THE BACKWARD MISLOCATION OF A MOVING OBJECT STARTING POINT IS DEPENDING ON VELOCITY

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Abstract

Deviations of the judged from the actual moving target onset (starting point, SP) have been reported both in- and opposite to- the direction of motion, but it is still not clear under which conditions the perceived SP is mislocalized back or forth. To solve this ambiguity we changed the typical experimental paradigm to obtain an estimation of SP as much accurate as possible. The method of constant stimuli was used and a cue was displayed before target onset, remaining on the monitor as a reference-system. Two velocities (2.23 and 11.13 cm/s) were used for a horizontal motion (two directions). An effect of velocity was found: the magnitude of the backward mislocation was larger with the slower velocity, whereas for the faster one the error was near to zero.

The first perceived position (starting point, SP) of a moving target is typically mislocalized. A mislocation error in the direction of motion (i.e., a forward mislocation) was discovered in the first half of the last century (Fröhlich effect, 1923) and confirmed by Müsseler and Aschersleben (1998); however, recent studies also confirmed the reverse error (i.e., a backward mislocation; Actis-Grosso et al. 1996; Actis Grosso & Stucchi, 2003; Bastianelli et al. 2005, 2006; Hubbard and Motes, 2002; Thornton, 2002). The apparent contradiction between these two results could be due to any of the many differences between the experimental paradigms used. At present, researches that try to solve this contradiction were focused on participants' task (Kerzel, 2003), on the attentional bias relative to motor judgements (Kerzel and Gegenfurtner, 2004) and on trial context (Müsseler & Kerzel, 2004). Consequently, tentative explanations of the difference between the two effects are mainly based on predictability and expectancy.

However, target velocity seems to play a crucial role. Both Thornton (2002) and Actis-Grosso and Stucchi (2003) found an effect of target absolute velocity on the SP backward mislocation, whereas Müsseler and Aschersleben (1998) found a Fröhlich effect with a very fast moving target (i.e. 44°/s). A model have been suggested by Actis-Grosso and Stucchi (2003), based on an early visual extrapolating mechanism (Nijhawan, 1994) that compensates the ~100 ms neural delay by transforming it into a spatial distance. According to this model, target's absolute velocity at the beginning of motion is a crucial factor, together with the presence of an anchor. Regarding target velocity, the model postulates (i) a modulation of the magnitude of the effect as a function of velocity modulation and (ii) that the mechanism has a threshold for target absolute velocity, above which it does not extrapolate the motion SP, simply cutting the first 100 ms of motion (thus shifting the direction of the error from a backward to a forward mislocation).

This work, which is a part of a research aimed to test the role of velocity on localization errors, is aimed to find whether this threshold is present. In previous experiments (Bastianelli et al., 2004, 2005) no effect of velocity was found on the magnitude of the effect, and a backward mislocation was always found for horizontal directions (whereas for vertical directions there was no effect). Here, we changed the experimental paradigm of previous experiments (which was also typically used in other researches, e.g. Thornton, 2002) to obtain an estimation of SP as much accurate as possible. The method of constant stimuli was used and two vertical lines were presented on the monitor before target appearance. The two white lines were aligned one below the other, with an empty space between them of 3.5 cm. The motion SP was in the empty space between the lines and could be (i) perfectly aligned with the lines, (ii) at the left of the lines or (iii) at the right of the lines. Thus, the two lines served both as a cue and as a reference system. Furthermore, participants' task was another main difference between this experiment and previous one. Here, participants' are requested to press a key when they see target SP in the direction of motion and to press another key when they see target SP in the direction opposite to motion, whereas mouse coordinates are typically recorded and confronted with target actual coordinates.

Experiment

Method

Participants. Six naïve participants (4 females and 2 males, average age 26.6 years) volunteered for the experiment. All had normal or corrected-to-normal vision.

Apparatus and stimuli. The stimuli were presented on a PC Pentium 4- based computer equipment connected to a 19 in. monitor with a resolution of 1280 x 1024 pixels and a refresh rate of 100 Hz. A red dot (5 pixels in diameter) travelled in a straight line on a black background, covering a horizontal path of 3 cm (either in the direction right-to-left or in the direction left-to-right). The velocity of the target could be 2.23 cm/s or 11.13 cm/s. At the beginning of each trial two vertical lines were presented in a position randomly located within a 80 pixels viewing square, centred on the middle of the screen. The two white lines were aligned one below the other with an empty space between them of 3.5 cm. After an interval between 500 and 1000 ms the dot appeared on the monitor and the motion started at once. Motion SP could be in one of seven possible positions. One of this position was in the empty space between the lines, aligned with them (Position 0, P0). The two lines served thus as a reference system; the other six SPs were located away from P0 (three at its left and three at its right) with steps of 2 mm, as reported in figure 1.

