Motion coherence during pursuit evaluated with a multiple-aperture display

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Introduction

The extraction of an object's direction of motion requires integration of spatially distributed local measurements, which are subject to the aperture problem -- i.e. the motion of 1D contours is ambiguous. We know little about this sort of pooling for a mobile eye, facing the additional problem of parsing self-induced and object motion.

Research question

Are motion signals pooled effectively to solve the aperture problem when the eye is moving with the stimulus?

Materials & Methods

A multiple-aperture motion stimulus was used, composed of 2 cpd, 40% contrast, gabor elements. Pooling of local motion signals across orientations is necessary to extract the global direction of motion.

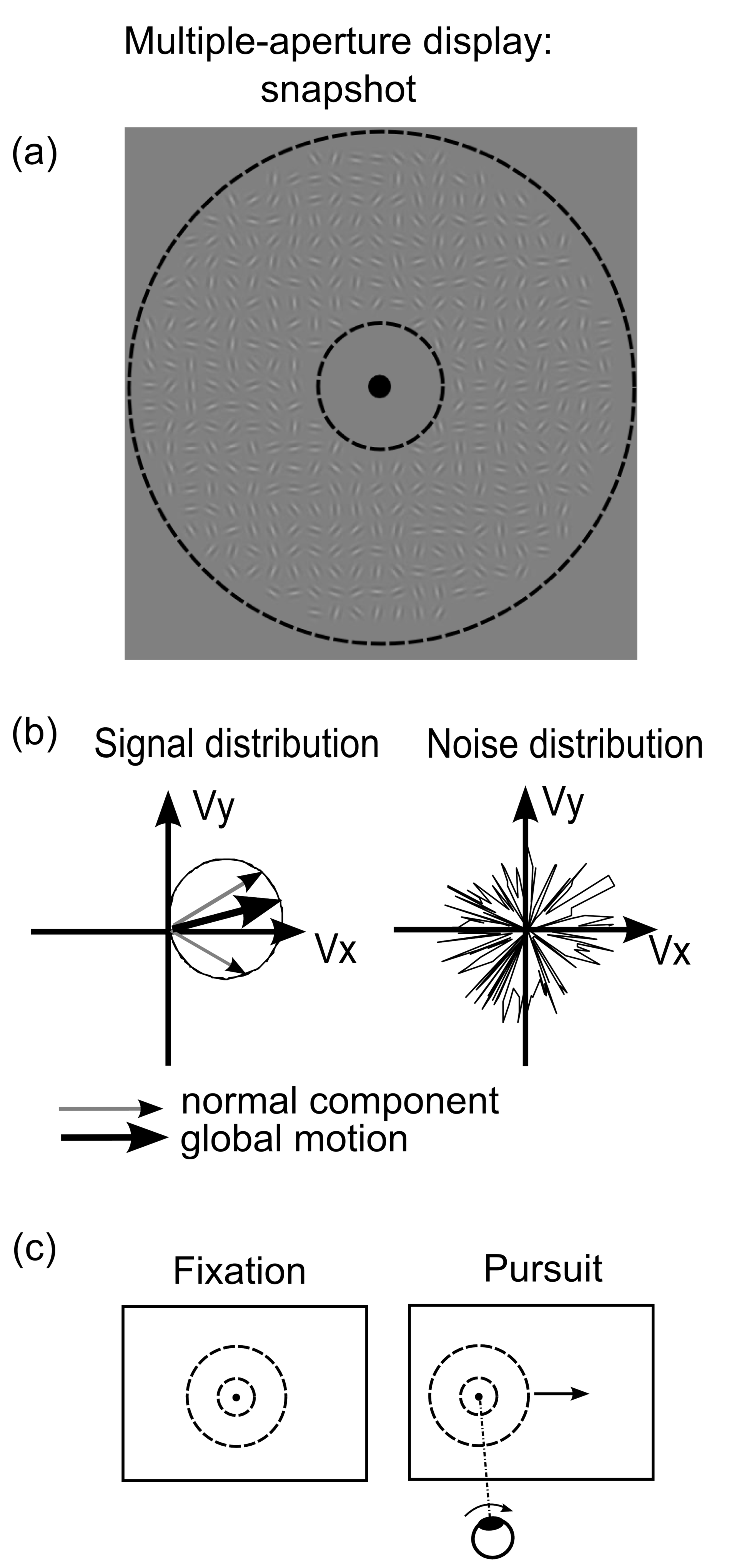

Figure 1. (a) stimulus used: a multiple-aperture (gabor) display, as introduced by Amano et al. [1]. (b) Signal and noise distribution from which the contour speed of the signal and noise gabors is drawn, resulting for the signal in global motion with a speed of 2.3 deg/sec. (c) Fixation and pursuit conditions.

