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THE CONTEXTUAL INTERFERENCE EFFECT ON SPORT-SPECIFIC MOTOR LEARNING IN OLDER ADULTS

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ABSTRACT
Purpose. The aim of this study was to investigate the contextual interference effect on learning a sport-related task in older adults. **Methods.** We selected 40 physically active individuals aged 65–80 years that were randomly divided into random and blocked practice groups. The task comprised throwing a bocce ball to three targets at distances of 2, 4 and 6 m. Practice consisted of 120 trials divided into two sessions. Two retention tests at a distance of 4 m were conducted (post-10 min and 24 h) and then two transfer tests with a target at 5 m (post-24 h) were performed with the preferred and non-preferred hand. Task performance and movement patterns were measured. **Results.** Comparisons between the practice groups revealed no contextual interference effect ($p > 0.05$); the random group showed improved performance during practice ($p < 0.05$) but the blocked group did not. Overall, the results showed similar performance between the groups in the retention and transfer tests, although it was inferred that the blocked group made insufficient corrective adjustments. **Conclusions.** It was concluded that contextual interference did not affect the learning of a sport-based skill in older adults. Nonetheless, it can be argued that the parameter modifications may have negatively influenced learning this task by the practice groups and/or they may have required more practice time.

Key words: Contextual interference, practice schedule, bocce, motor learning, older adults

Introduction

In the process of learning a given task, practice is both crucial and time consuming. In the last few decades, investigation of practice schedules in motor learning has been based on studies analysing verbal learning via modification within the context of practice [1]. The main assumption is that making learning seemingly more difficult would facilitate, rather than harm, the learning process in retention and transfer tests [1–3].

Studies on this topic have been developed by manipulating the contextual interference effect. This refers to the interference of a given task with others as they are performed in the same practice block [1–3]. Random (ABCBCA) and blocked (AABBCC) practice schedules have been experimentally manipulated in order to promote high and low contextual interference, respectively. The foregoing proposition on contextual interference has been grounded in the hypotheses that random practice promotes better elaboration and distinction of memory representations [1, 2, 4] or an action plan strengthened by improved consecutive reconstruction [5].

In general, studies on the contextual interference effect have aimed to: assess the effects of parameters or generalised motor programme manipulations on different tasks [3]; test the time intervals between transfer and/or retention testing [6]; investigate the influence of practice schedules in learning tasks, such as by different practice modalities [7] or altered skill level/task difficulty [8]; establish whether experts can benefit from contextual interference effect in skill acquisition [9]; and, of special concern in this article, discover whether it is possible to transfer the effect from laboratory setting to more practical sport and physical education contexts [10–14].

While the aforementioned studies advanced the existing knowledge on this subject matter, they are limited in that they focused on the learning of young adults (e.g. college students). Only a few studies on contextual interference effects have examined its implication in the motor skill learning of older adults [11]. Although there is evidence that older adults can positively modify their behaviour by practice [15–17], the literature has focused on relatively simple and artificial tasks such as coincident timing [18], serial reaction times [19–21], and manual positioning [22] tasks. When an activity of daily living was used as a learning task, it involved performing banking transactions on a machine and did not relate to a discrete motor task [23]. Furthermore, the above results show little consistency, preventing clear conclusions from being drawn since contextual interference effects were only evident in the retention tests of two studies [20, 21].

We hypothesise that the type of task should be taken into account in order to demonstrate contextual interference effects in the learning of older adults. Such motor tasks should have an intrinsic meaning, enabling the learners' active involvement, in order to increase motivation and therefore performance [19]. Consequently, the manipulation of an appropriate task could lead older adult learners to reconstruct an action plan or to utilise

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multiple and elaborate processing strategies, thus enabling them to benefit from contextual interference effects. From this perspective, the game of bocce was considered a suitable alternative for use in studying the learning of older adults as it had been previously applied in a younger population [24]. In bocce, players must toss the bocce ball as close as possible to a "jack" to score a point for the team. Bocce is played throughout the world and, in Brazil, is a popular game for older adults. Therefore, we sought to investigate the contextual interference effect on older adults' learning of bocce.

