Exp Brain Res (2001) 137:246–248
DOI 10.1007/s002210000607

RESEARCH NOTE

Marc H.E. de Lussanet · Jeroen B.J. Smeets
Eli Brenner

The effect of expectations on hitting moving targets: influence of the preceding target's speed

Received: 3 August 2000 / Accepted: 10 October 2000 / Published online: 20 February 2001

Abstract When hitting a target that is moving, the time for planning the interception is limited. Instead of waiting for all the necessary information about the target's position and speed before starting to move, subjects could use their previous experience with similar targets to make initial guesses and adjust as new information becomes available. In the present study we examined whether the speed of the preceding target influences a hitting movement. Subjects hit moving targets that appeared on a screen about 40 cm in front of them. The targets moved at 6, 12 or 18 cm/s. Both the hand's initial movement direction and the final hitting error depended on the speed of the preceding target. We conclude that people control the way they hit moving targets on the basis of the speed of the preceding target.

Keywords Interception · Human · Anticipation · Eye-hand coordination · Velocity

Introduction

In order to hit a target, people have to determine where to move and how. This takes time. If the target moves, one has to anticipate where the target will be by the time it is reached. To anticipate where to hit a moving target, one may rely on visual information about where the target is and how fast it is moving. However, in such a task, speed information does not seem to influence the hand's initial movement direction (Smeets and Brenner 1995). The reason for this may be that it takes about 200 ms to use speed information (Brenner et al. 1998), which is about as long as the whole reaction time. It may be more efficient to use speed information from previous experience to build an expectation of where and how fast the target will move, and only to rely on new visual information to correct these expectations (Smeets and Brenner 1995).

The results that we present here are based on the first experiment of an ongoing study in which we examine the influence of target speed on hitting movements. In the present paper we analysed the data to study the influence of the preceding target's speed on the movement.

M.H.E. de Lussanet (✉) · J.B.J. Smeets · E. Brenner
Vakgroep Fysiologie, Erasmus Universiteit, Postbus 1738, 3000 DR Rotterdam, The Netherlands
e-mail: delussanet@fys.fgg.eur.nl
Tel.: +31-10-4087567, Fax: +31-10-4089457

Materials and methods

The apparatus and experimental procedure were described in more detail in several previous papers (Brenner et al. 1998; Smeets and Brenner 1995; Brouwer et al. 2000). In short, subjects sat unrestricted in front of a strong 35×45-cm screen that was tilted backwards by 30°. The target was an 18-mm-long spider that appeared when the subject's hand had been at the starting position, 40 cm from the screen, for 1–2 s. Subjects were told that they had to hit each spider as soon as it appeared. Each target moved at a speed of 6, 12 or 18 cm/s (1 cm/s≈1 deg/s). Targets of 6 cm/s appeared 7 or 5.5 cm to the left of the hand's lateral position, targets of 12 cm/s appeared 8.5, 7 or 5.5 cm to the left of the hand and targets of 18 cm/s appeared 8.5 or 7 cm to the left of the hand. Half the targets moved at 12 cm/s, one-quarter at 6 cm/s and one-quarter at 18 cm/s.

For hitting, subjects held a rod in the way one holds a pencil. A target was hit if the tip of the rod came within 18 mm of its centre. Subjects received visual feedback about whether they hit the target. Fourteen subjects (including two of the authors) volunteered to hit 80 targets. Except for the authors, the subjects were naive with respect to the purpose of the experiment.

The movements of the hitting rod were measured at 250 Hz (Optotrak 3010, Northern Digital Inc., Waterloo, Ontario). The *reaction time (RT)* was the interval between the moment the target appeared and the moment the hand moved faster than 0.1 cm/s towards the screen. The *movement time (MT)* was the interval between when the hand moved faster than 0.1 cm/s and the moment the hand hit the screen. The *initial movement direction* was the angle between the tangent of the hand's path and a line perpendicular to the screen, after the hand had moved 2.5 cm. The *hitting error* was the horizontal distance (positive to the right) from the centre of the target to the centre of the tip of the rod.

