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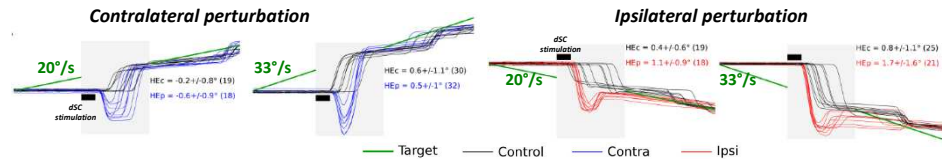
# Unsupervised learning of the trajectory of a moving visual target and evolution of its tracking in the non-human primate

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## Introduction

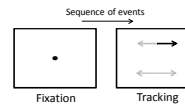
An object moving in the visual field triggers a saccade that brings its image onto the fovea. It is followed by a combination of slow (pursuit) eye movements and catch-up saccades that keep the target image onto the fovea as long as possible. The spatiotemporal accuracy of this ability to track the a moving target contrasts with the distributed nature of the encoding processes in the brain and the variable sensorimotor delays. Fleuriot & Goffart (2012) made observations which led them to hypothesize that the oculomotor system is driven by a command encoding the expected current spatiotemporal coordinates of the target (its here-and-now location), rather than a command encoding some (undefined) future location.



Obviously, the ability to continuously encode, in spite of neural conduction and stabilization delays, the here-and-now location of a moving target, requires that the goal follows an expected spatiotemporal trajectory and that its path has been memorized. We further developed this working hypothesis by studying how tracking a moving visual target is learned in the inexperienced rhesus monkey (*macaca mulatta*).

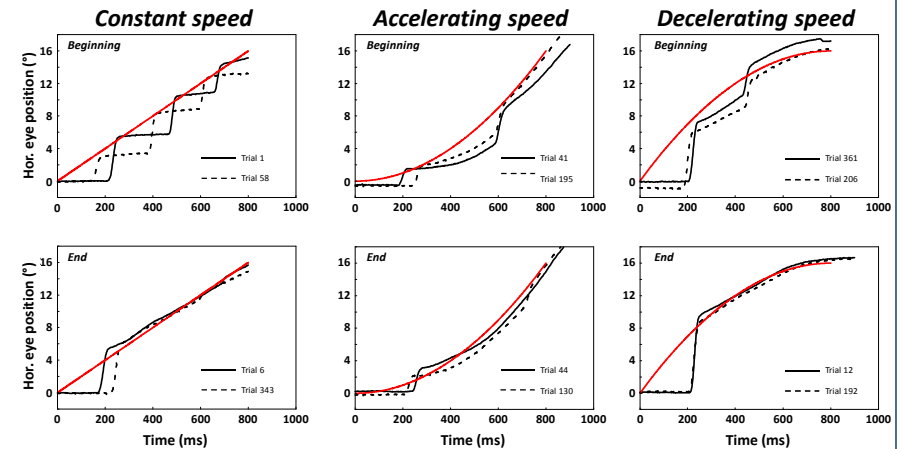
## Methods

6 monkeys were trained to track a target that moves along a horizontal path with a constant, accelerating or decelerating velocity (average velocity: 20°/s; constant duration: 800ms) in the upper or lower visual fields. The eye movements were recorded with the electromagnetic induction technique. Each trial started with the fixation of a small central target which, after an interval of 750-1500ms, stepped 16° on the vertical meridian (upward or downward) and immediately after, moved horizontally for 800 ms. The target moved 16° toward the left or right and disappeared there. The monkey was rewarded if it tracked the target up to this ultimate location.

