Delays in sensory processing give rise to a lag between a stimulus and the organism’s reaction. This presents a particular challenge to tracking behaviors like smooth pursuit where a difference in eye and target motion creates image motion blur on the retina. One strategy that might compensate for processing delays is to extrapolate the future target position and make anticipatory eye movements. We recorded eye position in humans and monkeys engaged in tracking tasks to test for predictive information in eye movements. We used tasks with randomized jumps and direction changes (1D and 2D) and created a Pong-like video game in which the subject moves a paddle to keep a ball bouncing within an arena. Using information theory, we show that in most tracking tasks, gaze behavior is predictive on short ~200 ms timescales. But while playing Pong, prediction extends over several seconds and is very close to the bound imposed by the predictability of target motion. We also develop a model of short time scale prediction based on retinal inputs that accounts for decisions to saccade or pursuit during tracking.

Context dependent predictive information in gaze behavior

- In active Pong, predictive information in eye position compensates for sensory delays, and is very near the bound determined by the predictive information in the target itself, thus all that is predictable about the target is incorporated into behavior and thus optimal.
- In contrast, watching a movie of the Pong game generates gaze that is more reactive than predictive.

2. Predictive information in human gaze behavior

3. Predictive information in monkey gaze behavior

4. Gaze decision model - eye crossing velocity (VxE)

A change in target motion is sampled after a delay, B. Target motion is extrapolated, otherwise the subject saccades.

- A model of gaze based on extrapolation of retinal inputs (image position, velocity) and is verified by VxE that best predicts saccade or pursuit after target jumps.

- A change in target motion is sampled after a delay, B. Target motion is extrapolated to time A in the future.

- A change in the velocity vector to track the new target (VxE) vector below a threshold, pursuit is maintained, otherwise the subject saccades.

5. The VxE model predicts gaze across a range of times

We find the time A at which VxE is extrapolated, and the future time B at which VxE is evaluated to maximize Jensen-Shannon divergence (JS) of distributions P(VxE | saccade) and P(VxE | pursuit).

6. Summary

We find that the brain incorporates predictive information in gaze behavior in a context dependent manner. Prediction on short time scales (100-400 ms) helps to compensate for visual delays. A model based on extrapolation of retinal inputs (eye crossing velocity) predicts gaze decisions on shorter time scales (i.e., decision to saccade or pursuit).

References: