of the constant practice, the results of studies have shown that the trial-to-trial stability produced by the constant practice impact more on the learning of the relative timing dimension of the task than the absolute dimension[13,15,16]. In other words, constant practice promotes the learning of a structure of movement, but does not favor the enhancement of parameter estimation in a transfer context.

Usually, these studies[13-16] applied transfer tests with a new absolute timing criterion far outside of the range practiced by constant group. As an example, the constant practice group practiced with an absolute timing criterion of 900ms, while random practice group practiced three absolute timing criteria (700, 900 and 1.100ms), and these groups were tested in a new absolute criterion timing of 1.300ms. The distance of the parameter scaling between the parameters experienced during constant practice and the parameter required in the transfer is higher than the distance required to the variable practice group. This methodological characteristic disrupts the intricate relationship between the type of processing experienced during the acquisition phase and the type of processing required in the transfer test (Fig. 1). The type of processing involved during constant practice should to facilitate the effective transfer only to a close new criterion. According to the "transfer-appropriate processing" view[23], transfer performance should be maximized when the type of processing used during practice is similar to that which is used during the transfer test. Moreover, recent studies have shown that neural activation observed in transfer of learning is associated with the brain activation verified in late stage of acquisition[24,25]. Transfer seems to be a form of accelerated learning, with brain activation that overlaps with that observed in late learning[24]. If the transfer requirements are different from that processed in the final part of acquisition, this overlap of brain processes cannot occur effectively. Together, the "transfer-appropriate processing" view and the findings concerning neural correlates in motor learning support our assumption that transfer tests with a new absolute timing value distant from that practiced, disrupt the complex cerebral processes experienced by the learner during the constant practice in the acquisition.

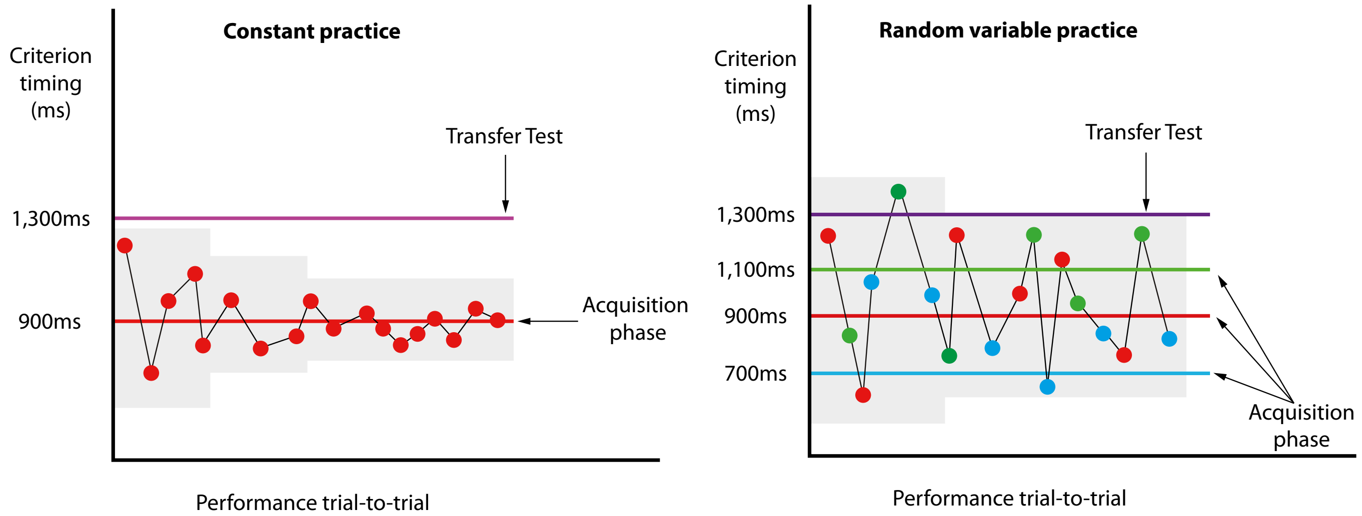

Figure 1. Constant practice requires different type of processing compared to random practice. Little temporal adjustment based on the error of the last trial occurs only in constant practice. The parameterization during the acquisition phase tends to became closer of the absolute timing criterion (900ms) and distant of the value required in the transfer test (1.300ms). The diminishing of grey range on figure exemplifies it. On the other hand, variable practice requires an ample range of parameterization during all acquisition and induces higher levels of error than constant practice does. The grey range is more ample than in constant practice and does not present significant narrowing.

Another factor that seems to influence the quality of the transfer of constant practice is the amount of practice. When the transfer test consists of performing a task with the same relative timing structure (same GMP) practiced in the acquisition phase, but with a new value of absolute timing, a lower amount of constant practice produces less relative timing errors than a higher amount of constant practice (Giuffrida, Shea, Fairbrother[13], see post-test 2). On the other hand, Giuffrida, Shea, Fairbrother[13] did not find an amount of practice effect on absolute timing errors. Using the schema theory concept[1], the amount of practice affected the GMP, but not the parameterization. A possible explanation for this interaction between the amount of practice and constant practice is that the relative and absolute dimensions were consolidated, in the course of acquisition, into a single unit that was unavailable for updating[13]. Studies using new paradigms of investigation have also shown that transfer depends on type and amount of practice experienced[26,27]. For instance, over-fitting of a neural representation may be observed when a task is extensively practiced. Over-fitting affects the manner in which memory is encoded and consolidated decreasing transfer capability[28].

In summary, two different aspects involved in studies that used constant practice seems to interfere in the quality of transfer. Namely, (1) the distance of the parameter scaling between the parameters experienced during constant practice and the parameter required in transfer and (2) the amount of practice experienced in acquisition. Thus, we investigated the effects of constant practice on motor learning and transfer conditions. The first experiment was conducted to replicate a well-investigated situation: a constant practice group tested with new absolute timing distant from that practiced. In the second experiment, we tested three constant practice groups on a distant and a close novel absolute timing task. Finally, a third experiment was conducted to investigate the relationship between the amount of constant practice and the quality of transfer.

