Dynamic integration of salience and value information for smooth pursuit eye movements

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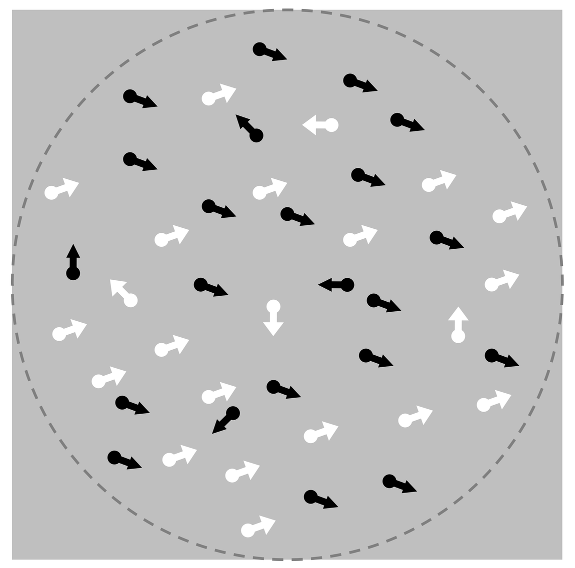
Introduction

We often direct our gaze to the part or object of a scene that appears to be most salient. Visual salience thereby strongly depends on bottom-up features, like relative luminance or color contrast [1]. Pursuit target selection is also known to be influenced by bottom-up features, like stimulus contrast or motion coherence [2,3]. However, top-down factors, like attention [3] or value [4] can also control smooth pursuit. Here we examine the integration of bottom-up salience and top-down value information for the dynamic guidance of smooth pursuit.

Methods



Our pursuit stimulus consisted of two overlapping random dot kinematograms (RDK) with opposite contrast polarities (black and white). The two RDKs moved either to the left or to the right, offset by 20 deg. The overall dot density was 1 dot/deg^2 and the RDKs moved with a velocity of 10 deg/s. The RDKs were presented in an aperture of 20 deg radius. Signal and noise dots had a lifetime of 200 ms and noise dots moved in a randomly selected direction for their whole lifetime [5].

To manipulate the relative salience, the coherence of the black RDK was set to 20, 40 or 80% whereas the white RDK had a fixed coherence of 40%.

In a salience baseline condition, we instructed subjects to simply pursue the stimulus. Here we also tested a control condition with only one RDK (black or white) to measure the individual variability of each observer. In a value condition, observers could gain a monetary reward for pursuing the white RDK. For the calculation of the reward, eye movement direction from 150 ms to 1500 ms after motion onset was used.

Conclusion

Our results show that salience and value information are dynamically integrated for smooth pursuit. The integration of the top-down value information seems to be slow since it is not present in the early phase of pursuit. This integration process also seems to be slower for the pursuit of moving stimuli than what we had previously observed for saccadic eye movements to stationary stimuli [7]. This could be due to limited top-down control of smooth pursuit or due to the higher complexity of moving stimuli.

References:

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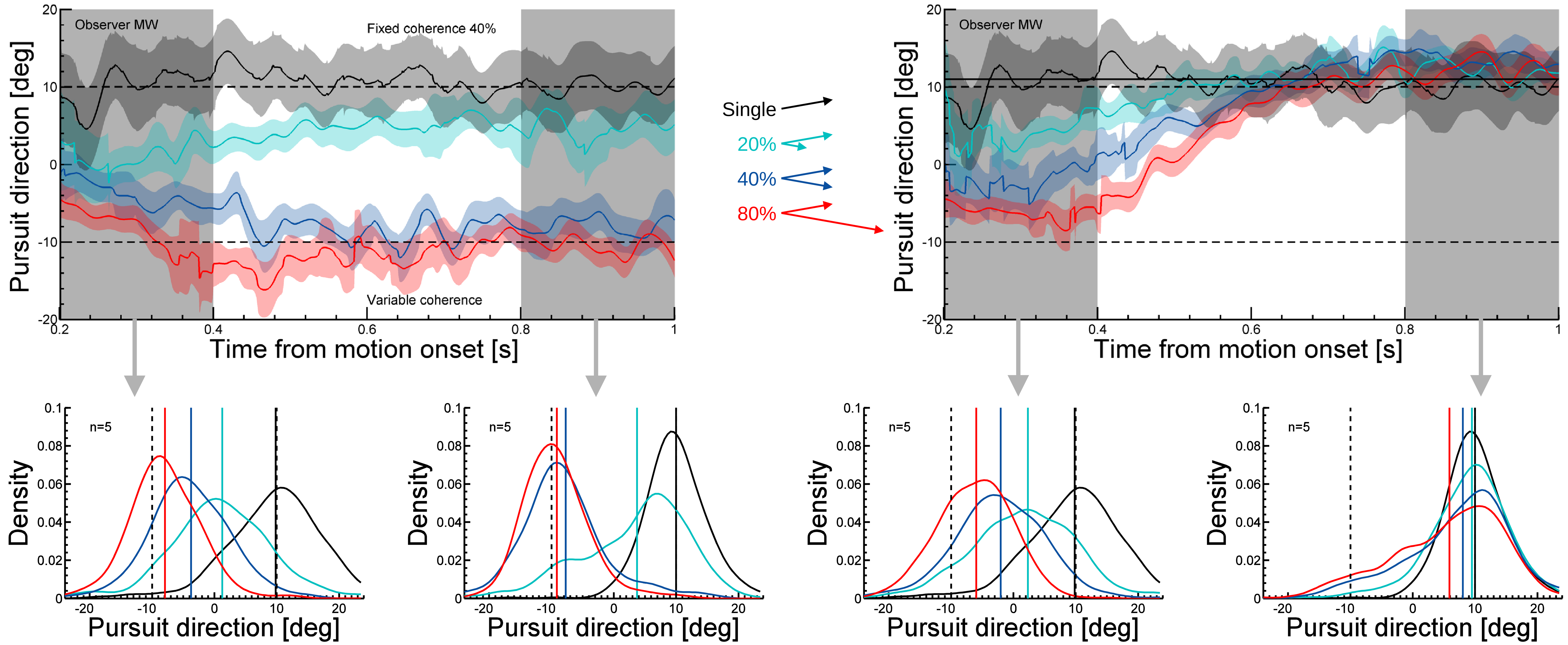
Salience