In order to examine the influence of the speed of the preceding target, we had to make sure that effects were not due to differences of the present target. Therefore, we examined whether three experimental variables influenced the movement parameters: the present target's position at RT, the speed of the present target, and the speed of the preceding target. We calculated the correlation of

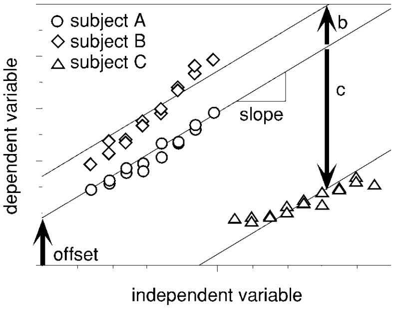

Fig. 1 Illustration of the method of covariance analysis on fictive data from three subjects. The method results in a single regression slope for all subjects and in coefficients (*b, c*) for the differences in offset between the subjects

each movement parameter with these variables using a covariance analysis (which is a special form of multiple regression analysis, Fig. 1). In addition to the continuous variables, we included 13 binary independent variables in the analysis: each contained *ones* for the trials of one of the subjects and *zeros* for all other subjects. By this method, the differences in offset between subjects were captured by the coefficients of the 13 binary variables, while one single coefficient was obtained for all subjects for each of the three continuous variables. The present target's position at the RT is correlated with its present speed, so the coefficients that are found for these variables are not informative. However, since we are not interested in the influence of the present target, this was not a problem. We only report the coefficients for the previous speed. The coefficients represent the slope, and therefore have the dimension of this variable divided by the dimension of target speed (cm/s).

For plotting the relation between the movement parameters and the speed of the present and of the preceding target, we first averaged the values within subjects, and then across subjects. We had to do this because the number of occurrences of each combination of present and previous speed differed between subjects due to the random order of presentation.

Results

Figure 2 shows the influence of the speed of the preceding target and that of the present target on each movement parameter. If the preceding speed has an effect on the parameter, the lines have a slope. This is so for the initial movement direction and the hitting error. If the present target's speed (or the correlated present target's position) has an effect, the lines differ in intercept, as is clearly the case for the MT and the initial movement direction. Figure 2D also shows that the previous speed has a larger effect on the hitting error than the present target has (the lines more or less overlap, but clearly have a slope).

We tested the statistical significance of the slopes in Fig. 2 with the covariance analysis. As explained in "Materials and methods," the only coefficient that is relevant and meaningful for the scope of the present study is the coefficient for the preceding target's speed. The effect of the preceding speed was highly significant (P<0.001) for the initial movement direction (0.17±0.05 deg s/cm, slope ± standard error) and for the hitting error (29±7 ms, slope ± standard error). The

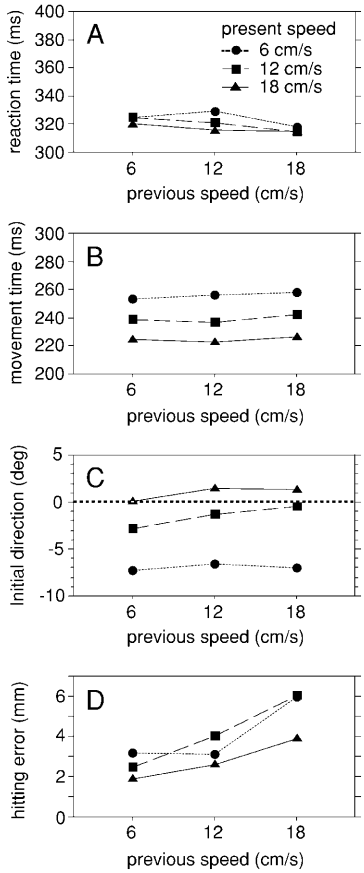

Fig. 2A–D Influence of the preceding targets' speed for each present target's speed. The preceding target's speed had a significant effect on the initial movement direction and on the hitting error

expected small effect on the RT (apparent in Fig. 2A) was not significant (P=0.07). Hitting errors were not large: on average 90% of all trials were hit by the subjects.

Discussion

Our results show that the speed of the preceding target did affect the initial movement direction and the hitting error. This result was not unexpected because Smeets and Brenner (1995) already proposed that subjects make use of an expected speed to hit a moving target. To our knowledge influences of the preceding target's speed have never been observed for arm movements. Also, the results imply that the range of target speeds should influence the interception movement. This was indeed found by Van Donkelaar et al. (1992) and by Brouwer et al. (2000). A different effect of the preceding trial on arm movements was found by Jaric et al. (1999). In their experiment, in which there was an unexpected change in the load on the arm between some trials, the MT and peak velocity depended on the previous load.

