Microsaccade Patterns Evolve During Learning of a Covert Spatial Attention Task

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Abstract:

Studies in humans and monkeys have shown that small eye movements during fixation systematically vary with cued spatial attention. However, it remains unclear how these microsaccades relate to spatial attention in the absence of visual cues, which themselves impact microsaccade directions. Here, we investigated microsaccade properties of three macaque monkeys during learning of a blocked spatial attention task. Even without a visual cue immediately preceding each trial, microsaccade directions showed a clear dependency on the locus of spatial attention. We furthermore found that this relationship developed with learning of the task. Our results indicate that the link between microsaccades and spatial attention is subject to dynamic changes during training. Together, our findings provide further support for the view that microsaccades are meaningfully involved in cognition.

Keywords: **microsaccade; spatial attention; learning**

Introduction

During visual fixation the eyes of primates perform tiny movements (microsaccades) up to three times per second. Studies have shown that microsaccades occurring during covert attention tasks are modulated by the cueing of the visual attention locus and it has been suggested that microsaccade directions can be used as a measure of covert attention (e.g. Hafed & Clark, 2002; Engbert & Kliegl, 2003). However the exact relation between microsaccades and visual attention depends on the type of cue involved (e.g. Hafed & Clark, 2002; Laubrock et al., 2005). Here we investigated the relationships between microsaccades and visual attention in primates performing a blocked attention task, with no visual spatial cues preceding trial onset.

Methods

All experimental protocols were approved by the local authorities (Regierungspräsidium Tübingen). Three macaques were trained to perform a disparity-discrimination task (Kawaguchi et al. 2018) on one of two stimuli (~8 dva eccentricity), only one of which was informative about the correct choice (cued block-wise).

Five human subjects performed the same task but indicated their choices with button presses.

During the task the subjects' eye movements were tracked using the Eyelink 1000 at 500Hz, and microsaccades were detected using (U'n'Eye, Bellet et al. 2019).

Results

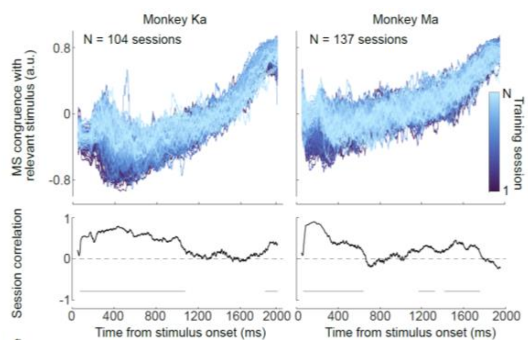

Figure 1: Microsaccade pattern evolves with task-learning.

Microsaccade pattern evolved during learning of the task, with an increase in congruence of microsaccades with the relevant stimulus at the beginning of the trial developing over training (Fig 1).

Microsaccades occurred typically shortly after fixation and stimulus onset and their direction reflected the locus of spatial attention during the trial in the fully trained animal. This pattern was similar even in the human subjects who indicated their choice with button presses.

Microsaccades directed towards the relevant stimulus at the beginning of the trial were associated with improved performance, particularly in easy trials. It suggests that an initial microsaccade not directed towards the relevant stimulus was indicative of a lapse of attention.

Conclusions

We found that microsaccade direction reflected the locus of spatial attention in a paradigm that does not involve cueing before each trial. This microsaccade signature of attention developed during the learning of the spatial attention task. It was predictive of the animals' performance, and may be useful to detect attentional lapses.

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