We hypothesized that constant practice will be less effective in transfer than random variable practice in experiment 1. We tested the hypothesis that the type of processing involved during practice facilitates the effective transfer only to a close new parameter in experiment 2. Finally, we tested in experiment 3 the following hypotheses: (1) intermediate amounts of practice facilitate the transfer of the absolute dimension without interference from the relative dimension; (2) low amount of practice is insufficient for the learner to acquire a relative timing structure and improve performance to the parameterization; (3) high amount of practice consolidated, in the course of acquisition, the absolute and relative dimensions into a single unit interfering negatively in transfer.

Experiment 1

Method

This study was approved by the ethical committee of the university (ETIC 343/04). All volunteers were requested to read and sign an informed consent form before taking part in the research.

Participants

Twenty right-handed (10 men and 10 women) undergraduate students, ranging from 18 to 40 years old, participated in this experiment. Volunteers had no prior experience with the experimental task and self-reported right-handed.

Apparatus

A computer, color monitor, and keyboard were placed on a standard table in the lab room. A specific software program was developed to control the experimental task and to register the time between pressing the keys. Participants were asked to sit on a chair, face the computer monitor and adjust the keyboard's position to comfortably use the numeric keypad with their right hand. All responses were made on the numeric keypad.

Task

The participants were asked to sequentially press four keys (2, 8, 6, and 4) on the numeric keypad using the index finger of the right hand; this sequence was the same in all experimental phases. The relative criterion segment ratios and the total criterion movement time (MT) were presented on the computer screen before each trial. The relative criterion segment ratios in all experimental phases were 22.2% (key 2 to 8), 44.4% (key 8 to 6) and 33.3% (key 6 to 4). The absolute timing criterions were 900 ms for constant practice group and 700, 900, and 1.110 ms for the random group. After the completion of each trial, the knowledge of results (KR) was displayed on the screen. The KR included the relative criterion segment ratios of the total criterion time for each segment and the total movement, as well as the relative error (RE) of the sum of the criterion segment ratios.

Procedure

Detailed instructions were provided for each participant about the information displayed on the computer screen, and all subjects were asked to be as accurate as possible on both the relative and total movement criteria. Before each trial, the MT and the criterion segment ratios for the task appeared on the screen. After the movement sequence was completed, the KR was displayed for 6 seconds. If a participant depressed the keys in the wrong order, a warning was displayed, and the trial was repeated. The participants were randomly assigned to one of two practice groups: 1) constant or 2) random.

All participants performed 120 trials during the acquisition phase. The experiment consisted of three phases: acquisition, immediate transfer test (ITt) and delayed transfer test (DTt). The immediate transfer test was conducted 15 minutes after acquisition and the delayed transfer test was administered 24 hours later. In the transfer tests, all participants performed a 12-trial block on the novel and distant absolute timing criterion (1.300 ms) with the same relative criterion segment ratios (22.2%, 44.4%, and 33.3%). The KR was not provided in the transfer test.

Measurement

Two dependent variables were measured: 1) the relative timing error and 2) the absolute timing error. Relative timing error (*A*E prop) was used as a measure of proficiency of the relative timing structure (e.g., GMP), and the absolute timing error (*A*E) was used as a measure of proficiency under the new parameter. To determinate the *A*E prop, the sum of the absolute differences between the observed and criterion time ratios for each segment was computed as follows:

*A*E prop = I*R1 – 22.2*I + I*R2*– 44.4I + I*R3* – 33.3I, where *Rn* = (the actual movement time of segment / total movement time) X 100.

The *A*E was computed as the difference between the actual movement time and the total criterion time:

*A*E prop = (MT*n*–total criterion time).

In order to investigate the dynamics of adaptation during the transfer test, it was defined the *mean adaptation rate* (α_{bl}) in the course of a block of trials to the absolute dimension of the task. A linear model of the performance as a function of the trials was assumed, in which α_{bl} was defined as the slope of the model. Therefore, α_{bl} should be interpreted as a global tendency presented by the block of the analyzed trials, a quantification of the mean tendency of the behavior. The α_{bl} estimative was obtained by a linear regression fit using the function *linregress* of the Scipy package of Python[29].

Results of experiment 1

The data were organized into blocks of 12 trials. The acquisition phase was analyzed by a two-way repeated measures ANOVA (2 groups X 10 blocks) with repeated measures in the second factor. The data from the both the immediate and delayed transfer tests were analyzed by a two-way repeated measures ANOVA (2 groups x 2 blocks) with repeated measures on the last factor. All post-hoc analyses were with Duncan's new multiple range tests[30,31]. An alpha level of .05 was set for all statistical tests. Effect sizes were calculated by eta-squared (η^2). The adaptation rate in both immediate and delayed transfer tests was analyzed by a two-way repeated measures ANOVA (2 groups X 2 transfer tests). An analysis of motor responses dispersion in the absolute dimension was conducted in the first and last block of acquisition.

Relative Timing Error (AE prop)

Acquisition

The two groups improved their relative timing accuracy from the first to the last block of the acquisition phase (Fig. 2). The constant group had smaller relative timing errors than the random group. The analysis indicated a main effect of Practice Conditions, $F(1, 18) = 11.58$, $p < .01$, $\eta^2 = .39$, and Blocks, $F(9, 162) = 5.77$, $p < .001$, $\eta^2 = .24$. The relative errors were smaller for the constant group than for the random group. The analysis of Blocks indicated that more errors occurred on block 1 than any other block ($p < .001$). The interaction of Practice Condition X Block was not significant.

Transfer tests

The AE prop increased in the transfer tests primarily in the constant group (Fig. 2). The analysis indicated a main effect of Practice Conditions, $F(1, 18) = 6.12$, $p < .05$, $\eta^2 = .25$, and Tests $F(1, 18) = 4.48$, $p < .05$, $\eta^2 = .17$. The relative errors were smaller for the random group than for the constant group. The analysis on Blocks indicated that more errors occurred on block 1 than on block 2. The interaction of Practice Condition X Block was not significant.