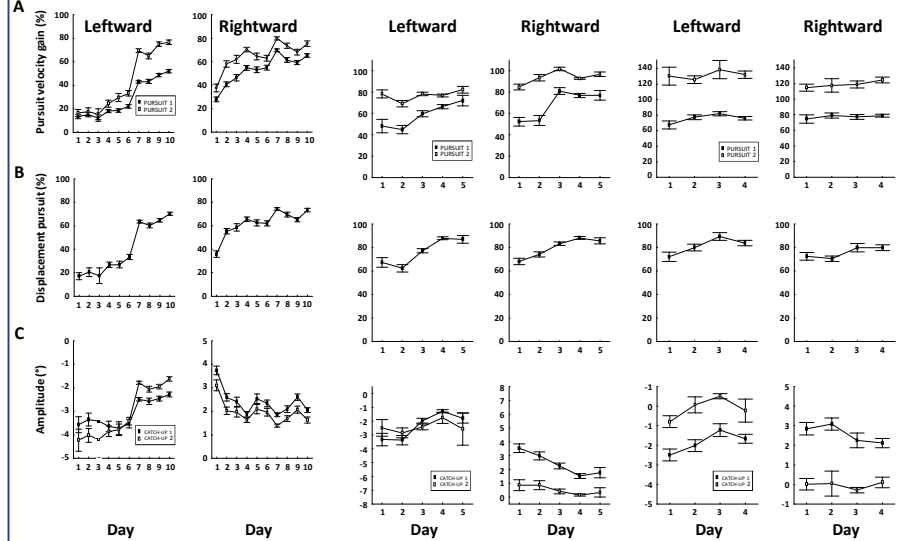


## Results

### Continuous speed tasks

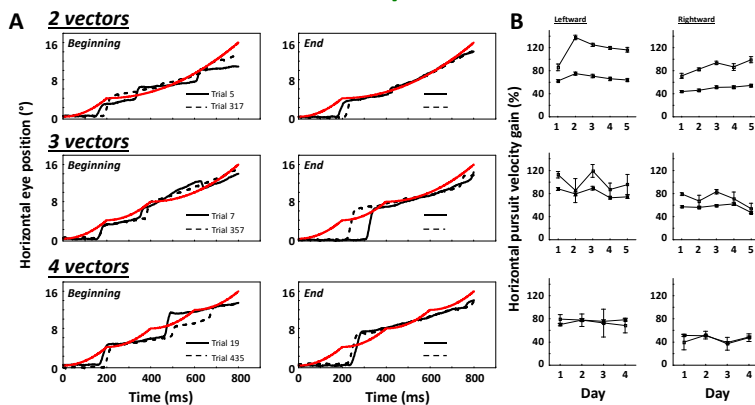


Selection of two representative trials (Constant velocity: monkey A, accelerating and decelerating velocities: monkey M) recorded at the beginning (first day) and the end (last day) of the training. The red and black traces correspond to the horizontal displacements of the target and the eye, respectively.



Evolution of the horizontal pursuit velocity gain (A), displacement pursuit (B) and catch-up saccade amplitude (C) during the first (filled symbols) and second (open symbols) pursuit episodes across the experimental sessions, for constant (left), accelerating (middle), and decelerating (right) velocities. The displacement pursuit corresponds to the ratio: sum of all pursuit displacements / complete eye displacement from the end of the interceptive saccade to the target offset time.

### Discontinuous speed tasks



A: Selection of two representative trials recorded at the beginning (left) and the end (right) of the 2 (up) 3 (middle) and 4 (down) acceleration vectors sessions.

B: Evolution across the experimental sessions of the horizontal pursuit velocity gain.

## Conclusion

The analysis of the tracking performance revealed a morphological evolution. In the beginning, the tracking was mostly saccadic, with very slow eye movements whose velocity was much slower than the target. Then, during the experimental session and the following training days, the velocity of slow eye movements increased together with the reduction of the size of saccades. These results show that the ability to maintain the image of a moving target onto the fovea is acquired and learned. During practice, the visuomotor channels are progressively reduced to those driven by foveal signals and the tracking gradually converges toward a continuous mode that mimics the dynamics of the target, re-instantiating its neural representation during the on-going action.