Smooth pursuit eye movements and the segregation of coherent motion

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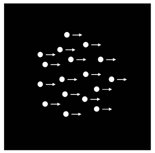
Introduction

Coherent motion stimuli have been used extensively as a research tool to study neuronal and perceptual motion sensitivity. Smooth pursuit eye movement are highly dependent on the percept of motion. However, so far coherent motion stimuli were rarely used in pursuit research[1,2]. **How sensitive are pursuit eye movements to variations in motion coherence?**

Methods

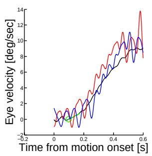
Stimulus: Moving random-dot pattern within a stationary circular aperture:



- Aperture radius: 10 deg
- Dot density: 2 dots/deg^2
- Dot life time: 200 ms
- Motion speed: 10 deg/s
- Motion coherence: 20 to 100%
- Coherent motion direction: left- or rightward

Analysis of pursuit eye movements: The average acceleration was calculated in a time interval of 50 to 150 ms after pursuit onset.

Determination of pursuit onset: 1. All traces were aligned to motion onset. 2. Eye velocity traces were averaged for each coherence level separately. 3. Single traces were shifted along the time axis to minimize the least-squares deviation from their corresponding average trace[3].



Discussion

Motion coherence was reflected in pursuit initiation (latency & acceleration), but not in steady state pursuit (velocity gain). Higher coherence resulted in shorter latency and faster acceleration. Prolonged exposure to high coherent motion seemed to diminish the advantage of high coherence, resulting in lower acceleration. This can be explained by motion adaptation, which has been shown to influence the initiation of smooth pursuit eye movements[4,5].

References:

[1] Heinen SJ & Watamaniuk SN. (1998). Spatial integration in human smooth pursuit. Vision Research 38, 3785-3794.

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[3] Osborne LC, Lisberger SG & Bialek W. (2005). A sensory source for motor variation. Nature 437, 412-416.

[4] Taki M, Miura K, Tabata H, Hisa Y & Kawano K. (2006). The effects of preceding moving stimuli on the initial part of smooth pursuit eye movement. Exp Brain Res 175, 425-438.

[5] Taki M, Miura K, Tabata H, Hisa Y & Kawano K. (2009). The effects of prolonged viewing of motion on short-latency ocular following responses. Exp Brain Res.

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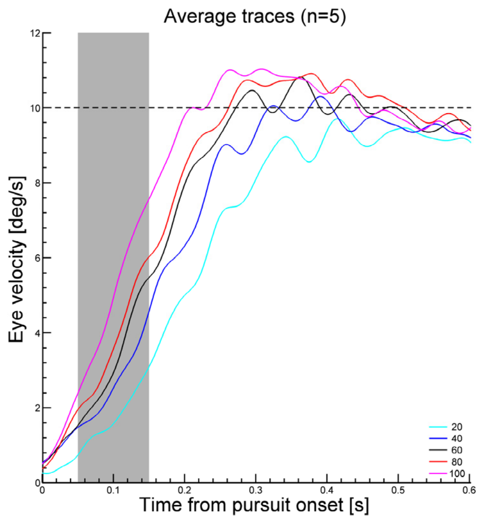
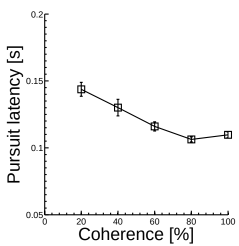
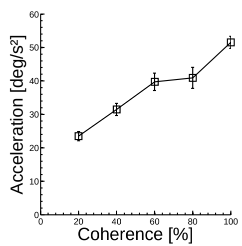
Motion Coherence

Methods: In the first experiment (n=5), we varied the coherence of the random-dot pattern (20, 40, 60, 80 & 100%). Subjects were instructed to pursue the motion as accurate as possible.



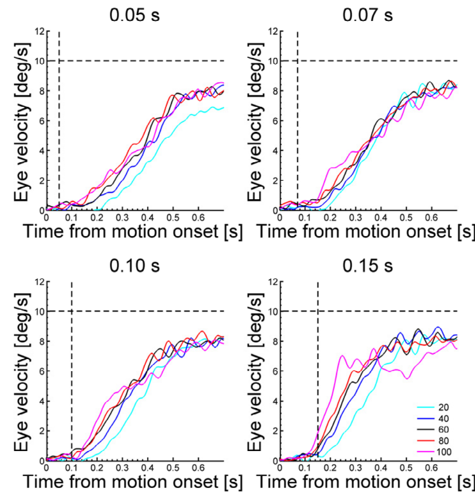
Results: The average traces (see above) showed a strong split between the different coherence conditions. For high coherences, there was a small overshoot of target velocity, which was not present for low coherences. Pursuit latency was negatively related to the coherence level (see below left). Initial acceleration was positively related to the coherence level (see below right) .



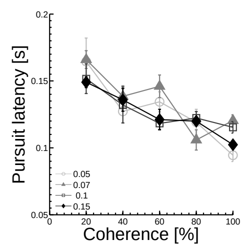


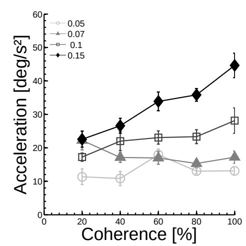
Motion Duration

Methods: In the second experiment (n=4), we presented the coherent motion only for brief durations (50, 70, 100 & 150 ms). After that the coherence dropped to 0% and all dots moved randomly. At the end of the trial, subjects had to judge the perceived direction of the initial motion. We analyzed only trials with correct judgments.

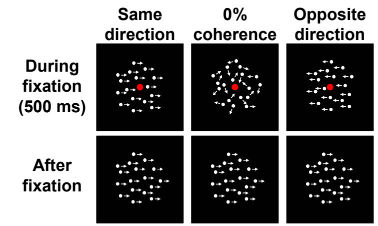


Results: Smooth pursuit gain was much lower than in the first experiment, but subjects were still able to execute smooth pursuit, although there was no coherent motion signal (see above). Pursuit latency was similar influenced by coherence for all motion durations (see below left). Acceleration however depended on initial motion coherence only for a initial motion duration of 150 ms (see below right).



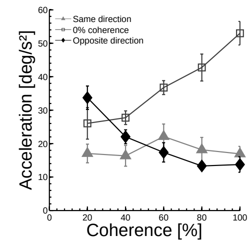


Motion before Pursuit



Methods: In the third experiment (n=4), we asked the subjects to keep fixation on a red, central fixation point for 500 ms. After the offset of the fixation point, subjects were required to initiate smooth pursuit eye movements.

Results: If the motion was the same, before and after fixation offset, there was no influence of the coherence level on the initial acceleration. However the general level of acceleration was very low at approximately 20 deg/s².



If there was only random motion during the fixation period, the results were the same as in the first experiment.

If the motion direction during fixation was opposite as during pursuit initiation, the relation between acceleration and coherence was inverted, showing large acceleration in the 20% coherence condition and low acceleration in the 100 % coherence condition.

Methods: To investigate this inverted relationship more closely, we varied the coherence before and after fixation offset independently in three steps (20, 60 & 100%) (n=2).

Results: Here, acceleration was inversely related to the fixation coherence level, showing the highest acceleration for 20% fixation coherence.

We also found again a positive relation between coherence and acceleration for fixation coherence levels of 20 and 60%.