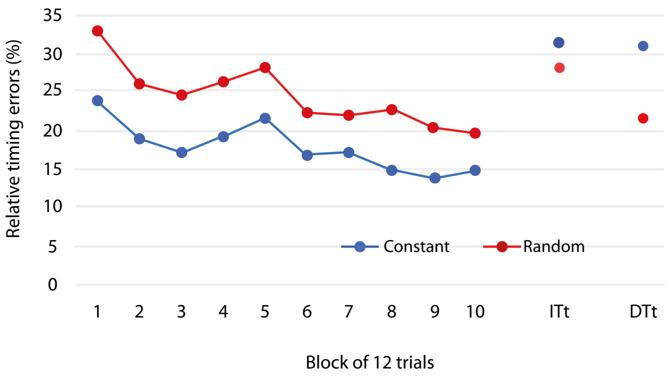

Figure 2. Relative timing errors (*A*E prop) in acquisition (blocks 1-10), immediate transfer test (ITt) and delayed transfer test (DTt).

Absolute Timing Error (AE) and Motor Response Dispersion

Acquisition

The analysis of performance dispersion in the first and the last block of acquisition shows that the parameterization during the acquisition phase tends to became closer of the absolute timing criterion (900ms) and distant of the value (1.300ms) required in the transfer test (Fig. 3). On the other hand, the variable practice requires an ample range of parameterization in both blocks of acquisition and the range narrowing of parameters is less accentuated than that of constant practice (Fig. 4).

The constant group demonstrated better accuracy of the parameterization compared to the random group in the acquisition phase (Fig. 5). The analysis indicated a main effect of Practice Conditions, $F(1, 18) = 16.49$, $p < .001$, $\eta^2 = .48$, and Blocks, $F(9, 162) = 5.70$, $p < .001$, $\eta^2 = .24$. The constant group was more accurate than the random group. The first block of the acquisition was less accurate than all other blocks ($p < .01$). There were no other significant results.

Transfer tests

The random group displayed better accuracy than the constant group in both the immediate and delayed transfer tests (Fig. 5). The statistical analysis indicated a main effect of Practice condition, $F(1, 18) = 5.13$, $p < .05$, $\eta^2 = .22$, with the random group being more accurate than the constant group. There were no other significant results.

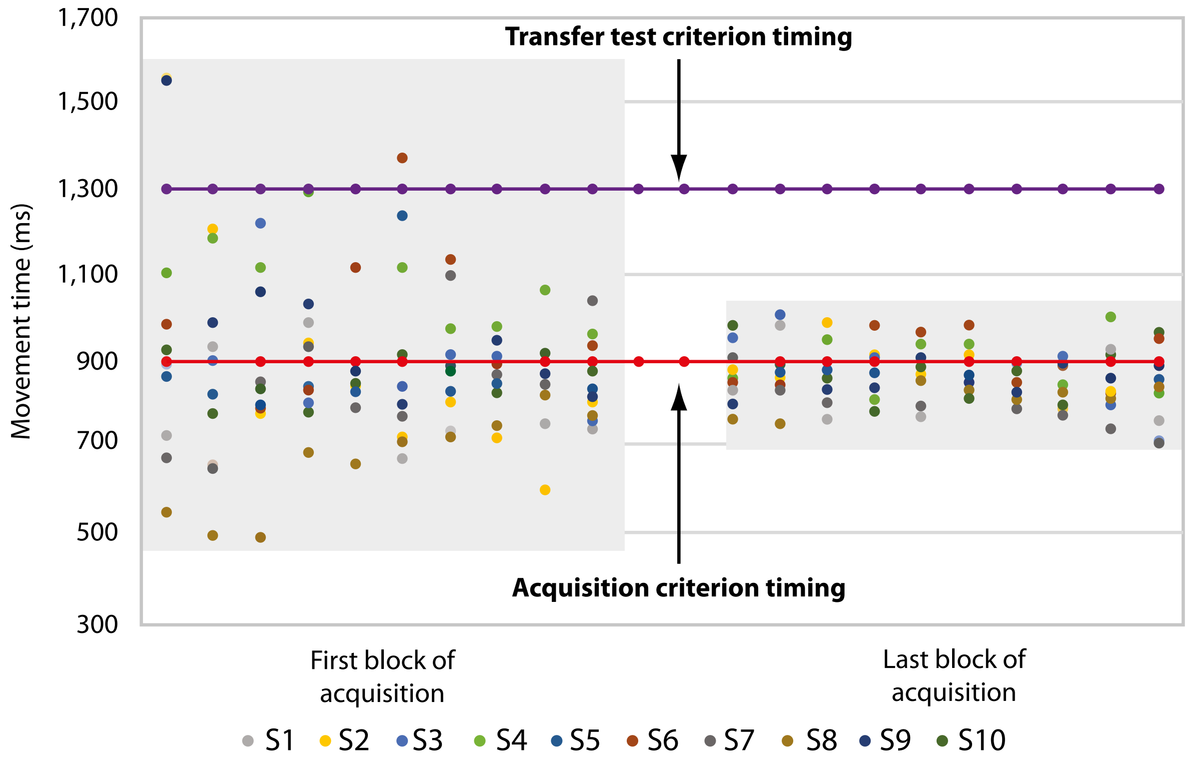

Figure 3. Motor response dispersion in the first and the last block of acquisition during the constant practice.

