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Adaptability from Contextual Interference in the Learning of an Open Skill is Context Dependent

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Abstract: *Objective:* Evaluation of the contextual interference effect in an open skill under blocked and random contexts.

Methods: Twelve participants performed a striking movement requiring anticipation of coincidence for targets moving at different velocities. In acquisition they practiced the task under low (LO) or high (HI) contextual interference. Assessment of retention and transfer of learning were made in situations of blocked and random target velocities.

Results: Analysis was conducted on absolute temporal error. In transfer under random target velocities the HI group had lower temporal errors in comparison with the LO group, while no significant difference was detected in retention or transfer in the blocked context.

Conclusion: High contextual interference in the acquisition of an open skill led to improved adaptation to a random sequence of target velocities.

INTRODUCTION

In open motor skills movements must be controlled in a strict relationship with a changing environment. This is especially evident in a number of sport related skills, such as those involving intercepting/hitting a moving ball through striking movements with a racquet, a bat or directly with a body segment. In those skills, an essential aspect to be successful is the capability to transfer from previous experiences to the requirements imposed by the specific situation faced at the moment. In this regard, previous research has indicated that contextual interference generated by the schedule of variations of a motor skill may have a role [1-3]. Namely, when variability of practice is implemented in a random way (high contextual interference) adaptability to a transfer task is frequently superior to conditions in which variability is implemented in blocks of the same variant of the task (low contextual interference; see Magill & Hall [4] for a review).

Particularly in experimental situations using open tasks, like depressing a switch coincidentally with the arrival of a moving stimulus at an interception position, the results have generally supported the advantage of practice under high contextual interference for retention or adaptation [5-8]. These findings suggest that learning of open sport related skills should be made primarily under high intertrial variability. However, Hebert *et al*. [9] have shown contradictory results in a study assessing participants with different skill levels of proficiency. In that study, participants practiced forehand and backhand tennis groundstrokes under either blocked or alternating schedules. The results revealed that for low-skilled learners the blocked schedule was more advantageous than the alternating schedule, while no difference between practice conditions was observed for the high-skilled learners (see also Del Rey *et al.* [10]). Observations like those have led to the proposition that high contextual interference would benefit learning only in relatively simple motor skills, while more complex movements would benefit from a context of low interference during initial learning [11-13].

An aspect that has not been properly taken into consideration in the analysis of the contextual interference effect on learning open skills, however, is the context of assessment. As sport related open skills are performed in a context of high contextual interference, with different movement requirements being faced trial after trial, this situation should be reproduced in an appropriate assessment of adaptability. Support for this argument has been presented by previous findings of increased adaptability from high contextual interference in an open skill when assessment was made in a random but not in a blocked sequence of trials [14]. In order to further evaluate the issue of context of assessment of the contextual interference effect in open skills, we employed a multi-degree-of-freedom task, requiring a soft forehand drive movement, similar in structure to those performed in racquet sports. Variability in the task acquisition was produced by varying velocity of the target to be intercepted, and retention/adaptability was assessed in blocked versus random sequence of velocities.

MATERIALS AND METHODOLOGY

Participants

Ten male and two female university students, age range 18-20 years, participated in the study. All of them declared to be right-handers. Ethical approval for this study was granted by the Institutional Review Board.

Equipment and Task

The apparatus consisted of a horizontal 2-m-long electronic trackway, holding a continuous series of 1-cm-diameter light emitting diodes (LEDs), arranged in a straight line from one extremity to the other. The LEDs were quickly turned on

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and off in sequence, producing a clear perception of continuous motion of a luminous spot (target) at a constant velocity. Target velocity was modified by changing the turn on-off time of the LEDs. The displacement characteristics of the target were controlled through a microcomputer. At the receiving end of the trackway there was a force transducer inside a tennis hemiball filled with rigid plastic material, sending input signals to the controlling computer about the time at which the sensor was touched (accuracy of measure = 1 ms). The trackway was held at 70 cm above the ground, and participants stood upright beside its receiving end.

The task was to softly hit the hemiball with a badminton racquet with a movement similar to a forward component of a tennis forehand drive at the instant the moving target arrived at the receiving end (last LED) of the trackway. The last LED of the trackway was adjacent with the hemiball to be hit. The badminton racquet was manipulated with the participants' right arm. Movement amplitude was set at 65 cm by asking participants to start their movements from a vertical screen positioned behind the receiving end of the trackway at the hemiball height.

Following the racquet/hemiball contact the target moved to the opposite side of the trackway at the velocity of 1 m/s. The subsequent trial was started at the moment that the moving target reached the other end of the trackway. Temporal accuracy in the task performance was measured as a function of the modular difference between the time arrival of the target at the last LED of the trackway and the time at which the racquet made contact with the hemiball (absolute temporal error[1]).

Experimental Design and Procedures

Initially, participants adjusted their position in relation to the trackway, in order to hit the hemiball with the badminton racquet oriented perpendicularly to the axis of displacement of the target. Ambient light was dimly lit, so that the luminous target running across the trackway was highly distinctive, although not hindering vision either of the hemiball or of the arm/racquet. To get familiarized with the task and feedback communication, participants performed five trials with target moving at 3 m/s.

