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

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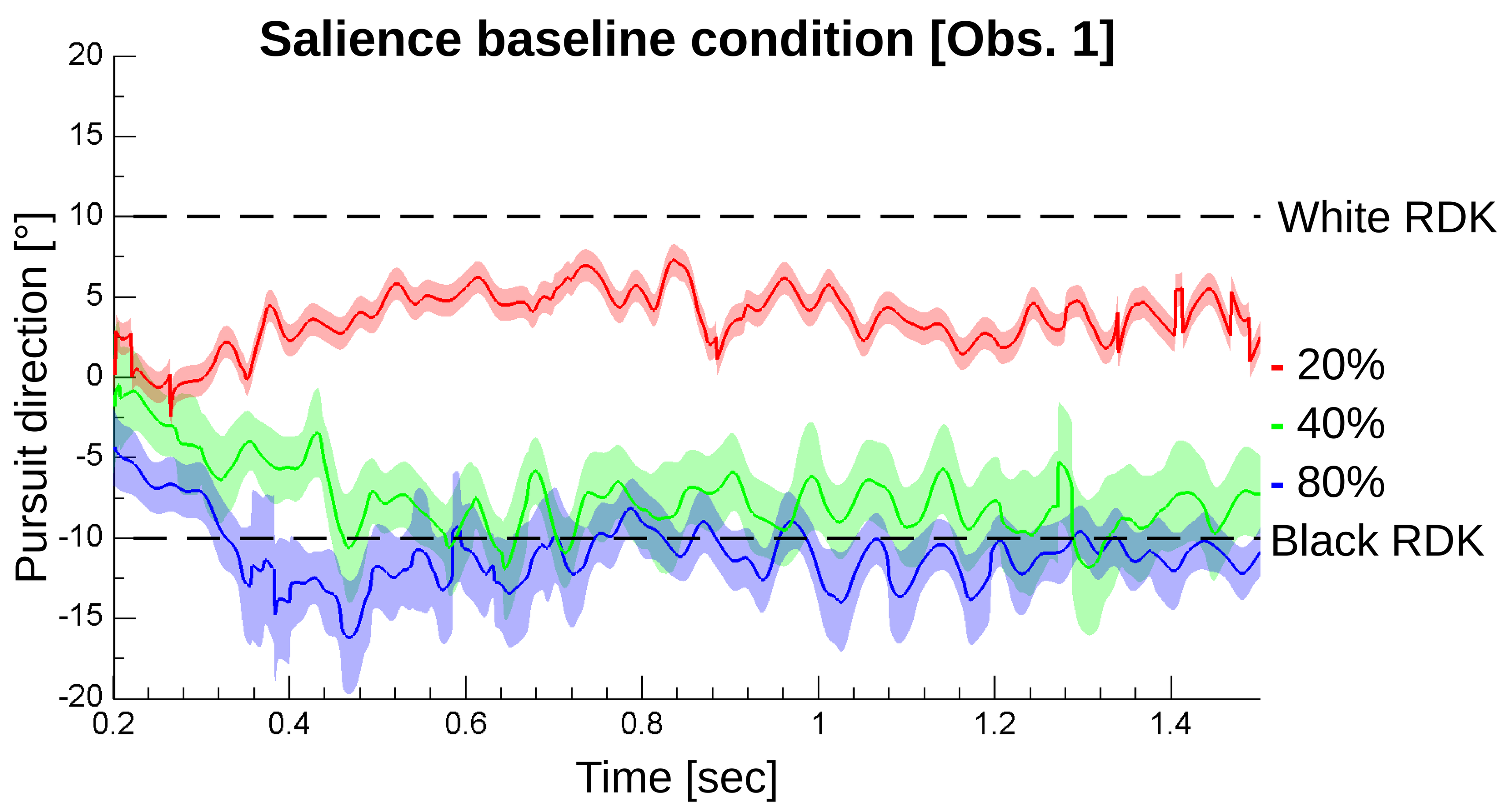
Introduction