Material and methods

Participants

Forty physically active older adults, both male (n = 20) and female (n = 20), aged from 65 to 80 years were recruited from community-based physical activity programs held at the School of Physical Education and Sport of the University of São Paulo. The participants were randomly assigned into two practice groups: blocked (M = 70.75 years) and random (M = 69.65 years). In each group, both sexes were equally represented and 19 participants were right-handed and one left-handed. For inclusion in the study, participants were required to be active for the last six months at a minimum, have no previous experience with the task, and to achieve a score higher than 25 on the Mini-Mental State Exam [25], in which the blocked group scored 29.4 (± 0.8) and random group scored 29.3 (± 0.84). Physical activity level was ascertained, finding that the participants attended PE teacher-led classes (e.g. fitness and swimming) at least twice a week. All participants gave informed consent and the study protocol received approval from the ethics committee of the University of São Paulo.

Apparatus and task

The throwing motion involved in bocce was used as the motor task to be learned, in where the participant would need to throw a bocce ball as near as possible to the centre of a target. The task was carried out in a controlled environment and required the participant to perform the action slowly and smoothly, minimizing the occurrence of injury or fatigue. For the bocce court, we used a carpet (9.5 m long × 4 m wide) that was adapted to the available space of the test room. Official bocce balls (950 g) and a computer for recording data were also used.

Design and procedures

The experimental design involved two acquisition sessions, 10 min retention (Rt1), 24 h retention (Rt2), and two transfer tests completed after Rt2, a "near" transfer test (Tr1 – executed with the participant's preferred hand) and a "far" transfer test (Tr2 – performed with the non-preferred hand). In the acquisition phase, both groups performed 20 trials of each distance in each session. The blocked group practiced 20 trials of each task consecutively, while the random group practiced no more than two trials consecutively of the same task. Before starting practice, participants watched a video of two experts performing the throw and received instructions about how the task should be performed. Participants observed the ball trajectory until it stopped rolling, which provided them with visual knowledge of results.

The test court included three targets for the acquisition and retention phases all aligned in the centre of the court and positioned after a delineated starting line. Each of these targets had seven concentric circles, each 20 cm larger in radius than the previous one. The first target was at 2 m distance from the starting line and painted blue (A), the second at 4 m and was yellow (B) and the third at 3 m and painted red (C) (Figure 1). For the retention tests, participants executed the task at distance B. For the transfer task, a new distance was included, where the target was placed at 5 m and painted white (D). Participants performed 120 acquisition trials equally divided into two sessions (separated by 48 h rest). Ten trials were performed in the each of the tests.

The movement pattern was video recorded in order to assay kinematic parameters. The camera (EXILIM-HS100, Casio, Japan) was positioned on a tripod and filmed at 120 Hz and a resolution of 640 × 480. Video analysis software (Tracker ver. 4.8x, Douglas Brown) allowed for the identification of the most central point of the bocce ball, held in the participant's hand, and automatically traced the ball's path. To eliminate any image distortions during the analysis, a perspective filter included in the software was applied before analysis. The starting point of each movement was treated as the rearmost position to which the participant moved the bocce ball, that is, the starting point of the forward swing. The end of the path corresponded to the tenth frame after the release of the ball by the participant.

Kinematic data were based on time (t) and planar position, i.e. movement in the anteroposterior (x) and vertical (y) axes. A recursive low-pass fourth-order Butter-

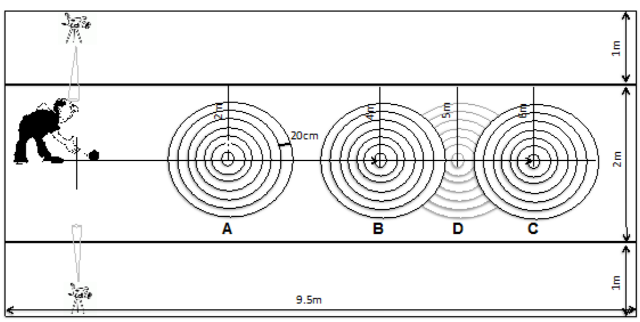


Figure 1. Schematic representation of the court, with the acquisition (A, B, C), retention (B) and transfer targets (D)

worth filter with a 10 Hz cut-off frequency was applied to reduce noise. The first order (speed) and second order (acceleration) derivatives between the position measurements for each frame were calculated using R software (R Foundation, [26]), in which the "signal" filter was applied for processing. The obtained kinematic measures comprised: a) ball amplitude in the forward swing (cm), as the variation of the space between the starting point of the forward swing and the moment the participant released the ball; b) average velocity of the ball during the forward swing (cm/s), acquired by the variation of space divided by the change in time; and c) average speed of the ball after release (cm/s), calculated from the instant of ball release and the next 10 frames as the variation of space and time.