Eye movements were recorded with a sampling rate of 1000 Hz, using a video-based eyetracker, the Eyelink 1000. The motion stimulus was shown for 500 ms during steady-state pursuit or during fixation (Figure 1c). Saccade size (<1°) and pursuit gain (eye velocity/target velocity > 0.8) inclusion criterions were applied during this critical interval.

Exp. 1: Direction discrimination task

Global motion direction was 10 deg upwards or downwards from the horizontal, either opposite to the pursuit direction or in the same direction. Observers had to report whether the direction of global motion was upwards or downwards (2AFC).

Exp. 2: Coherence discrimination task

Global motion direction was opposite or in the same direction as pursuit. Observers had to select one of two intervals on which coherent motion was shown (2IFC).

Results

Exp. 1: Coherence thresholds (Figure 2 and 3) are much higher during pursuit as compared with fixation (ps< 0.05), for global motion in the direction of pursuit (*same)* or in the opposite direction (*opposite*).

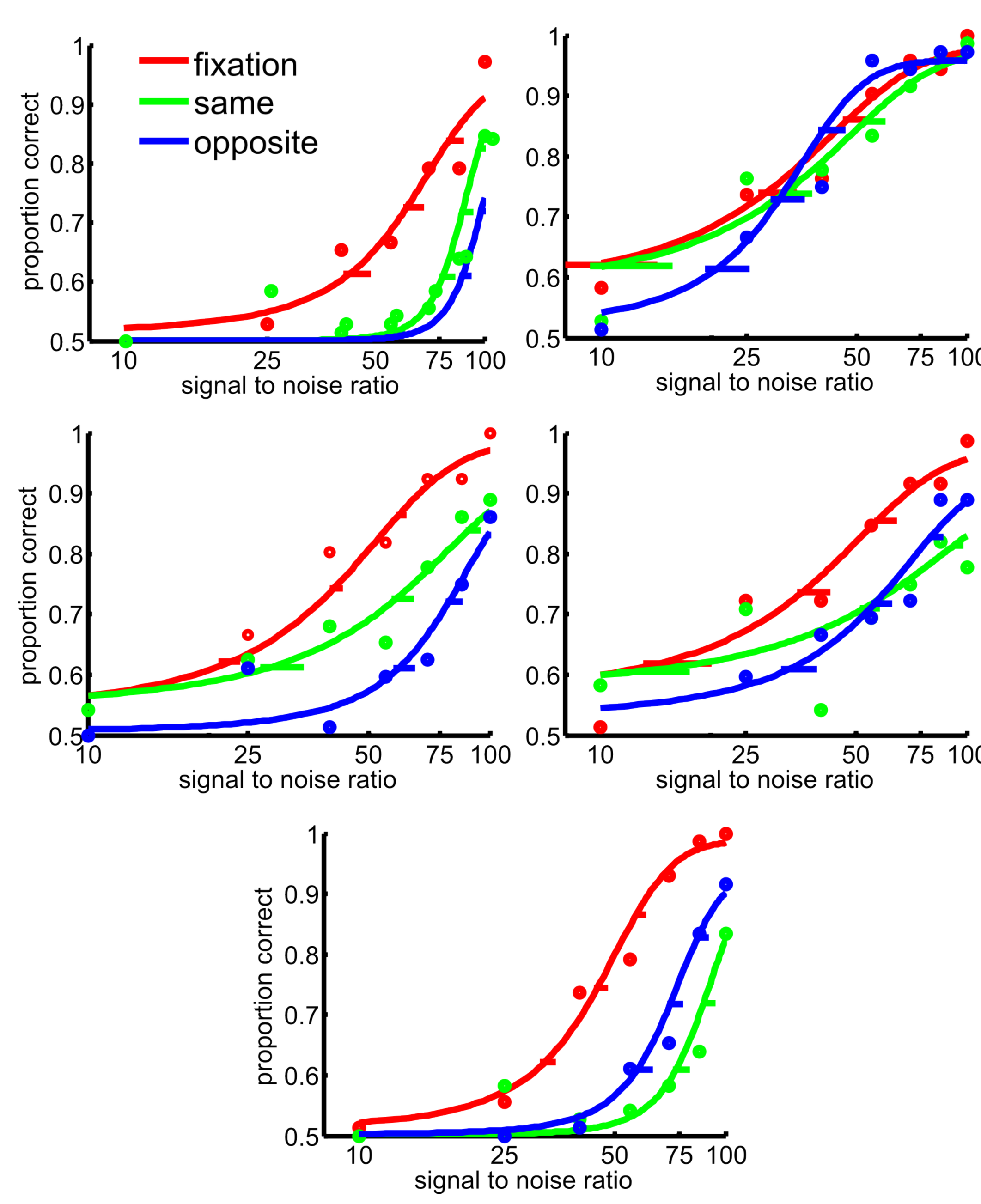

Figure 2. Exp. 1 individual psychometric functions.

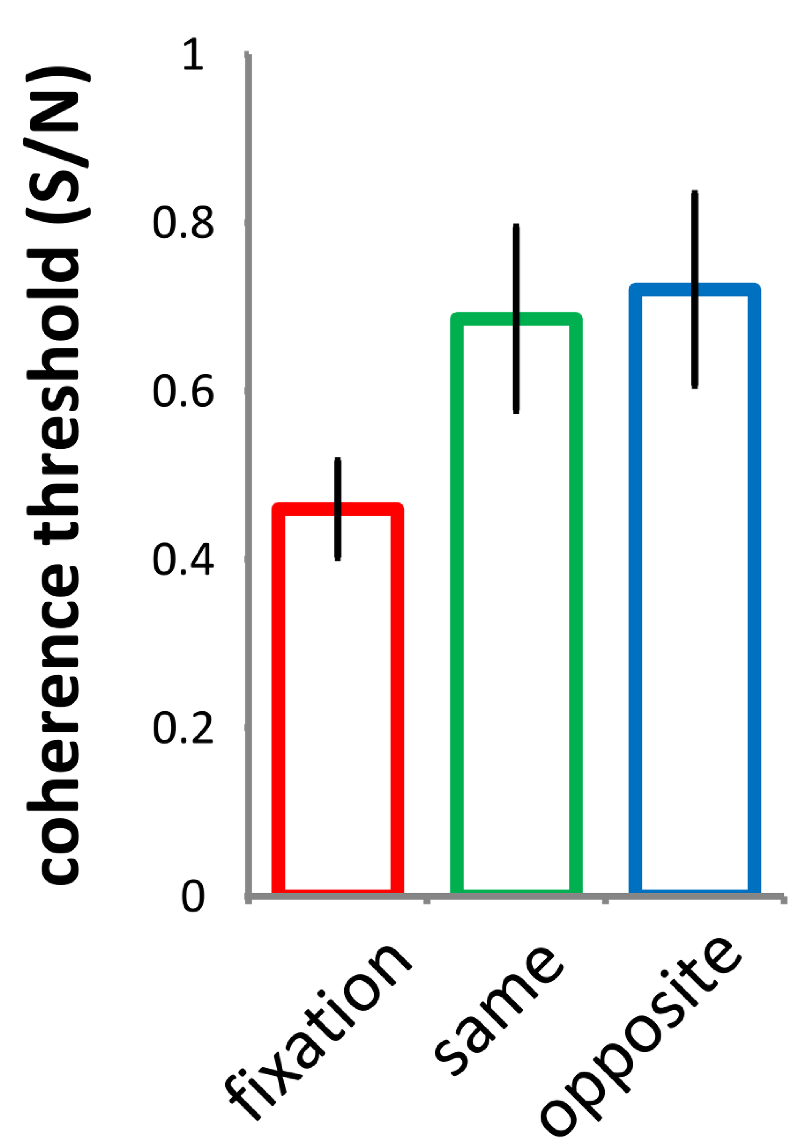

Figure 3. Exp. 1 coherence thresholds yielding 75% correct, group data. SEM error bars.

Exp. 2: Coherence thresholds, in a coherent motion discrimination task, depend on the direction of motion relative to the pursuit direction (Figure 4), being highest for global motion opposite to the pursuit direction (fixation vs. opposite, $p < 0.01$).

