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The effect of priming on interceptive actions

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ABSTRACT

Time constraints in ball sports encourage players to take advantage of any relevant advance information available to prepare their actions. Advance information, therefore, can serve to prime movement parameters (e.g. movement direction) and reduce the amount of time required to prepare the upcoming movement. Regularly, however, players face situations in which the information used to prepare the action turns out to be outdated just prior to movement initiation and the prepared action needs to be changed as soon as possible. The aim of the experiment presented here was to determine whether the *priming effect*, generally reported for reaction time tasks, could be generalised to interceptive actions. A secondary aim was to examine the strategies employed by the participants to cope with valid, invalid, or no advance information. The results indicate that, when available, the participants used advance information to prepare their movements. More specifically, in comparison with valid advance information, hit rate and spatial accuracy were reduced when the participants had no advance information and were even smaller when the information conveyed was invalid. The results also suggest that in the absence of valid advance information, the strategies employed to intercept the moving target were tuned to the time remaining until the interception was due to occur.

1. Introduction

Ball sports such as baseball and tennis demand that motor preparation be completed with only brief observations of the ball's trajectory. Frequently during sports matches, observations of the ball's flight may last only about 0.5 s (Watts & Bahill, 1990). To overcome these strict time limitations, evidence suggests that players use either their opponent's body movements (e.g., Abernethy, 1990; Morya, Ranvaud & Pinheiro, 2003) and/or their previous experience (de Lussanet, Smeets & Brenner, 2001, 2002; Gray, 2002a,b) to predict the most likely ball trajectory. Predictions of this sort allow some advance preparation of execution parameters such as movement amplitude and direction. However, precise information about exactly where a ball is going and when it will arrive there is only available from the moving ball itself (Regan & Gray, 2000; Tresilian, 1999) and so refinements to the execution parameters must occur during the short time that the ball is in flight.

Most models for the control of interceptions propose that motor command initiation is triggered when a perceived variable that determines time-to-contact (TTC) with the moving object reaches a criterion value (Zago, McIntyre, Senot & Lacquaniti, 2009). The time between the start of the target's motion and the moment at which the perceived variable reaches criterion determines what we have called the "final stage of motor preparation" in interceptions (see Marinovic, Plooy & Tresilian, 2008, 2009a). Investigating this final stage of motor preparation, we have recently shown that the information about movement amplitude in a brief interception must be provided at least 200 ms prior to movement onset (Marinovic, et al., 2008). This minimum preparation interval, however, can be longer (≈250 ms) if information about movement direction is needed (Marinovic, Plooy & Tresilian, 2009b). In our previous studies (Marinovic, et al., 2008, 2009b), we tackled the issue of how long it takes for different movement parameters to be specified into "motor programs" when no advance information is given about the parameter to be specified. Here we expand on this work by examining how people deal with situations in which a prepared response is inappropriate due to a subsequent, unexpected change in the circumstances that requires an alternative type of response such as a change from a backhand return to a forehand return in tennis.

An experimental technique well-suited to investigate the costs of incorrect anticipation in reaction time (RT) tasks is the priming technique developed by Rosenbaum and Kornblum (1982). The participants are precued about the characteristics of the oncoming movement (e.g. direction and amplitude), but this information is sometimes incorrect. Typically there is an unequal distribution of valid and invalid precues. The priming method therefore creates a state of preparedness for the response most likely to be required next.

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Movements toward the expected (validly precued) and unexpected (invalidly precued) targets may differ in one or more dimensions of the movement (arm, direction, and amplitude). It has been found that RT is greater when an invalid precue is presented than it is when either a valid precue or no-precue is presented (Posner, Nissen & Ogden, 1978; Scheibe, Schubert, Sommer & Heekeren, 2009; Schmidt & Gordon, 1977; Welsh & Elliott, 2004). The RT lengthening is traditionally attributed to the time necessary to inhibit the initiation of an incorrect response plus the time required to reprogram a new one with parameters appropriate for the task.

In the experiment reported here we sought to determine whether the *priming effect*, the shortening of reaction time for validly precued trials, could be generalised to rapid interceptive actions. Additionally, since movement time was left unconstrained and displacement could occur in two-dimensions (see Fig. 1), the present experiment permits us to examine a combination of strategies (e.g. slower movements and directional corrections or faster movements and directional corrections), which could be employed by the participants to cope with invalid precues (or no-precues). The task employed was an adaptation of a 2-D interceptive hitting task used in a previous study (Tresilian, Plooy & Marinovic, 2009). A stimulus indicating which movement direction would be required was provided at different times prior to the arrival of the moving object at one out of two possible interception zones. Due to the nature of interceptive tasks, the costs of incorrect anticipation cannot be measured in terms of increased RTs as the performer has to start his/her movement when TTC reaches a criterion value. However, incorrect anticipation can be measured in terms of spatial errors as demonstrated by Gray (2002a).

2. Materials and methods

2.1. Participants

Participants were 12 (9 men and 3 women, age range 19–38; mean = 28.1 years) self-reported right-handed adults with normal or corrected to normal vision. All participated voluntarily in the experiment and gave their informed consent prior to commencement of the testing sessions.