The influence of the present (and of the previous) target's speed was not significant, though the magnitude was about the same as found in earlier studies (e.g. Smeets and Brenner 1995), where it was significant. The present target's speed apparently has a relatively large influence on the hand's initial movement direction. This effect is a bit misleading, because it reflects the summed influence of present target position and speed on the initial movement direction (on the RT the 6-cm/s targets were on average more to the left than the 18-cm/s targets). The highly significant effect of the preceding target's speed on the hitting error is surprising at first sight, as the *present* target's speed did not seem to influence the hitting error (Fig. 2D). We can interpret the influence of the preceding target's speed on the hitting error as being a result of the effect that the preceding target's speed has on the initial movement direction. If this effect of the preceding target on the initial direction is never fully compensated, it may still be present in the hitting error. The mass spring model of Smeets and Brenner (1995) illustrates this interpretation. According to this model, the effect of the expected speed decreases during the movement, but does not completely disappear due to the inertia and damping of the arm. Following the same line of reasoning, we can understand why the previous target's speed did not affect the MT. The MT depends on the hand's velocity, which is corrected on the basis of the *present* target's speed (e.g. Brouwer et al. 2000). Thus there is no need to let the previous speed influence the MT.

In the present experiment we used visual targets. This means that the information for making the arm movement is likely to be based on where the eye is looking. Some interesting examples of the influence of previous trials on eye movements may therefore be related to the effects that we found in the present study. Kowler and Steinman (1981) showed that anticipatory eye movements are made when subjects fixate a target that they expect to jump. When the direction of the jump was unknown, the direction of the anticipatory movement was correlated to the direction in which the previous two or three targets jumped. Kowler et al. (1984) showed that even the saccadic latency and the size of the saccade were influenced by the direction of the previous targets' jump. Not only saccadic eye movements, but also smooth pursuit movements have been shown to be influenced by previous movement cycles of a target (Kao and Morrow 1994).

How far back the influence of previous targets on a present movement goes may affect the amount of variability one may find in a randomised experiment. If, for example, the expected speed from Smeets and Brenner's (1995) model is the average of many previous targets' speed, it can be regarded as a constant that does not impose extra scatter on the data. If, however, only the speed of the preceding target influences the movement, as would be closer to Kowler and colleagues' (1984) findings for eye movements, this would cause extra variability in a randomised experiment. A covariance analysis including the second preceding speed did not reveal any effect, suggesting that the influence of the target before last is very small at best.

Acknowledgements The first author was supported by the Netherlands Organisation for Scientific Research (NWO: grant 575-23-002). We wish to thank the referee for valuable comments.

References

Brenner E, Smeets JBJ, de Lussanet MHE (1998) Hitting moving targets: continuous control of the acceleration of the hand on the basis of the target's velocity. Exp Brain Res 122:467–474

Brouwer A-M, Brenner E, Smeets JBJ (2000) Hitting moving targets: the dependency of hand velocity on the speed of the target. Exp Brain Res 133:242–248

Kao GW, Morrow MJ (1994) The relationship of anticipatory smooth eye movement to smooth-pursuit initiation. Vision Res 34:3027–3036

Kowler E, Steinman RM (1981) The effect of expectations on slow oculomotor control – III. Guessing unpredictable target displacements. Vision Res 21:191–203

Kowler E, Martins AJ, Pavel M (1984) The effect of expectations on slow oculomotor control – IV. Anticipatory smooth eye movements depend on prior target motions. Vision Res 24: 197–210

Jaric S, Milanovic S, Blesic S, Latash ML (1999) Changes in movement kinematics during single-joint movements against expectedly and unexpectedly changed inertial loads. Hum Mov Sci 18:49–66

Smeets JBJ, Brenner E (1994) The difference between the perception of absolute and relative motion: a reaction time study. Vision Res 34:191–195

Smeets JBJ, Brenner E (1995) Perception and action are based on the same visual information: distinction between position and velocity. J Exp Psychol Hum Percept Perform 21:19–31

Van Donkelaar P, Lee RG, Gellman RS (1992) Control strategies in directing the hand to moving targets. Exp Brain Res 91: 151–161