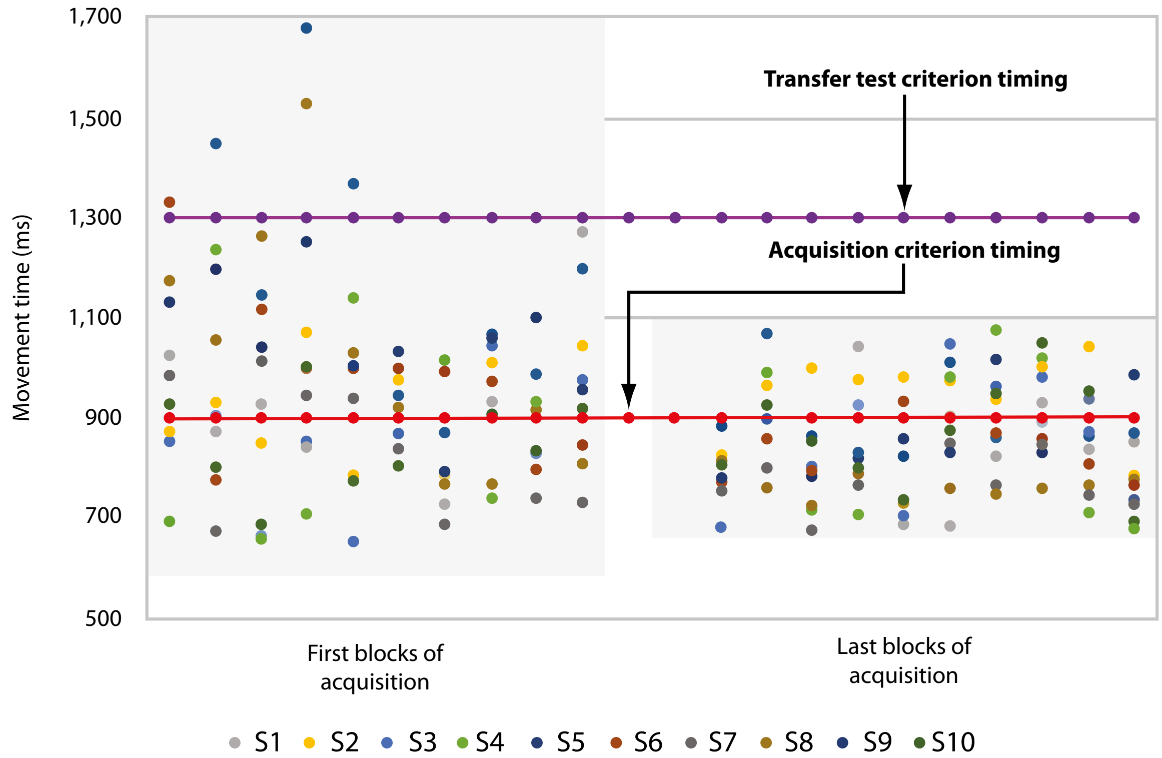

Figure 4. Motor response dispersion in the first and the last block of acquisition during the random practice.

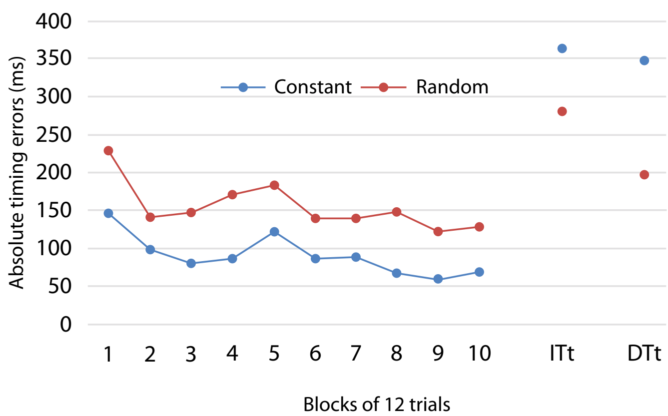

Figure 5. Absolute timing errors (*A*E) in acquisition (blocks 1–10), immediate transfer test (ITt) and delayed transfer test (DTt).

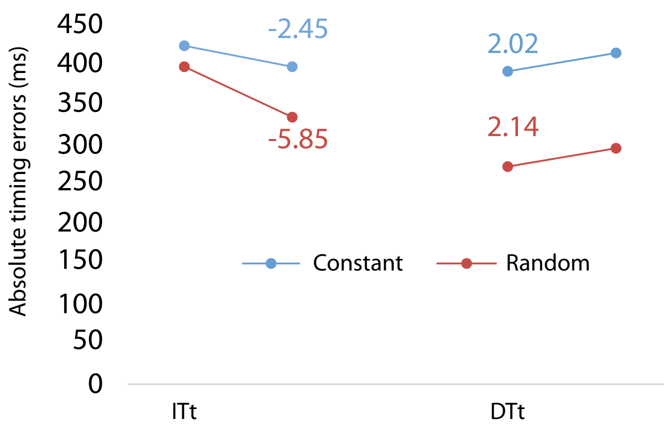

Figure 6. Adaptation rates and regression slopes in relative and absolute timing measures in both immediate (ITt) and delayed transfer (DTt).

Adaptation Rate in Transfer Tests

A descriptive analysis of the rate of adaptation indicates a higher level in immediate transfer test than that in the delayed transfer test. Moreover, while the slope of adaptation rate points to a diminishing of errors in the immediate transfer test, it is observed an increasing of errors in the delayed transfer test. The random group presented a higher adaptation rate in the absolute dimension, mainly in the immediate transfer test, than in the constant group (Fig. 6). The inferential analysis of adaptation rate in the absolute timing error indicated also a main effect of the moment of transfer tests, $F(1, 18) = 6.08$, $p < .05$, $\eta^2 = .25$. The absolute adaptation rate of the immediate transfer test (12.54) was higher than that in the delayed transfer test (6.78). There were no other significant results.

Discussion of experiment 1

The aim of experiment 1 was to investigate the effects of constant practice in a transfer condition with distant and novel time criteria. The experimental design used a typical comparison observed in the literature: a constant versus a random group (e.g., Lage, Vieira, Palhares, Ugrinowitsch, Benda[5], Lai, Shea[15]). As expected, the constant practice group, compared to the random practice group, performed better, indicated by fewer absolute timing errors during the acquisition phase. However, the constant practice group performed less well than the random practice group in the transfer tests. The characteristics of the processing experienced by the subjects in constant group did not favor an effective transfer to a new distant criterion. When comparing the parameters dispersion in the acquisition, it is possible to observe that random practice produces a larger range than that of constant practice. This type of behavior seems to facilitate parametrization of a new timing criterion.