Data analysis

In order to consider the contextual interference effect on the learning of older adults, data were analysed in relation to the task goal, movement pattern and ball displacement. Task goal measures involved calculating the magnitude and variability of the scores and execution error (ball falling out of target range) over 10 trials. The movement pattern measures comprised the amplitude, velocity and variability of the forward swing, which were calculated by the averages of amplitude and velocity and the coefficient of variation of the forward swing in blocks of 10 trials, respectively. Analysis of ball displacement involved the velocity of the ball after release, which was calculated as the average in blocks of 10 trials.

Excepting the execution error, we examined the interactions between the practice schedule (blocked and random) and blocks of trials (first and last acquisition block, retention 1 and 2, and transfer 1 and 2) using a 2 × 6 design ANOVA with repeated measures on the last factor. The significant effects were analysed post hoc using Tukey's honest significant difference test. The observed difference in the degrees of freedom reported in the *F* test results referred to missing data. For execution error, the Friedman test was used for intra-group analyses. The observed significant effects were examined using the Wilcoxon test. Inter-group comparisons were made using the Mann–Whitney U test.

All statistical analyses were preceded by the Shapiro–Wilk and Bartlett's tests to check for normality and homogeneity of variance. Data processing was performed using the Statistica 12.0 software package (StatSoft, USA) and the level of significance was set at $p < 0.05$.

Results

Task goal measures

Concerning the magnitude of performance as calculated as the sum of scores (Figure 2a), ANOVA revealed an interaction between practice schedules and blocks of trials, $F(5, 190) = 4.49$, $p < 0.01$, $\eta^2 = 0.11$. Post-hoc testing showed that the blocked group had a higher score than the random group in the first acquisition block ($p < 0.05$), and that the random group had a lower score in this first block of trials than in the remaining blocks ($p < 0.01$).

Regarding performance variability (Figure 2b), ANOVA (practice schedules × blocks of trials) also revealed an interaction, $F(5, 130) = 2.35$, $p < 0.05$, $\eta^2 = 0.08$. Post-hoc testing showed that the random group exhibited lower variability in Rt1 than in Rt2 and Tr2 ($p < 0.05$).

For execution error or the number of throws that fell out of the target range (Figure 2c), the Friedman test revealed effects in both the blocked group, $\chi^2(5, n = 20) = 11.65$, $p < 0.05$, and random group, $\chi^2(5, n = 20) = 35.68$, $p < 0.01$. The Wilcoxon test showed that the blocked group's execution error in the last acquisition block was lower than in the Rt1 and Rt2 blocks ($p < 0.05$). In the random group, error in the first acquisition block was higher than those of all the other blocks ($p < 0.05$), and that the last acquisition block had a lower execution error than in Rt2 and Tr2 ($p < 0.05$).

Concerning intergroup comparisons, the Mann–Whitney U test revealed a difference between the random and blocked practice groups only in the first acquisition block ($Z_{adjusted} = –2.60$, $p < 0.05$). In this case, the blocked group had a lower error execution error than the random group.

