Illusory bending of a pursuit target sheds light on early direction estimation

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Coordination for Optimal Decisions in Dynamic Environments

Introduction

To pursue a target of interest, its motion must be segmented from that of the background. Initially, various sources can provide information interfering with pursuit of the target direction e.g.

- If a direction is cued, pursuit can be biased towards the cued direction[1].
- Irrelevant background motion in a direction away from the target direction can bias early pursuit[2].

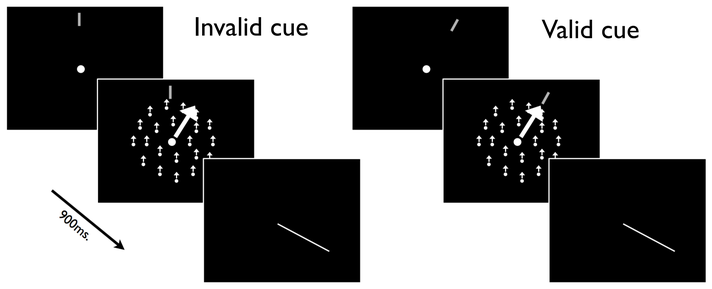
We wanted to know what would happen if both of these information sources were presented at the same time with a pursuit target.

Methods

5-7 subjects pursued a central target that moved outwards at 10 deg/s in a random direction along a straight line for 900ms. A 100% coherent RDK background (in a circular window) moved with target motion at the same speed but with a direction offset of 10°, 15°, 20°, or 25° away from target direction. A cue consisting of a short grey line was presented peripherally and could be either valid (aligned with target direction) or invalid (aligned with background direction). We changed the contribution of the cue in 4 experiments:

Exp.1: Cue presented before and during target motion (**Cue before + during**)
Exp.2: Cue presented only before target motion (**Cue before**)
Exp.3: Cue presented only during target motion (**Cue during**)
Exp.4: No cue presented during the trial (**No cue**)

At the end of each trial subjects adjusted the orientation of a long line to match the perceived initial direction of the target.



Discussion

We show that the presence of a cue and moving background influence initial pursuit, and also cause a perceptual illusion: the target direction initially appears to be towards the direction of cue and background. After motion segmentation it appears to bend back towards the target direction.

See our illusion 'Bend it like Beckham' at the demo night

Effects of valid vs. invalid cue

Fig.1: Perceived initial target direction and direction of early pursuit for each background direction offset. Data points represent decision angles averaged across subjects. Lines represent a linear fit on the data points.

Results: With an invalid cue, initial perceived and pursued target direction were shifted towards background direction. With a valid cue, perception was near veridical while the background's influence on pursuit was reduced.

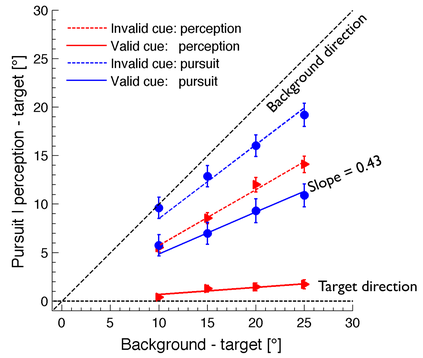
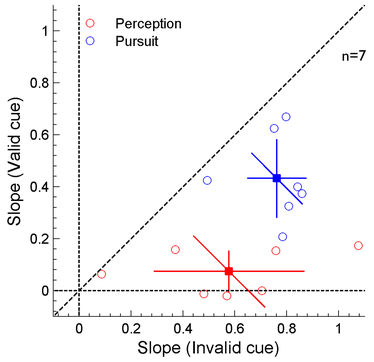


Fig.2: Open symbols represent the slope of a linear fit on decision angles (as shown in fig.1) for each subject. A value of zero indicates that the decisions were veridical on target direction, a value of unity indicates that the decisions were on background direction.