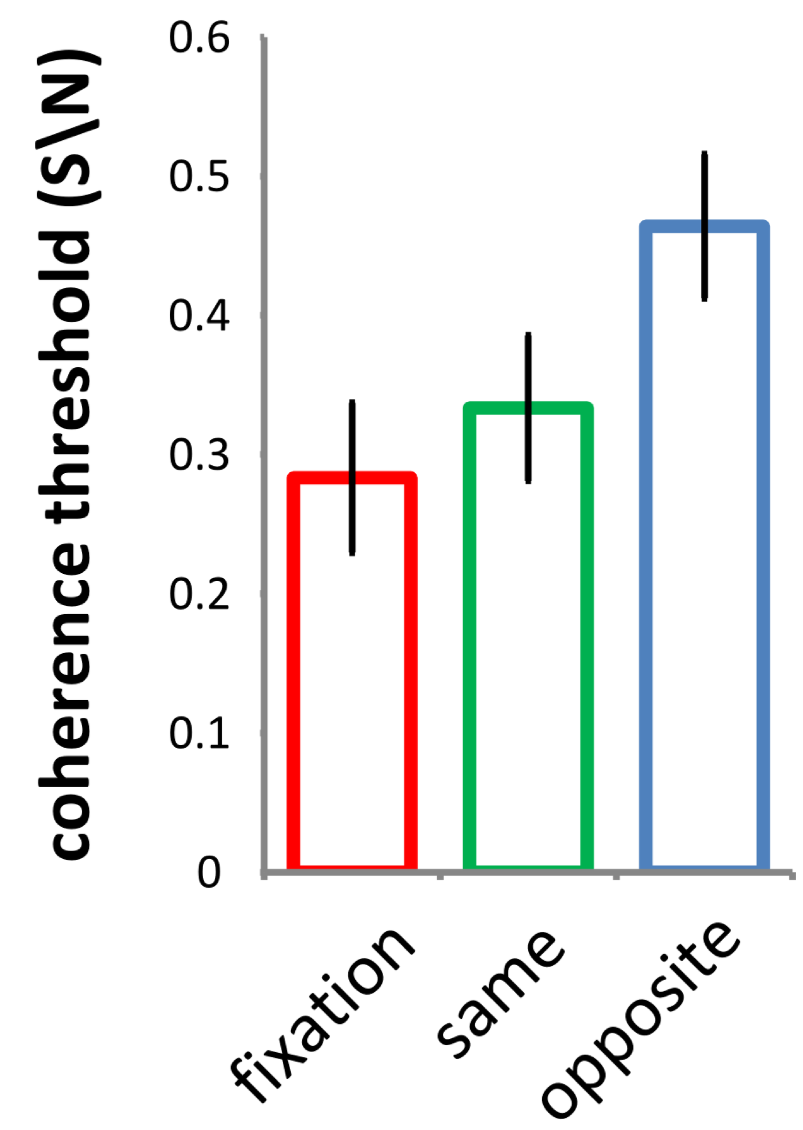

Figure 4. Exp. 2 coherence thresholds yielding 75% correct, in a 2IFC coherence discrimination task. SEM error bars.

Discussion

Coherence thresholds for direction discrimination are equally higher during pursuit conditions compared to fixation, suggesting ineffective pooling of motion signals across orientations, or alternatively a distorted perception of the elements during pursuit. In contrast, Greenlee et al. [2] showed "pop out" of same-direction motion signals with random dot kinematograms.

Coherence discrimination judgements indicate higher coherence thresholds with global motion opposite to pursuit than in the same direction, implying the influence of an extraretinal signal -- since retinal slip is similar for both opposite and same directions.

We speculate that the pooling of motion signals in the direction of pursuit is enhanced, although the particular way in which local signals are weighted leads to inaccurate estimates of global motion direction and of coherence compared to those obtained during fixation.

References

[1] Amano, K., Edwards, M., Badcock, D. R., & Nishida, S. (2009). Adaptive pooling of visual motion signals by the human visual system revealed with a novel multi-element stimulus. Journal of Vision, 9(3), 4 1-25.

[2] Greenlee, M. W., Schira, M. M., & Kimmig, H. (2002). Coherent motion pops out during smooth pursuit. Neuroreport, 13(10), 1313-1316.

Acknowledgements

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