In the salience baseline condition, smooth pursuit initially moved in a salience-weighted average direction (200-400 ms). During steady-state, pursuit showed a winner-take-all behaviour and followed the RDK with higher coherence in most of the trials (800-1000 ms). For equal coherences there was a preference for the black RDK.

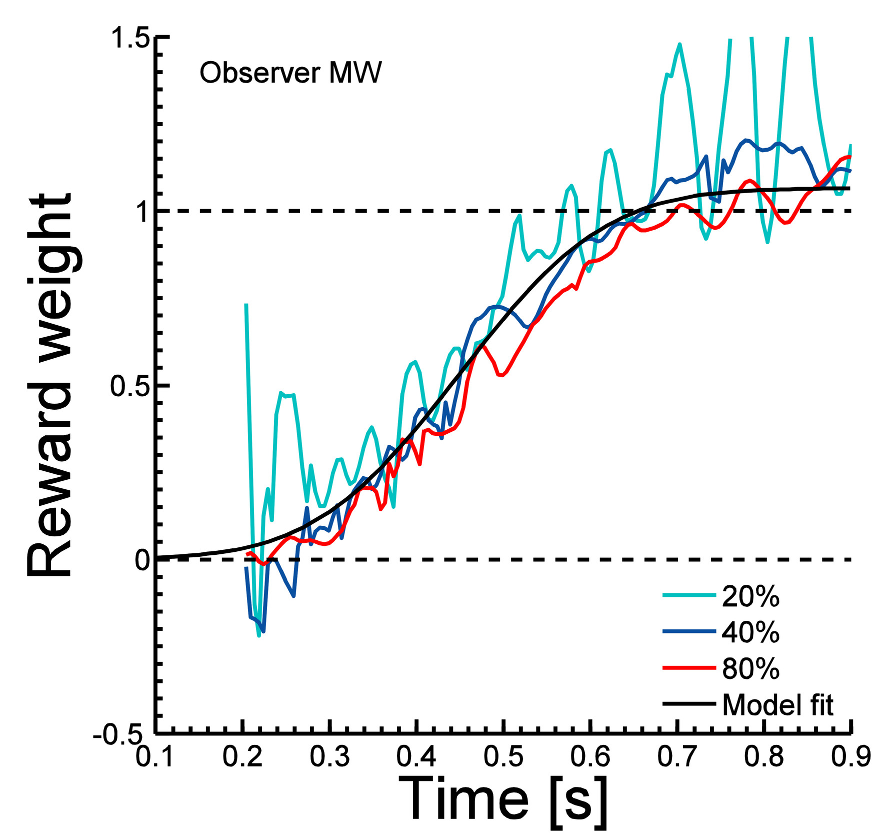
Value

In the value condition, both salience and value information influenced the fine-tuning of pursuit but with a different weighting over time. Observers initially followed a salience-weighted average direction. After about 400 ms, pursuit successively changed from the salient to the rewarded direction.



Model

We used the variability of the single RDK trials to predict the optimal pursuit direction according to the MEGaMove model [6]. To compute a relative weight of salience and value, we divided the difference between the pursuit direction in the salience and value conditions by the difference between the pursuit direction in the salience condition and the optimal pursuit direction. This value is zero, if pursuit is identical in the salience and value conditions and unity, if pursuit follows exactly the predicted optimal pursuit direction in the value condition.



We modeled the change from salience to value driven pursuit by a cumulative Gaussian function. Gray curves display results for single observers; the black curve the mean across observers. On average observers gave more weight to value than to salience 512 ms after motion onset and 402 ms after pursuit onset. There was no correlation between pursuit onset and the latency of the change from salience to value driven pursuit (rho = -0.04, p = 0.94). The average maximum weight observers gave to the value information was 80% according to our model.