Human detection and localization of speed differences during fixation and smooth pursuit eye movements

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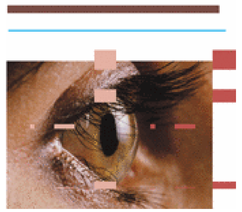
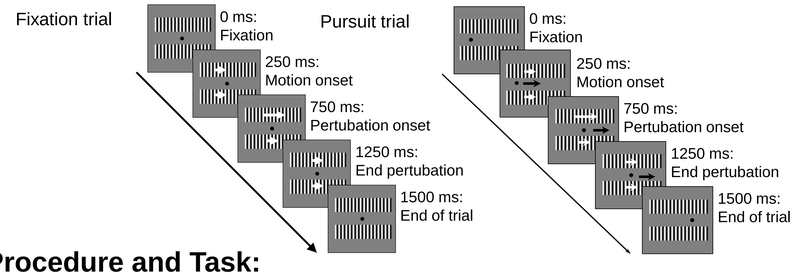


Introduction

Human observers are quite good at discriminating speeds of moving objects (1, 2). However, in natural situations several objects move at different speeds and sometimes change their movement speed. Thus we investigated the ability to perceive speed changes when several objects are moving while the observer is either fixating or smoothly pursuing a target.

Methods

Stimuli: Two vertically oriented sine wave gratings (0.5 cpd) moved horizontally at a constant speed (pedestal speed). They were 27 deg wide and 9 deg high and separated vertically by a 2 deg gap. In fixation trials the central small spot in the gap was stationary, in pursuit trials the spot moved in the same direction as the gratings at the same or a different speed (eye speed). During the trial one of the gratings changed its speed for 500 ms.



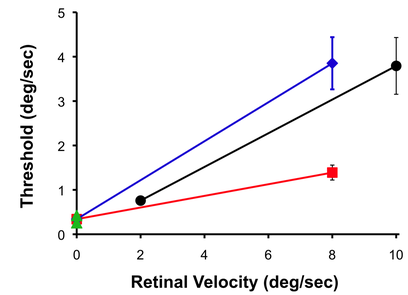
Procedure and Task:
Localization: Subjects had to indicate whether the speed perturbation affected the top or the bottom grating.
Detection: Subjects had to indicate in which one of two intervals the speed perturbation took place.
Discrimination: Both gratings changed their speed in the same way. Subjects had to indicate whether they got faster or slower.

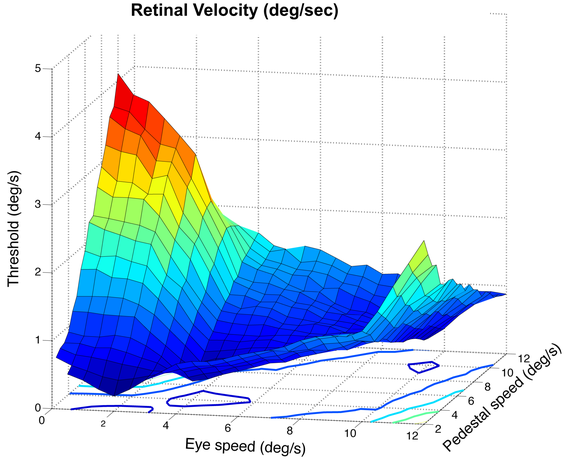
Eye Velocity	0	2	10	0	2	10
Pedestal Velocity	2	2	2	10	10	10
Retinal Velocity	2	0	- 8	10	8	0

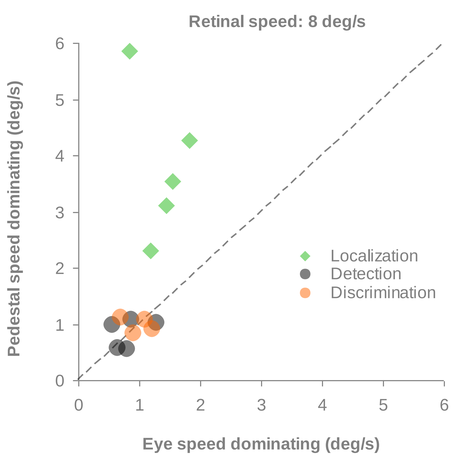
Observers: Four naive observers (students) and one author.
Pursuit: Eye position was recorded with an EyeLink 2 System.

Results

Localization

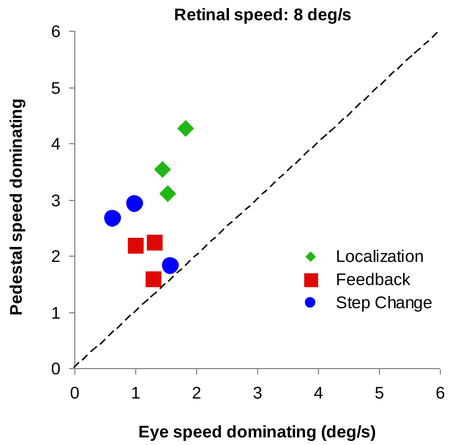






Thresholds for detecting or discriminating speed perturbations were in the normal range of Weber fractions of 10% or less. In contrast, localization thresholds were dramatically increased to Weber fractions of about 30% - 40% during fixation. We found a large effect on localization thresholds dependent on the relation between eye speed and pedestal speed as shown in the contour plot on the left: When the retinal motion was mainly due to pursuit (eye) movements, thresholds were reasonably low (around 10%); when the retinal motion was mainly due to object (pedestal) movements, they were high. When the eyes were moving continuously at the same speed as the gratings (dark blue diagonal) and thereby reducing the retinal image slip velocity, localization thresholds were very low.

Control experiments



While thresholds were reduced for step changes and by feedback, the facilitation in conditions were the retinal speed was dominated by the eye speed persisted even in these control experiments.

Conclusions

We conclude that different from detection and discrimination, it is exceedingly difficult to localize a speed change of a peripheral stimulus in the presence of other moving objects. This is probably due to the dominance of relative motion signals. Smooth pursuit is an effective means to improve performance under these conditions.

References:
McKee, S. P. (1981) A local mechanism for differential velocity detection. Vision research, 21, 491-500.
Orban, G. A., DeWolf, J. & Maes, H. (1984) Factors influencing velocity encoding in the human visual system. Vision Research, 24, 33-39.

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