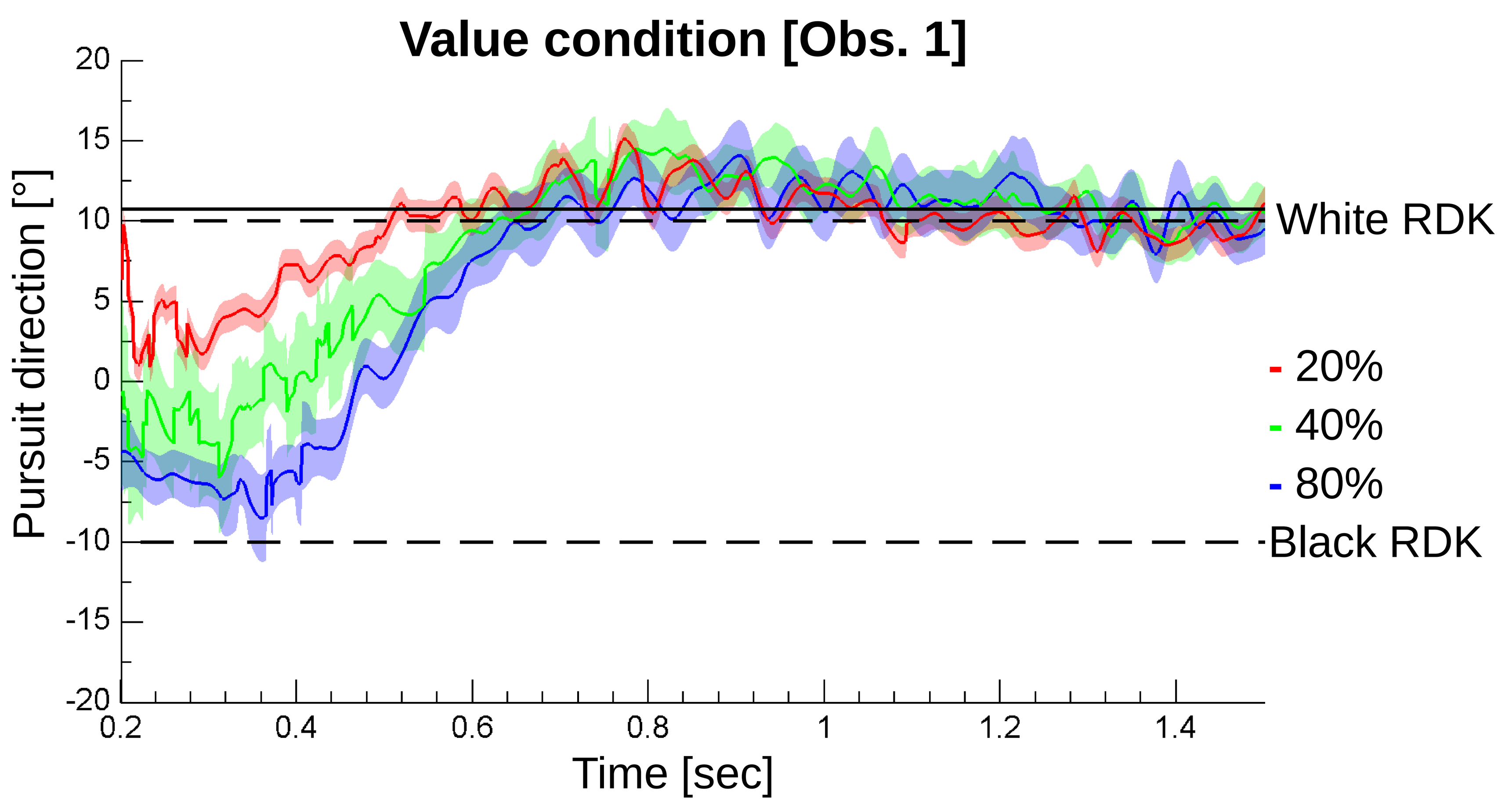
We often direct our gaze to the part or object of a scene that appears to be most salient. Visual salience thereby strongly depends on bottom-up features, like relative luminance or colour contrast (Itti & Koch, 2001). Pursuit target selection is also known to be influenced by bottom-up features, like stimulus contrast or motion coherence (Spering, Montagnini & Gegenfurtner, 2008; Krauzlis & Adler, 2001). However, top-down factors, like attention or task demands are also an important determinant of eye movement control and target selection (Land, 2006). Value information has recently been identified as an important determinant of behavior (Trommershäuser, Maloney & Landy, 2003). Value information modulates activity in various areas of the cortex (Sugrue, Corrado & Newsome, 2004), which are also involved in eye movement control. In the current study we examined the integration of bottom-up salience and top-down value information in the dynamic guidance of smooth pursuit.

Data



Salience effect:

In the salience baseline condition the smooth pursuit eye movements were biased in a salience-weighted average direction. The pursuit of our observers was shifted towards the direction of the motion of the target that appeared to be more salient.