Experiment was divided into three phases, acquisition, retention, and transfer. In the acquisition phase, the task was performed with the target moving at three velocities: 2, 3, and 4 m/s. These velocities correspond to periods of target displacement through the trackway of 1000 ms, 667 ms, and 500 ms, respectively. Participants were assigned to two groups (n = 6 each), low (LO) or high (HI) contextual interference. For the LO group the three target velocities were practiced in block, with all trials of each single velocity being performed in a row. Sequence of blocks was specific for each participant. Under high contextual interference, the three target velocities were pseudorandomly varied across trials, keeping the number of trials among target velocities the same. The experimental groups had 180 trials for each target velocity, totaling 540 practice trials during task acquisition. Practice was scheduled in three blocks of 180 trials, with 1-min. intervals between blocks. Trials were performed consecutively within the blocks.

[1]Absolute error was selected as dependent variable from considerations that it is one of the most appropriate measures for movement accuracy [19].

During this phase, feedback on magnitude and direction of temporal error (in milliseconds) was provided verbally on every trial.

Assessment of retention and transfer of learning were made 24 h after the end of the acquisition phase. We used the intermediate velocity of practice (3 m/s) to assess retention, and two new velocities to assess for adaptability: 2.5 and 3.5 m/s. The transfer velocities correspond to periods of target displacement equal to 800 ms and 570 ms, respectively. The practiced target velocity and the two transfer target velocities were used in the main test to assess retention and transfer in two contexts of task execution, blocked or random sequences of velocities. In the blocked context participants performed 10 trials in a row for each target velocity. Sequence of blocks was counterbalanced across participants within groups. In the random context, participants had the retention and transfer trials pseudorandomly interspersed in three blocks of 10 trials. No feedback was provided during these assessment trials.

Normality of data distribution was preliminary assessed by using the Kolmogorov-Smirnov test, and the main analysis was performed through factorial analyses of variance separately for practice, retention, and transfer (specific statistical models are described in the Results section). Post hoc comparisons were made through Newman-Keuls procedures.

RESULTS

For the practice phase, improvement of performance was evaluated separately for each target velocity across blocks of 30 trials employing a three-way 2 (contextual interference group, CI) x 3 (velocity) x 6 (block) analysis of variance with repeated measures on the last two factors. This analysis pointed out significant main effects of velocity, $F(2, 20) = 5.81$, $P < 0.02$, and block, $F(5, 50) = 6.88$, $P < 0.001$. Post hoc comparisons indicated that the main effect of velocity is due to greater errors when the target moved at 4 m/s, while significant reductions of errors from the second block of trials onward responds for the main effect of block. No effect associated with CI was detected, although Fig. (**1**) suggests greater errors for the HI group in the first three blocks of acquisition trials.

Retention was analyzed by comparing errors achieved on the last block of acquisition with those observed in the retention phase, when the target moved at 3 m/s in the blocked and random contexts. For these comparisons, a two-way 2 (CI) x 3 (context of assessment: end of acquisition x blocked x random) analysis of variance with repeated measures on the second factor was employed. The results showed no significant effects, F values < 0.7, p values > 0.4, indicating that both groups made temporal errors of similar magnitude and maintained performance achieved at the end of practice in retention in both the blocked and random contexts (Fig. **2**).

Assessment of transfer was made by comparing temporal errors in the transfer velocities in the blocked and random contexts. These comparisons were made through a three-way 2 (CI) x 2 (context of assessment) x 2 (velocity) analysis of variance with repeated measures on the last two factors. The results indicated a significant CI by context interaction, $F(1, 10) = 5.83$, $p < 0.05$. Post hoc comparisons showed that this effect was due to significant lower errors of the HI group in comparison with the LO group in the random context (Fig.

2a), while no significant difference was detected when assessment was made in the blocked context (Fig. **2b**).

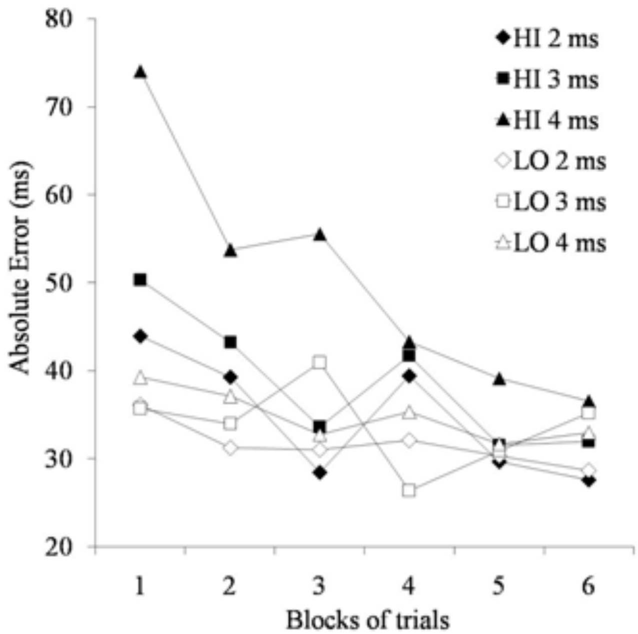

Fig. (1). Mean temporal absolute error (ms) in the practice phase for the low (LO) and high (HI) contextual interference groups for velocities of 2, 3 and 4 m/s.