Some studies have shown an effective role of constant practice in maintaining the learned movement structure in transfer tests[15,16,31]. However, we found, similar to the finding of Giuffrida, Shea, Fairbrother[13] in their post-test 2, a worse performance on absolute timing errors for the constant group. A possible explanation for these results was offered by Giuffrida Shea, Fairbrother[13] (p.363), "...in the constant practice schedule condition, the GMP and parameters were consolidated into a single unit that was unavailable for updating."

Another possible explanation (or, perhaps, a complementary explanation) is that constant group participants paid more attention to the relative timing dimension while learning the structure of movement during the acquisition phase. This may have occurred due to the low attentional demand required in the absolute dimension of the task because there was no change in the parameter value and there was no need for expressive adjustments between trials. When the participants were challenged by a novel parameter specification, the relative dimension of the skill was negatively affected because the type of processing experienced during practice was not the same as the type of processing reIn the immediate transfer test, a descriptive analysis shows that the lower adaptation rate of constant group seems to support the proposition that the processing experienced by the subjects in constant group did not favor an effective transfer to a new distant criterion. In contrast, the random group presented a higher adaptation rate diminishing error from the first to the last trial of the immediate transfer test. In this sequential task performed without KR in the transfer tests, the speed of adaptation informs us how the motor system is dealing with predictions during the planning of the next movement. This rate depends on the uncertainty of the motor system's own state[32]. While random group seems to exploit parameters values to each next trial, the constant group has a less dynamic form of parameter prediction. The type of processing experienced during random practice is similar to the processing required on the transfer test.

The adaptation rate of groups decreased significantly from the immediate to the delayed transfer test. It seems that offline learning and memory stabilization, processes involved in skill consolidation[33,34,35], reduce the uncertainty of the motor system, as consequence, decreasing the necessity of an exploratory prediction of parameters values. Further research needs to be carried out to analyze the effect of skill consolidation in the adaptation rate of groups between similar transfer tests.

Experiment 2

Method

Participants

Thirty right-handed (15 men and 15 women) undergraduate students, ranging from 18 to 40 years old, participated in this experiment. Volunteers had no prior experience with the experimental task and were requested to read and sign an informed consent form before taking part in the experiment.

Apparatus

The apparatus used was identical to that in experiment 1.

Task

The task was similar to that of experiment 1, but the constant practice groups were given three different MT criteria (700, 900, and 1.110 ms).

Procedure

The procedures were similar to those of experiment 1. However, there was a difference in the number of constant groups. Participants were randomly assigned to one of three practice groups: (1) constant 700 ms, (2) constant 900 ms, or (3) constant 1.100 ms.

A second difference was the number of transfer tests. The transfer tests were conducted 24 hours after the acquisition period. All participants performed a 12-trial block on two new MT criteria, as well as a 12-trial block on the same MT criterion practiced during acquisition. Thus, the 700 and 1.100 ms groups were required to perform a close and a distant MT criterion test. For instance, subjects of the constant 700 ms group performed both a close 900 ms and a distant 1.100 ms transfer test. Moreover, these subjects also completed a retention test (700 ms). The constant 900 ms group was required to complete two transfer tests at the same distance of the parameter scaling, but with a slower (1.100 ms) and a faster (700 ms) MT than that practiced in the acquisition. The same relative criterion segment ratios (22.2%, 44.4%, and 33.3%) were required for all tests. An interval of 5 minutes was given to the participants between the tests and the order of tests was counter balanced across participants and groups. The KR was not provided in the transfer tests.

Measurement

The measurements were identical to those of experiment 1. We evaluated the adaptation rate to measure absolute timing error, in each transfer test.

Results of experiment 2

The analyses were similar to those of experiment 1. The acquisition phase was analyzed by a two-way repeated measures ANOVA (3 groups X 10 blocks). We compared the first and last blocks of the acquisition. The data from the transfer tests was analyzed by a one-way ANOVA (3 groups x 1 block). The adaptation rate in both immediate and delayed transfer tests was analyzed by a two-way repeated measures ANOVA (3 groups X 3 transfer tests).

Relative Timing Error (AE prop)

Acquisition

All groups improved their relative timing accuracy from the first to the last block of the acquisition phase (Fig. 7). The analysis indicated a main effect of Practice Conditions, $F(2, 27) = 7.60$, $p < .01$, $\eta^2 = .36$; and Blocks, $F(9, 243) = 3.74$, $p < .001$, $\eta^2 = .12$. The relative errors were smaller in the constant 900 ms group than in the 700ms ($p < .001$) and 1.100 ms groups ($p < .05$). A marginal difference was found between the constant 700ms and 1.100 ms groups ($p = .06$). The analysis on Blocks indicated that more errors occurred on block 1 than the 4, 5, 6, 7, 8, 9, and 10 blocks ($p < .01$). The interaction of Practice Condition X Block was not significant.

Transfer tests

As the parameter scaling distance increased in transfer, *A*E prop also increased in both the constant 700 ms and the constant 1.100 ms groups (Fig. 7). The analysis showed a significant interaction between Practice Condition X Blocks, $F(4, 54) = 4.34$, $p < .001$, $\eta^2 = .24$. The main results of the inter-group analysis were:(a) the constant 700 ms group had smaller relative errors than the constant 1.100 group ($p < .05$) in the 700 ms learning test, and (b) the constant 1.100 and 900 ms groups exhibited smaller relative errors than the constant 700 ms group ($p < .01$). The main results in the intra-group analysis were: (a) the constant 700 ms group had higher relative errors from the 700 ms to the 1.100 ms test ($p < .01$), and (b) the constant 1.100 ms group had higher relative errors from the 1.100 ms to the 700 ms test ($p < .05$). There were no significant main effects of Practice Condition or Blocks.