Effect of value information:

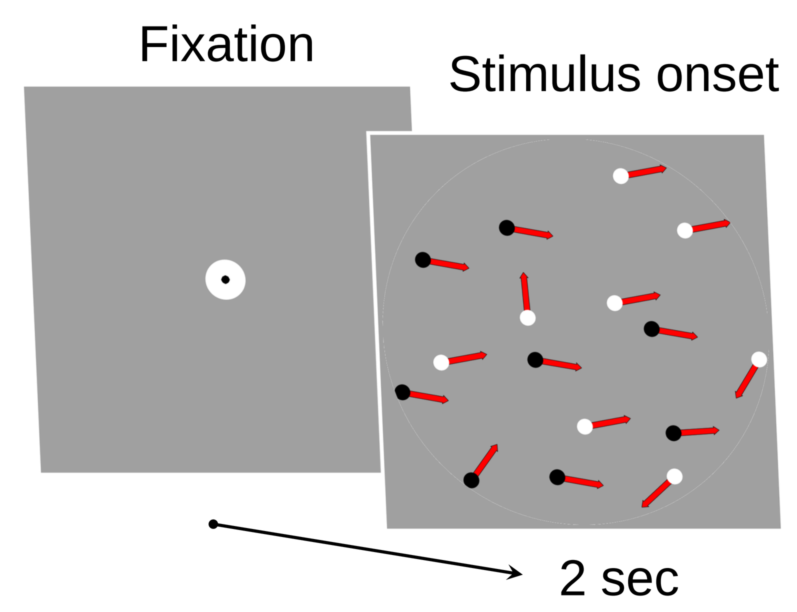
In the value condition both salience and value information influenced the fine-tuning of pursuit but with a different weighting over time. The pursuit direction was initially biased towards the stimuli which where more salient. In our experiment subjects exclusively followed the rewarded (white RDK) target after about 450 ms. Our observers showed differences concerning their performance but some actually executed pursuit in a direction that maximized expected gain.

Methods

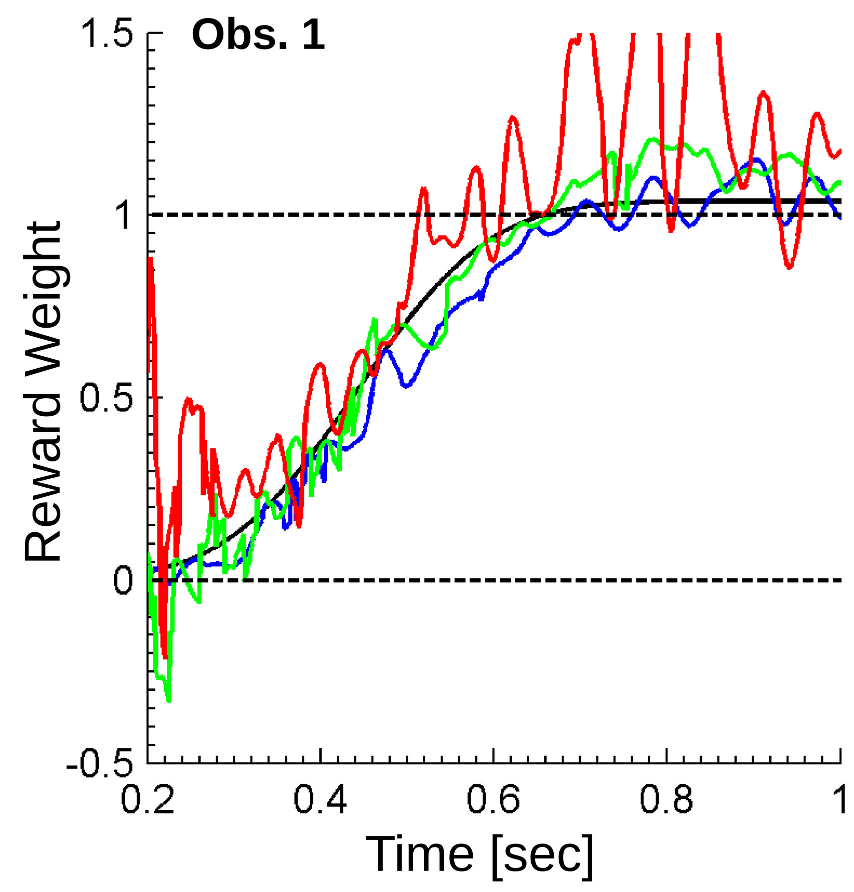
Our pursuit stimulus consisted of two overlapping random dot kinematograms (RDK) with opposite contrast polarity (black and white). The two RDKs moved either two the left or to the right differing by 20° . The overall dot density was 1 dot/deg² and the RDKs moved with a velocity of 10 deg/sec. The circular area in which the RDKs were presented had a radius of 20 deg.