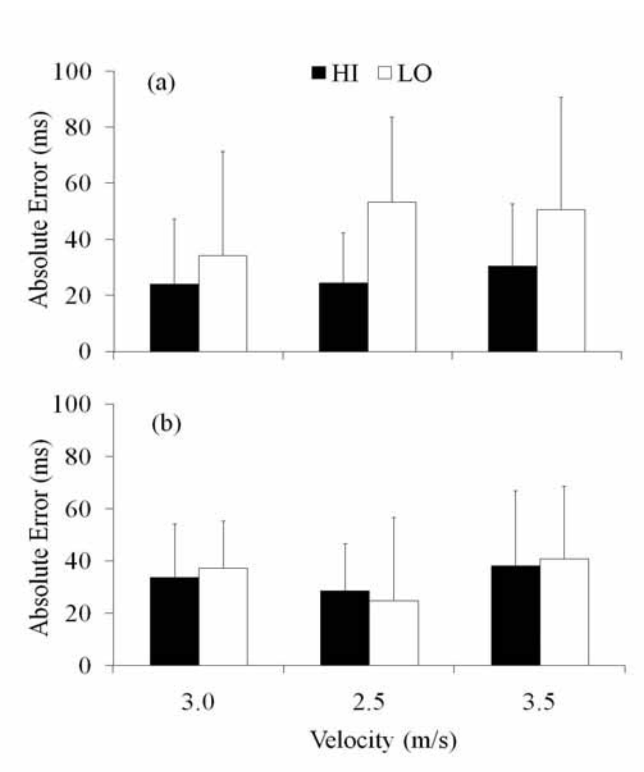

Fig. (2). Mean temporal absolute error (ms) in random (**a**) and blocked (**b**) contexts of assessment for the low (LO) and high (HI) contextual interference groups in the retention (3 m/s) and transfer (2.5 and 3.5 m/s) phases.

DISCUSSION

The main finding from the present results was that the experimental group practicing under high contextual interference had fewer errors than the group practicing under low contextual interference in the random context of assessment, while in the blocked context no significant difference was observed between the groups. Interestingly, such a difference was observed only in the transfer situation, despite the fact that retention was also assessed in both blocked and random contexts. This result suggests that high contextual interference in open skills leads to advantage of performance mainly when adaptation to a new situation is required in the random context. Such an observation is consistent with data presented by Del Rey [14] using a simpler switch depressing task, extending the conclusions to more complex movements involving movement control of multi degrees of freedom to strike a virtually moving target.

One aspect which might lead to a specific advantage of the HI group in the random context is the acquisition during practice of a differential capacity of processing visual information from the beginning of the target displacement, and to rapidly specify the more appropriate movement time for that situation. As the HI group underwent this sensorimotor processing requirement throughout the acquisition phase, the studied subjects seem to have become particularly adapted to properly generate online movement time specifications. The continuous analysis of target velocity across trials is supposed to require increased attention, which has been shown to be related with the positive effect of high contextual interference during task acquisition [15, 16]. These results, thus, are reminiscent of the concept of transfer appropriate processing in motor learning [17]. Low contextual interference, on the other hand, allows the learner to preprogram movement time and the moment of movement initiation as a function of the known time of the target arrival. In this situation, thus, there is reduced demand of target motion analysis and online movement organization. While such a processing demand seems to be appropriate to adaptation in the blocked context, in which target velocity is known a priori, we showed that in a random context scheduling variability in blocks during practice is ill-adaptive. The results also showed that the learning effects were not completely specific to the practice conditions, since the HI group was equally accurate as the LO group in the blocked context. In this sense, the HI group seem to have acquired also the capability during practice of taking advantage of the reduced uncertainty in the blocked context.

In this investigation we simulated a forehand drive movement in order to assess a more complex task than those usually used in previous experimental research, particularly in those studies assessing the effect of contextual interference in open skills. From the results, we provided somewhat contradictory findings to the proposition that low rather than high contextual interference would be more appropriate for beginners in complex motor tasks [11-13]. However, two aspects should be considered in this regard. First, we provided a relatively great number of practice trials to participants. In this case, the benefit of high contextual interference might have been more prominent at the end of the task acquisition phase than during the beginning of practice (cf. [18]). Second, in spite of using a global motor pattern, our task was not as complex as those performed in real sport actions, with numberless variations in spatial and temporal components of each skill. As such, the generalizability of the present results to learning of open skills characteristic of racquet sports is a matter open to debate.

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