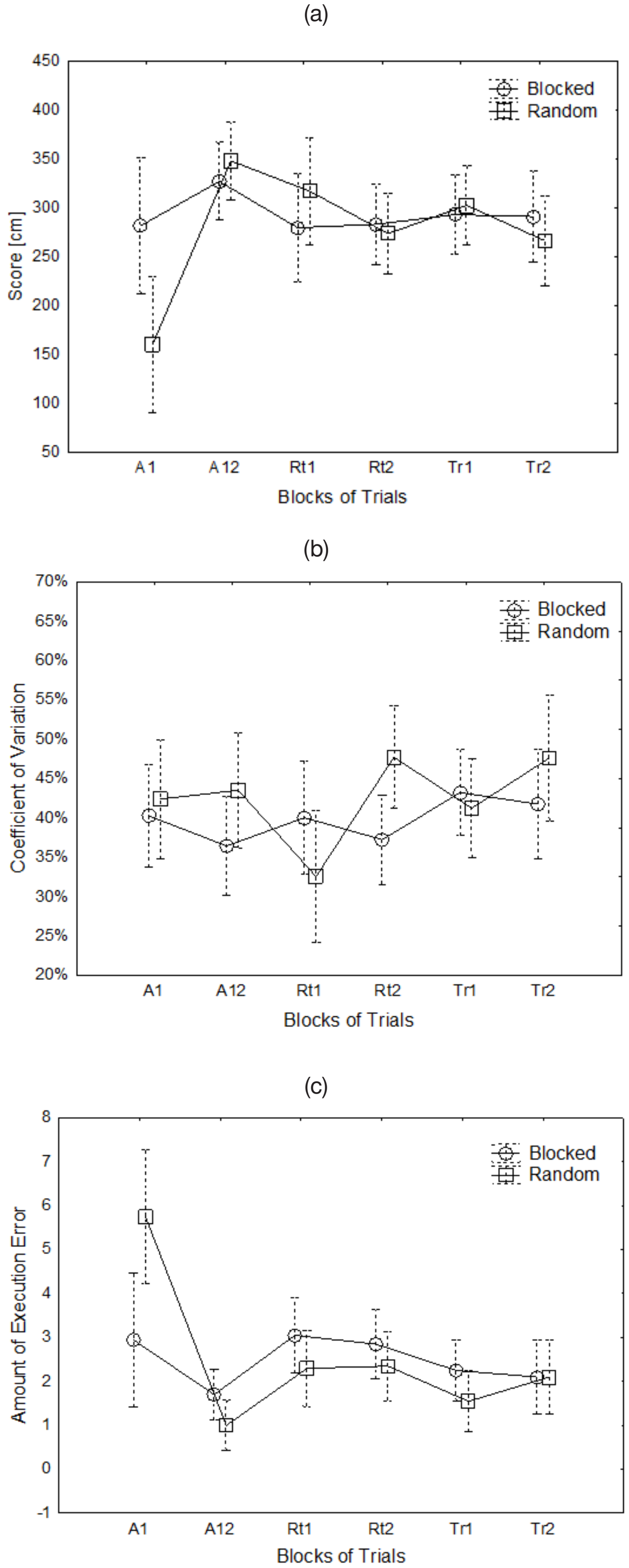
To summarise, these results show that the blocked practice group had better performance at the outset, as was expected, but did not improve over practice, whereas the random group showed improved performance from the beginning to the end of the acquisition phase and maintained performance in subsequent testing. In other words, while the random practice group demonstrated learning, the improvement achieved by this group was at a level similar to the blocked group.

Movement pattern measures

Concerning forward swing amplitude (Figure 3a), ANOVA (practice schedule × blocks of trials) revealed an interaction, $F(5, 185) = 2.35$, $p < 0.05$, $\eta^2 = 0.10$. Post-hoc testing showed that the amplitude of the forward swing from the first to last acquisition block increased in the blocked group ($p < 0.05$).