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%. The direction (left or right) and angle (10° upwards or 10° downwards relative to the horizontal axis) of the coherent motion were randomised for the two RDKs.

In a salience baseline condition, we instructed subjects to simply pursue the stimulus. In a value condition, subjects won points for pursuing one RDK and lost points for pursuing the other RDK. The subjects were instructed to make as many points as possible, which were converted into a monetary reward at the end of the experiment.

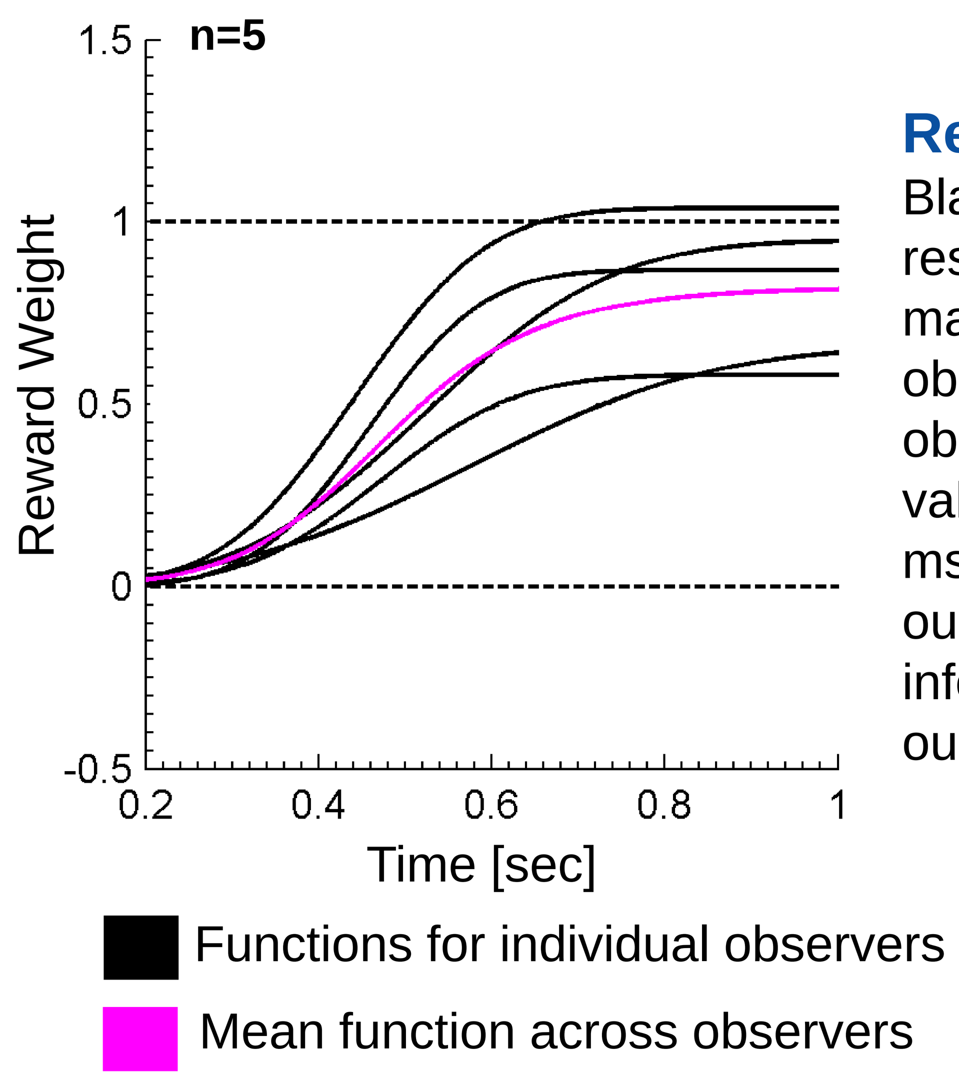


Model



Weight given to value information:

We modelled the change from salience to value by means of a cumulative gaussian function, which determines the relative weight of salience and value. For the first 442 ms, pursuit is dominated by the salience information of the stimuli. After 442 ms the observer started to follow a direction dominated by the value information



Results for all subjects:

Black curves display individual results for each observer, the magenta curve the mean across observers. On average our observers started to follow a value-weighted direction after 494 ms. The average maximum weight our observers gave to the value information was 82 % according to our model.

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 time-consuming since it is not present in the early phase of pursuit. This integration process seems to be slower for the pursuit of moving stimuli than what we had previously observed for saccadic eye movements to stationary stimuli (Schütz & Gegenfurtner, 2010). This could be due to limited top-down control of smooth pursuit or due to the higher complexity of moving stimuli.

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