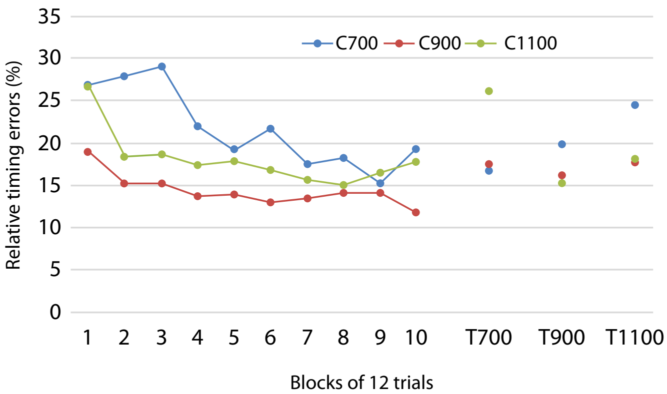

Figure 7. Relative timing errors (*A*E prop) in acquisition (blocks 1-10), Constant 700 ms test (T700), Constant 900 ms test (T900) and Constant 1.100 ms test (T1100).

Absolute Timing Error (AE)

Acquisition

The constant 900 ms and the constant 700 ms groups had better accuracy in the novel parameters compared to the constant 1.100 ms group (Fig. 8). The analysis found a main effect of Blocks, $F(9, 243) = 3.15$, $p < .001$, $\eta^2 = .11$. The first block of the acquisition was less accurate than the other blocks ($p < .05$). There were no other significant results.

Transfer tests

As the distance of the parameter scaling increased in transfer, *A*E also increased for both the constant 700 ms and the constant 1.100 ms groups (Fig. 8). However, statistical analysis indicated only a main effect of Tests, $F(2, 54) = 7.06$, $p < .01$, $\eta^2 = .21$. Block 3 (1.100 ms) contained a higher level of absolute errors than blocks 1 and 2 ($p < .01$). There were no other significant results.

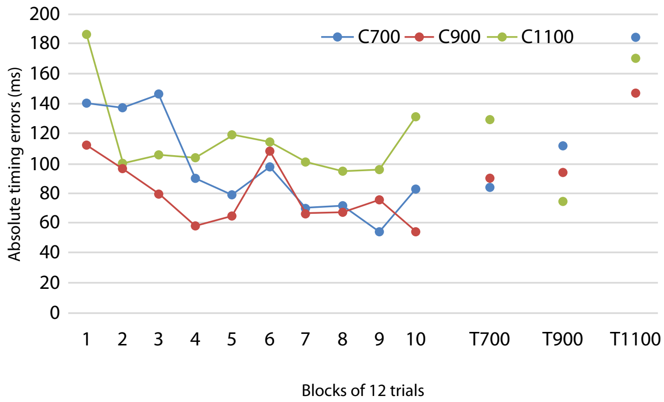

Figure 8. Absolute timing errors (*A*E) in acquisition (blocks 1-10), Constant 700 ms test (T700), Constant 900 ms test (T900) and Constant 1.100 ms test (T1100).

Adaptation Rate in Transfer Tests

A descriptive analysis of the adaptation rate indicates a higher adaptation rate to the G1100 in the distant transfer (T700) compared to the other groups. However, the adaptation was in the direction of increasing errors. The same was not observed when compared the G700 in the distant transfer (T1100). The slope of adaptation rate of the G1100 points to increasing errors in the distant transfer (Fig. 9). The analysis of absolute timing error indicated a main effect of tests, $F(2, 54) = 4{,}90$, $p < .05$, $\eta^2 = .15$. The adaptation rate of T700 (5.34) was higher than T900 (4.52) and T1100 (2.48). There were no other significant results.

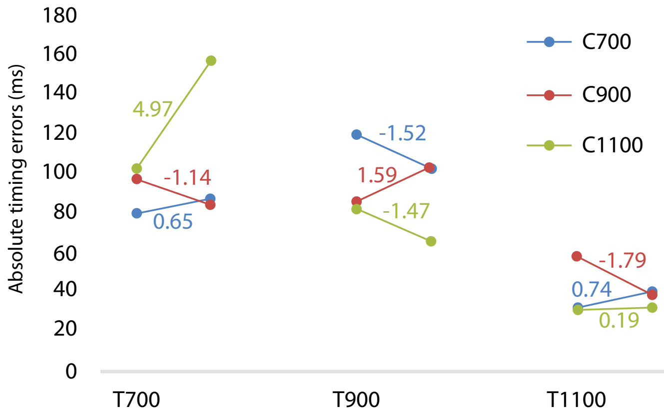

Figure 9. Adaptation rates and regression slopes in relative and absolute timing measures in Constant 700 ms test (T700), Constant 900 ms test (T900) and Constant 1.100 ms test (T1100).

Discussion of experiment 2

In experiment 2, we tested three constant groups in both distant and close criteria times. The results partially confirm our hypothesis that the effective transfer would be achieved only on the close parameter value. This was because the level of transfer in the absolute dimension of the task was identical among groups and of the parameter scaling distances. The level of error was higher in the 1.100 ms transfer test than those of the other tests. This result confirms a well-known motor control phenomenon in which response timing is more accurate in fast movements[36]. The analysis of the adaptation rate revealed a higher level of adaptation in the 700 ms transfer test. A faster test imposes more uncertainty to the motor system. In a descriptive analysis, it is possible to observe that G1100 suffered more to perform in the 700 ms transfer test. It happens because G1100 presented the highest adaptation rate, but in the direction of increasing errors.

The main findings about transfer were related to the relative timing errors. We observed participants' inability to preserve the relative timing structure when the parameter scaling distance increased in transfer. Together, the results of experiment 1 and 2 strengthen the proposition of transfer-appropriate processing[23] and transfer of learning associated with the brain activation verified in late stage of acquisition[25]. The features of the brain activation strengthen the evidences of retrieval of an internal representation, which representing the newly acquired sensorimotor mapping[24]. Distant transfers disrupt the intricate relationship between the type of processing used by the learner and the context in which he or she is tested. However, the relative timing dimension was preserved in the close parameter value. Again, it is possible that participants paid more attention to the relative than the absolute dimension of the task during the acquisition. The relationship between transfer-appropriate processing and attentional focus on the relative dimension seems to facilitate the maintenance of the movement structure in a close transfer.