Procedure. Participants sat at a comfortable distance from the screen (about 60 cm) in a dimly lit room. The method of constant stimuli was used. The task of participants was to judge, after the end of motion, whether target Sp was **in** the direction of motion (by pressing the left key

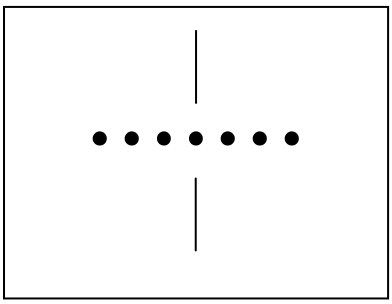

Figure 1. A schematic representation of the seven different SPs used in the experiment.

with their left hand) or **opposite to** it (by pressing the right key with their right hand). Each trial was separated by a random interval between 500 and 1000 ms.
The completely within-subjects experimental design included three factors: Direction (2 levels) x Velocity (2 levels) x Position (7 levels) for a total of 28 stimuli. Each stimulus had 10 replications, for a total of 280 trials. The duration of the whole experimental session was approximately 15 minutes. The order of presentation was randomized for all the participants.

Results

For each subject the proportions of responses “opposite to the direction of motion” was calculated. In figures 2 and 3 the proportion of responses averaged over subjects are reported for each position as a function of velocity. Proportions were then transformed into z scores. Linear regression was used to calculate the line that fit the data. The point of subjective equality (PSE) for each velocity was then calculated by determining the value on the stimulus scale that corresponds to a null z. PSE for the slower velocity (2.23 cm/s) was -1.87 mm, whereas PSE for the faster velocity (11.13 cm/s) was – 0.62 mm. The difference between the two thresholds was significant (t = -3.49 p< .01) when the *jnd* was used as an estimate of σ. JND was calculated with the linear regression coefficient b, where JND = $\frac{1}{b}$.

Discussion

When the target travelled at a constant speed of 2.23 cm/s its SP was shifted opposite to the direction of motion by 1.87 mm, whereas, when the dot travelled at a constant speed of 11.13 m/s, its SP was shifted opposite to the direction of motion of 0.62 mm. In other words, the magnitude of the error was drastically reduced with the faster velocity, and its value is very near to zero.

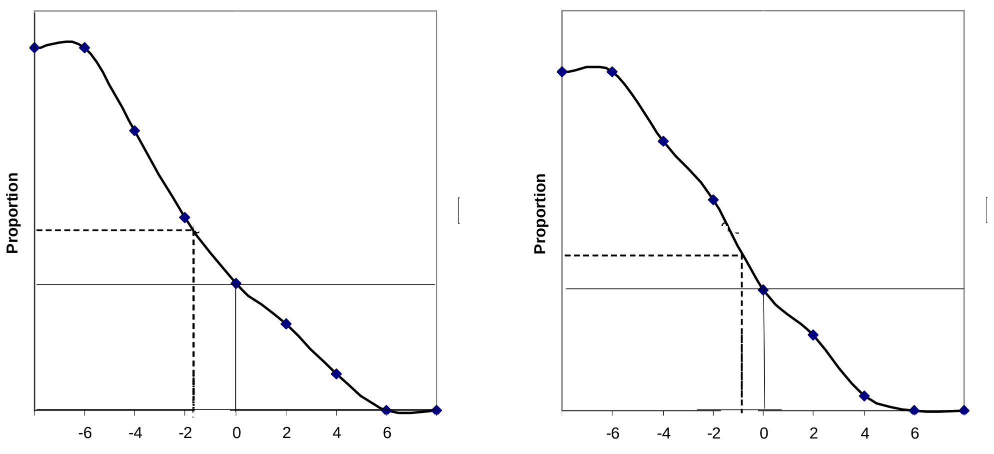

Figure 2. Proportion of responses averaged over subjects for each position as a function of velocity 2.23 (left) and 11.13 (right).

The fact that, when a reference system is present, the magnitude of the error decreases as velocity increases, seems to suggest that the faster velocity used in this experiment (11.13 cm/s) is near to the threshold, at least for a dot of 5 pixels in diameter. Actually, given that the presence of a reference system improves accuracy, we should expect a better accuracy for the slowest velocity: in this case target is present for a longer period of time and, consequently, also the presence of the first position is longer. In fact, the opposite is true: accuracy is better for faster velocity (i.e. perceived SP is nearer to actual SP).

This support Actis-Grosso and Stucchi (2003) hypothesis of a mechanism that extrapolates the first 100 ms of a motion mainly on the basis of target velocity (exaggerating the transformation of a temporal delay into a spatial distance with slower velocities) and that has a threshold above which the first 100 ms of motion decay anyway.

Therefore, we might expect that a Fröhlich effect would be observed, within this experimental paradigm, if target absolute velocity would be higher than the one used here.

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