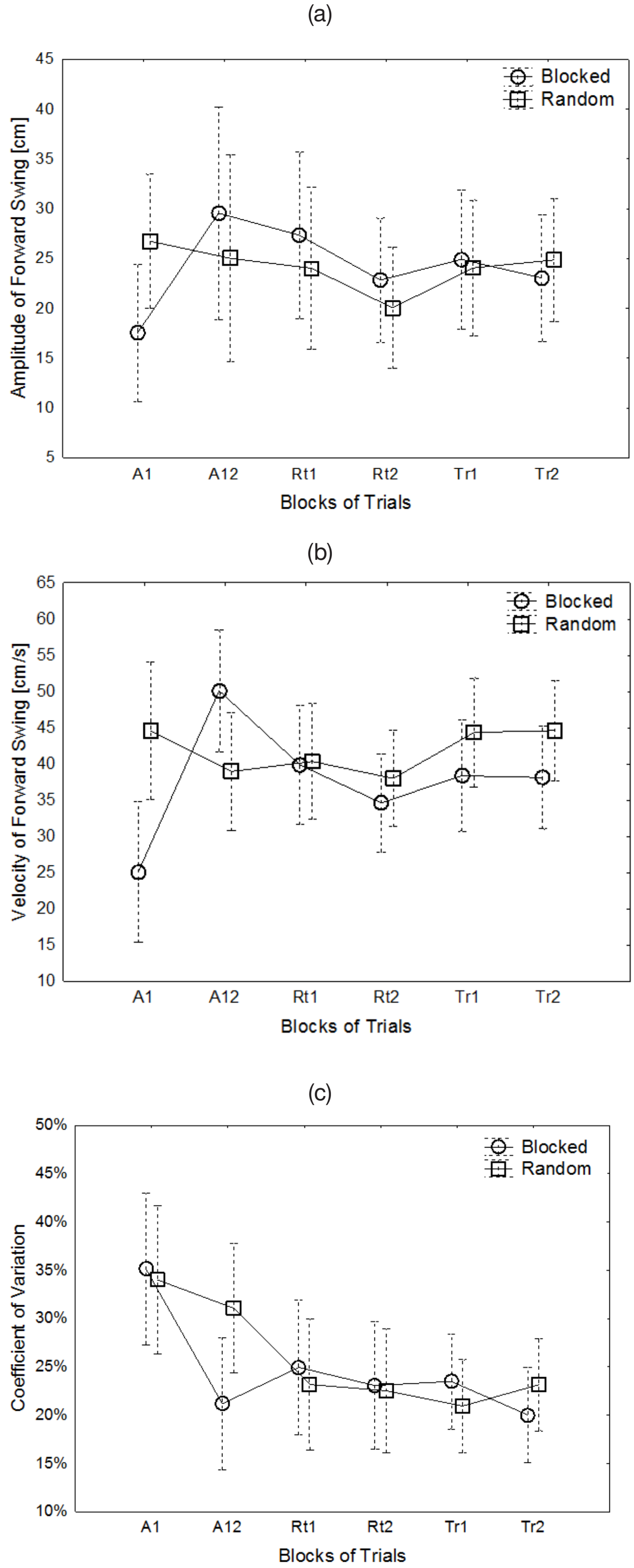
For forward swing velocity (Figure 3b), ANOVA (practice schedule × blocks of trials) also revealed an interaction, $F(5, 185) = 7.65$, $p < 0.01$, $\eta^2 = 0.17$. Excluding Rt2, post-hoc testing showed that forward swing velocity increased from the first to the remaining blocks in the blocked group ($p < 0.05$). Velocity was diminished from the last acquisition block to Rt2 and Tr2 ($p < 0.05$).

Regarding forward swing variability (Figure 3c), ANOVA (practice schedule × blocks of trials) revealed an effect only in the blocks of trials, $F(5, 185) = 6.71$, $p < 0.01$, $\eta^2 = 0.15$, where post-hoc testing indicated that



A1, A12 – first and last acquisition blocks; Rt1, Rt2 – first and second blocks of the retention test; Tr1, Tr2 – first and second blocks of the transfer test

Figure 2. Magnitude of performance (a), coefficient of variation (b) and amount of execution error (c)



A1, A12 – first and last acquisition blocks; Rt1, Rt2 – first and second blocks of the retention test; Tr1, Tr2 – first and second blocks of the transfer test

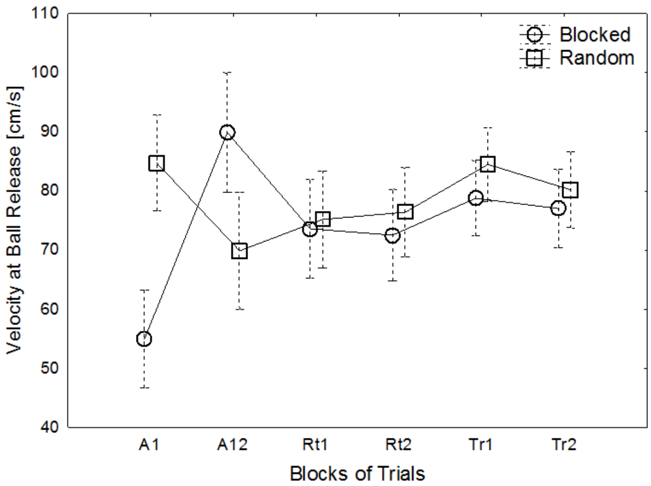
Figure 3. Amplitude of forward swing (a), velocity of forward swing (b) and the coefficient of variation (c) of the forward swing

the variability in the first acquisition block was higher than in all the other blocks ($p < 0.01$).