The results of experiment 2 replicated the results of Giuffrida, Shea, Fairbrother[13]. The constant group was unable to maintain the relative timing structure when a new parameter value was required in a distant transfer. These results are contradictory to those of Lai, Shea, Wulf, Wright[16] in which the constant groups performed better on the novel timing structure in the transfer test compared to the variable groups. Thus, the conclusions of these experiments are controversial.

Experiment 3

Method

Participants

Thirty right-handed (15 men and 15 women) undergraduate students, ranging from 18 to 40 years old, participated in this experiment. Participants had no prior experience with the experimental task and were requested to read and sign an informed consent form before taking part in the experiment.

Apparatus

The apparatus used was identical to those of experiment 1.

Task

The task was identical to that of experiment 1.

Procedure

The procedures were similar to those of experiment 1; the difference was in the number of constant groups. Participants were randomly assigned to one of three practice groups: (1) a low practice-constant group that performed 40 trials during acquisition, (2) a medium practice-constant group that performed 80 trials during acquisition, and (3) a high practice-constant group that performed 120 trials during acquisition.

The transfer test (Tt) was administered 24 hours after the end of the acquisition phase, and all participants performed a 12-trial block on a new distant MT criterion (1.300 ms) with the same relative criterion segment ratios (22.2%, 44.4%, and 33.3%). The KR was not provided in the transfer tests.

Measurement

The measurements were identical to those of experiment 1.

Results of experiment 3

The analyses were similar to those of experiment 1. The acquisition phase was analyzed by a two-way repeated measures ANOVA (3 groups X 2 blocks) with repeated measures in the second factor. We compared the first and the last blocks of the acquisition. The data of the last block of both the acquisition and transfer test were analyzed by a two-way repeated measures ANOVA (3 groups x 2 block) with repeated measures in the second factor. We chose to use this analysis to assess consistency across the different levels of practice during the acquisition phase and the transfer test. The adaptation rate in the last block of acquisition and transfer test was analyzed by a two-way repeated measures ANOVA (3 groups X 2 blocks).

Relative Timing Error (AE prop)

Acquisition

The medium and high practice-constant groups stabilized at approximately 15% of *A*E prop on block6, but the low practice-constant group did not have a sufficient amount of practice to achieve the same performance (Fig. 10). The analysis indicated a main effect of Blocks, $F(1, 27) = 38.34$, $p < .001$, $\eta^2=.59$. The errors were larger in the first block than in the last block in the acquisition phase. There were no other significant results.

Last block of the acquisition and transfer test

The high practice-constant group finished the acquisition with a smaller *A*E prop than the medium practice-constant group, but the group performances were inverted in the transfer test (Fig. 10). The analysis showed a main effect of Practice Conditions, $F(2, 27) = 3.32$, $p < .05$, $\eta^2=.20$, and Blocks, $F(1, 27) = 38.07$, $p < .001$, $\eta^2=.59$. The low practice-constant group was less accurate than the other groups ($p < .01$). The high practice-constant group tended to be less accurate than the medium practice-constant group (p = .06). More errors were present in the block of the transfer test than the last block of the acquisition. There were no other significant results.

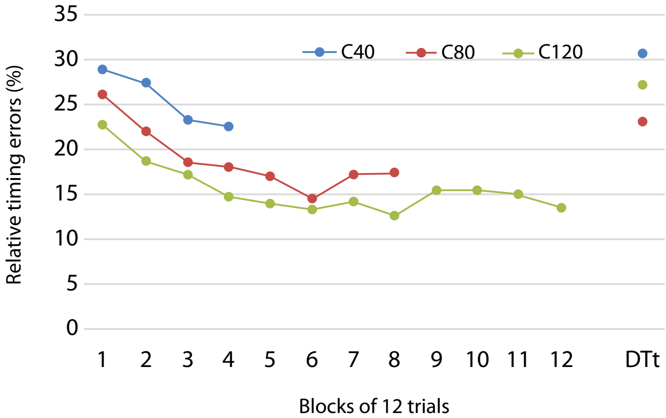

Figure 10. Relative timing errors (*A*E prop) in acquisition and transfer test (Tt).

Absolute Timing Error (AE)

Acquisition

The high practice-constant group finished the acquisition with smaller relative timing errors than the medium practice-constant group, but the group performances were inverted in the transfer test (Fig. 11). The analysis indicated a main effect of Blocks, $F(1, 27) = 37.502, p < .001, \eta^2=.58$. The errors were larger on the first block than on the last block of the acquisition. There were no other significant results.

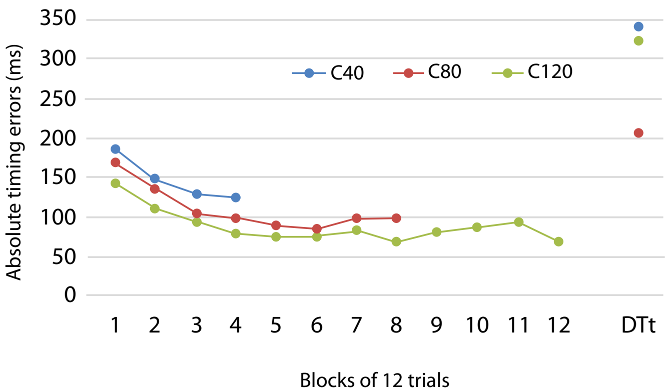

Figure 11. Absolute timing errors (*A*E) in acquisition and transfer test (Tt).

Last block of the acquisition and transfer test

The high practice-constant group finished the acquisition with less relative timing errors than the medium practice-constant group, but the group performances were inverted in the transfer test (Fig. 11). The analysis showed the main effects of Blocks, $F(1, 27) = 67.70, p < .001, \eta^2=.72$. More errors were present in the block of the transfer test than in the last block of the acquisition. There were no other significant results.

Adaptation Rate in Transfer Tests

A descriptive analysis of the adaptation rate in both independent measures indicates a higher adaptation rate to the C40 group in the last block of acquisition compared to the other groups. The C120 group also presented higher adaptation rate compared to the C80 group. In the transfer test, the C40 and C120 groups presented higher levels of adaptation rate compared to the C80 group (Fig. 12). The inferential analysis of adaptation rate in the absolute timing error indicated no significant results.