2.2. Task and apparatus

The experimental task was to hit a moving target in one of two possible locations along its horizontal path. The apparatus used in the experiment is shown in Fig. 1. The 2-d.f. task employed by Tresilian et al. (2009) was adapted to allow the investigation of the effect of priming in interceptions. The moving target was mounted on a carriage, which was attached to a belt system driven by computer controlled torque motor. The participants were allowed to move the bat along 2 axes as shown in Fig. 1A. For this experiment, two plastic rectangles (1 cm wide and 20 cm tall), which served to indicate the interception zones, were suspended from a platform so that they were in line and 0.5 cm behind the moving target. The zone on the right of the participant was referred to as zone 1, whereas the zone on the left of the participant was referred to as zone 2. The two interception zones were separated by a distance of 18 cm from each other. The distance from the initial position of the tip of the bat and the centre of the two interception zones was 14.2 cm. The location where the moving target was to be hit was specified during its approach to the interception zone by an indicational cue (IC) which was preceded by a precue. When the precue was valid, the IC served to confirm the location where they should hit the target. When the precue was invalid, the IC served to indicate the correct location where the interception should occur. The target was made of clear plastic material with embedded LEDs (green and red positioned approximately in the middle of the moving target as shown in Fig. 1B) which illuminated with the corresponding colour of the interception zone at a given trial. The target was flat and rectangular, 14 cm tall and 6.1 cm in length. The indicational cue (IC) was presented at varying times prior to the arrival of the moving target at the interception zones. The target was seen for at least 2.2 s before its arrival at the interception

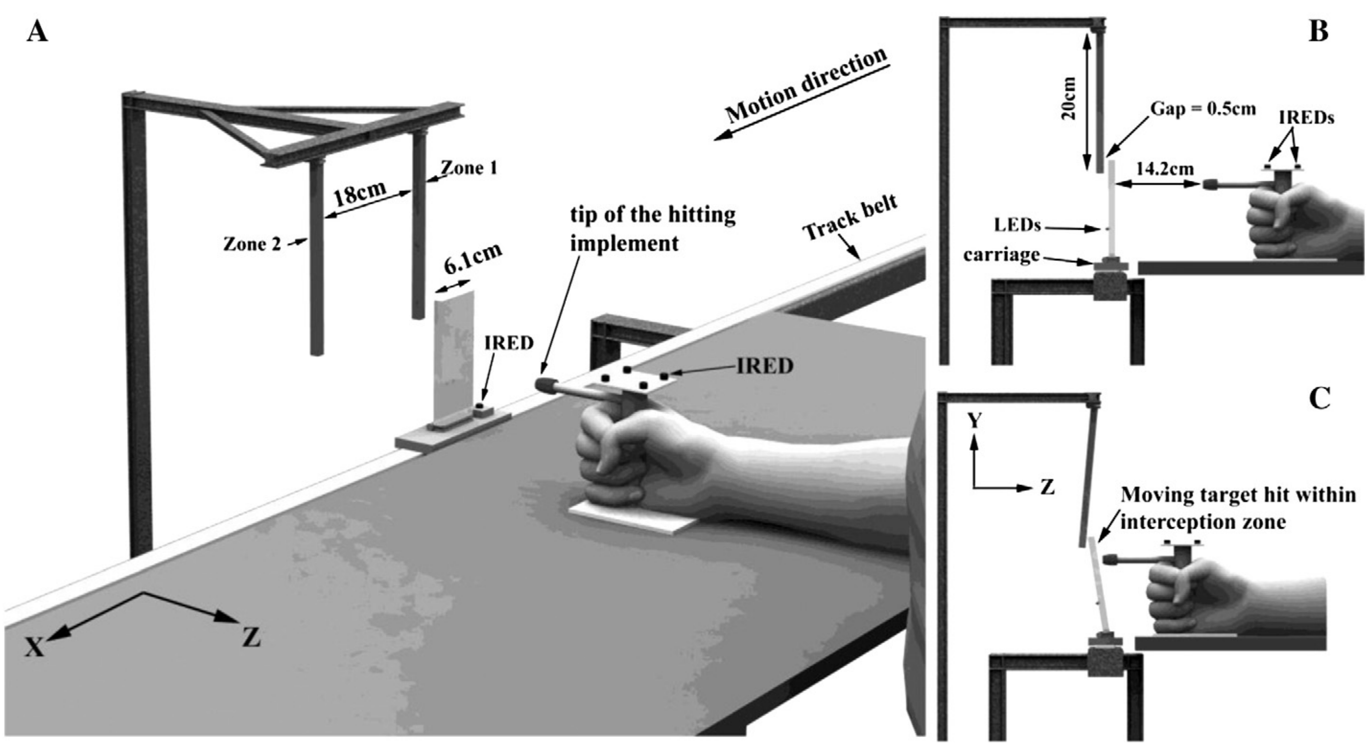

Fig. 1. A — experimental setup used in the experiment (not to scale). The participants held the hitting implement with which they should hit the moving target within the interception zone. The target was attached to the track belt and moved along a straight path (right-to-left). The participants were constrained to move the bat along the *Z* and *X*-axes. B — lateral view before interception. C — lateral view when the moving target was successfully intercepted within the interception zone.