Ball displacement measures

Concerning velocity at ball release (Figure 4), ANOVA (practice schedule × blocks of trials) revealed an interaction, $F(5, 185) = 18.53$, $p < 0.01$, $\eta^2 = 0.33$, in which post-hoc testing showed that the blocked group showed increased velocity at ball release from the first to remaining blocks ($p < 0.05$). Velocity diminished from the last acquisition block to Rt1, Rt2 and Tr2 ($p < 0.05$). In the random group, post-hoc analysis also showed that the average velocity at ball release in the first acquisition block was superior to that in the last block ($p < 0.05$), although this block had a velocity inferior to that in Tr1 ($p < 0.05$).

In summarising the kinematics measures, the blocked group exhibited increased forward swing amplitude throughout practice and increased forward swing velocity during acquisition, but reduced velocity from the last acquisition block to Rt2 and Tr2 and increased velocity at ball release during practice, with a reduction from A2 to Rt1, Rt2 and Tr2. Meanwhile, in the random group, the velocity of this measure increased only in Tr1. Thereby, while the blocked group evidently introduced various adjustments, the random group maintained performance throughout the study duration.



A1, A12 – first and last acquisition blocks; Rt1, Rt2 – first and second blocks of the retention test; Tr1, Tr2 – first and second blocks of the transfer test

Figure 4. Velocity at ball release

Regarding the kinematic measures, it was observed that the random group maintained the same performance behaviour in the measures of amplitude, velocity and variability of the forward swing, whereas the blocked group showed changes in these kinematic measures after the last acquisition block, which were reinforced by an alteration of velocity at ball release. Therefore, the additional practice schedule variability (intra-task variability) had a positive effect on the random group's performance during acquisition, whilst in a more similar condition, the blocked group tried to introduce adjustments during the test phases although this was not enough to correct errors. These results are in contrast with other studies, where a random practice group was found to engage in compensatory strategies and show better performance than a blocked group in retention tests while, in later transfer tests, this effect was not observed [20, 21].

Many factors need to be taken into consideration regarding the contextual interference effect, as it is difficult to compare the findings of studies that differ in method and task [11, 13, 14, 27, 28]. It is possible that the motor and cognitive demands of the present task could have negatively influenced both of our groups in the retention and transfer tests [29, 30]. Or that such practice variation could have caused a perturbation in the learning process [3], considering that the participants were unable to introduce appropriate adjustments in order to change throwing distance. It can also be argued that an overload of information processing capacity made it impossible for the learners to improve test performance. Furthermore, while the random group showed improved performance in acquisition, performance in the subsequent tests demonstrated that the functional difficulty related to the task influenced the participant's retention and transfer results [28].

These findings indicate that it is still a challenge for researchers to find a balance between the necessary

Discussion

The aim of this study was to investigate the contextual interference effect in older adults learning a sport-based skill. This study differs from others on contextual interference effect as it focused on an elderly population and employed task goal and kinematic measures to evaluate produced movement patterns. It was expected that the contextual interference effect would be observed in a ball throwing task extracted from the game of bocce, in which we proposed that such a task would hold some intrinsic meaning, thereby enabling the learner's active involvement and increasing his or her motivation.

Based on our results, the contextual interference effect was not observed in the learning of this task. In terms of the score and the amount of errors in the acquisition phase, the random group improved its performance and reduced execution error, while the blocked group maintained the same performance level almost from the beginning to the end of practice, with increased execution error from the last acquisition block to the retention test blocks. The most interesting observation was that, after the last acquisition block, both groups showed similar performance in the retention and transfer tests for both measures. It should also be noted that when variability was analysed, no inter-group differences were found, although the random group showed increased variability in the total score after the first retention block.

and relevant points for learning a task via contextual interference effect where task difficulty is matched to the skills of the learner, an aspect that has been conceptualised as the "challenge point" [8]. For this reason, other strategies [3, 8] should be tested with older adults using sport-based tasks.

Conclusions

Contextual interference did not affect the learning of a sport-based skill in older adults. As the parameter modifications herein may have negatively influenced the practice groups in the bocce throwing task, future studies should investigate the learning of older adults by varying aspects of a generalised motor program over blocked and random practice schedules.

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