Results: Early pursuit direction was biased towards the background direction in both cue conditions. Perceived target direction was only biased towards the background direction with an invalid cue.



Effects of cue timing

Fig.3: Using the slope values described above, we looked at perceived initial target direction (open symbols) and direction of early pursuit (filled symbols) for different cuing conditions (Exp. 4 is shown on the unity line, because it does not have valid/invalid cue components).

Results: With no cue, initial pursuit integrated background and target direction, while perception was veridical. Pursuit was influenced by valid and invalid cues, but only if they were presented before target motion. Perception was influenced by cues before and during target motion, but only if they were invalid.

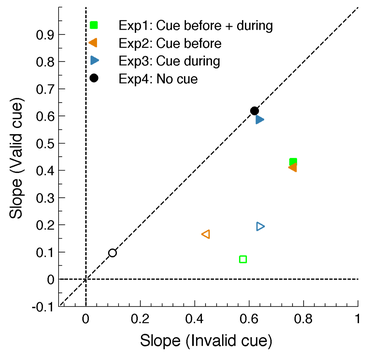
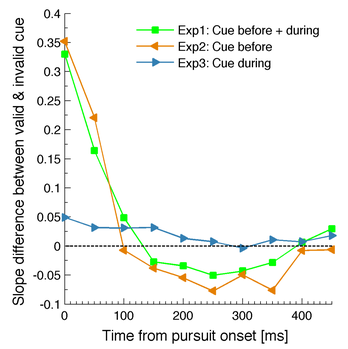


Fig.4: Data points represent the difference in pursuit direction between valid and invalid cue conditions in 100 ms time windows.

Results: The early influence of the cue on pursuit in exp 1 & 2 only lasted up to 100ms after pursuit onset.



Perceived and pursued trajectories

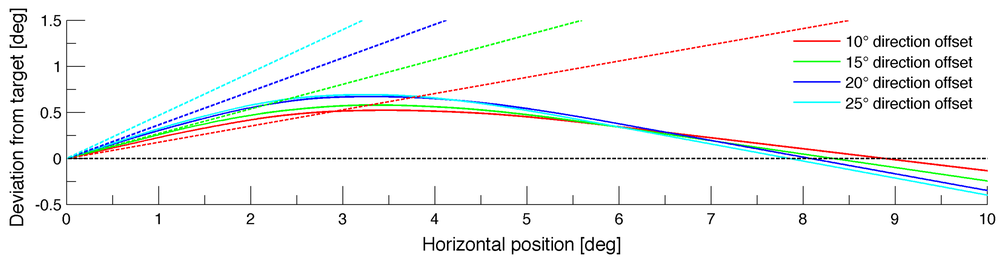
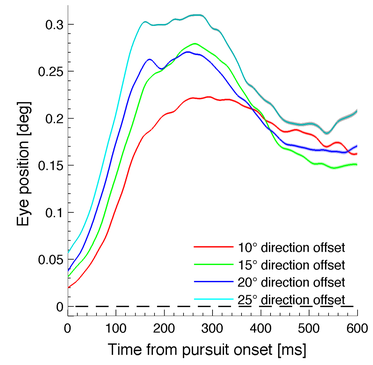


Fig.5: Average perceived target position (in a separate experiment where an invalid cue was presented before + during target motion). After each trial, subjects adjusted a line defined by two free parameters: position of target at the point of perceived bend and perceived target end position. Oblique dotted lines represent veridical background/cue direction offsets; the horizontal line represents target direction.

Fig.6: Eye position orthogonal to the target trajectory, when an invalid cue was presented before + during target motion. The largest influence of the background direction occured between 100 and 300 ms after pursuit onset.



References:
[1] Krauzlis & Adler (2001) Effects of directional expectations on perception and pursuit eye movements. Visual Neuroscience 18(3) 365-376
[2] Debono et al. (2010) Receptive fields for smooth pursuit eye movements and motion perception. Vision Research 50(24) 2729-2739

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