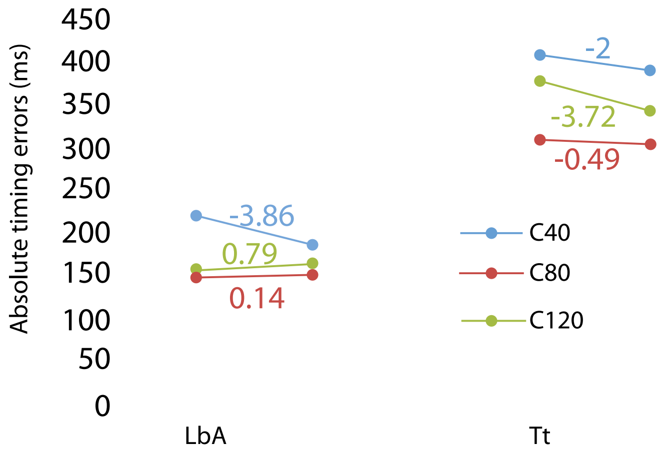

Figure 12. Adaptation rates and regression slopes in relative and absolute timing measures in last block of acquisition (LbA) and transfer test (Tt).

Discussion of experiment 3

In experiment 3, we investigated the interference of the amount of constant practice on transfer to a novel parameter. We hypothesized that an intermediate amount of practice favored the transfer of the absolute dimension without interference by the relative dimension. Our hypothesis was partially confirmed because the medium practice-constant group (a) had a better performance in the relative dimension of the task when compared to low practice-constant group, and (b) there was a tendency (p = .06) towards better performance in the same dimension when compared to the high practice-constant group.

There were no differences among groups on the transfer by the absolute dimension of the task. Similar result was found in the adaptation rate. Taken together, the results of relative and absolute relative timing permit the inference that the medium practice-constant group did not consolidate the relative and absolute dimensions into a single unit. Brain processes required in the intermediary stage of acquisition seem to be more associated with those of transfer of learning than the processes involved in low and high amount of constant practice. These processes may be related to error detection and correction, working memory and attention. The intermediate amount of practice allowed participants to perform at the same level in the novel parameter as the participants of the other groups and achieve better performance in the new relative dimension. These results are in accordance with the findings of Giuffrida, Shea, and Fairbrother[13].

Participants in the high and low practice-constant groups found it difficult to maintain the relative timing structure when they performed a novel variation of the skill. Nevertheless, it is possible that a different path was responsible for this difficulty in transfer. The low practice-constant group did not have sufficient practice to stabilize their performance, which prohibited a high quality transfer. In other words, adaptive and flexible modification of motor behavior seems not to be developed with low amount of practice. Brain regions which are more active during the early stages of learning would not be re-engaged at transfer[25]. In contrast, the high practice-constant group had enough practice, but to the extent that the relative and absolute dimensions were consolidated into a single unit that was unavailable for updating[13]. In other level of analysis, the mechanism underlying memory encoding and consolidation seems to affect the quality of transfer, over-fitting the neural representation[28]. As a result, the interaction between the constant condition and the high amount of practice generated a more stereotypical behavior that may be adequate for retention of the context practiced, but it is not satisfactory for transfer contexts.

General discussion

Overall, interesting and new results were found in the three experiments reported. The main findings about transfer and constant practice were that for processing involving only a timing criterion, few parameter adjustments influenced the quality of transfer. The findings of experiment 1 support the results of experiment 2. When observed the parameters dispersion in the acquisition, it is possible to observe that constant practice produces a narrow range of motor response dispersion. This type of behavior seems to undermine the parameterization of a new timing criterion. When the transfer was close to the temporal parameter value practiced, the relative timing structure was maintained, but the same was not true when a distant parameter value was tested. In terms of absolute dimension, we did not find differences in the groups' performances when the distance of the parameter scaling in transfers was compared. Moreover, the amount of practice affected only the relative dimension of the task. High and low amounts of constant practice seemed to engender less flexible behavior compared to an intermediate amount of constant practice. The common explanation to the all findings of the study is based on the distinct processes involved in acquisition and transfer.

The analyses of adaptation rate in all experiment did not show significant difference between groups. The constraint of producing a new absolute timing criterion without knowledge of results in the transfer test induces high level of uncertainty, as consequence, producing high intragroup variability. In studies with learning of visuomotor rotations[37], the adaptation to a new rotation angle is experienced with availability of visual input increasing the certainty of motor system. The adaptation rate in the present study suffered effects of the moment in which the transfer test is applied. The adaptation rate of groups decreased significantly from the immediate to the delayed transfer test. Skill consolidation seems to reduce the uncertainty of the motor system decreasing exploratory prediction of parameters values. Another result was that fastest transfer test produced higher level of adaptation.

While a number of studies have observed that a constant group preserves the relative timing structure when a new parameter value is required in transfer conditions[15,16,21], one study found that the constant group could not maintain the relative timing structure[13] . A possible explanation to these discrepant results may be in the way the relative timing goals and feedback were presented. While Lai and Shea[15], Lai, Shea, Wulf, Wright[16] and Shea, LaiWright, Immink, Black[21] provided segment goals expressed as ratios of the total time (e.g., 22.2%, 44.4%, 33.3%), as well as feedback related to the total time (absolute error) and segment ratios (*AE* prop), Giuffrida, Shea, Fairbrother[13] gave feedback related to the movement time in each segment. Shea, Lai, Wright, Immink, Black[21] found that the type of goal and feedback information influenced the relative timing structure in transfers for the variable practice groups. However, further research needs to be carried out to analyze this interaction in constant practice groups. We provided segment goals expressed as ratios of the total time and feedback related to the total time (absolute error) and segment ratios (*AE* prop), yet had similar results to those found by Giuffrida Shea, Fairbrother[13]. Therefore, future studies should investigate the relationship between the type of information provided and the maintenance of relative structure on transfer in.

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