World-relative object motion: How the brain detects object motion while we are moving

ABSTRACT:

Background
The ability to detect and assess world-relative object motion is a critical computation performed by the visual system. This computation, however, is greatly complicated by observer motion, which generates a global pattern of motion on the observer's retina.

Aims
Here we aimed to understand how the visual system implements this computation by manipulating the relative motion velocity between the observer and the object within a stationary scene as a strategy to test how the brain accomplishes object-motion detection.

Method
26 healthy volunteers participated in the fMRI study. We first identified a set of egomotion-related visual areas (CSv, pCi, PIC, V6, V3A, VIP and MT+) by using the flow field stimulus and then examined their response to the main fMRI experiment consisting of observation of movies reproducing different velocities of visually induced translational self- and object-motion within a realistic virtual environment. Repeated-measures ANOVAs were used to test the brain sensitivity to different combinations of self- and object-motion. A parametric modulation analysis and a representational similarity analysis were used to test whether the activity of these regions was modulated by self- and object-motion velocity.

Results
We found that, among all the egomotion areas, CSv and V6 showed a remarkable preference for pure self-motion with respect to pure object-motion and to any combination of self- and object-motion. We also found that all the egomotion regions (except area PIC) responded to all the possible combinations of self- and object-motion and were further modulated by the self-motion velocity. Results from parametric modulations further revealed that area MT+ was also modulated by the object-motion velocity. Results from parametric multivoxel dissimilarities revealed that areas MT+, V3A and V6 showed a multivoxel pattern reflecting different velocities of both self- and object-motion.

Conclusions
A differentiated profile emerged among the egomotion regions during a visual motion stimulation including self- and object-displacements and a combination of them. In particular, areas MT+, V6 and V3A showed a response profile reflecting different self- and object-motion velocities. We suggest that these egomotion regions may be involved in the critical computational process needed to detect scene-relative object motion during visually induced self-motion.

Keywords

Optic flow, Motion detection, Flow parsing, Virtual reality, Functional magnetic resonance imaging (fMRI)

Published Work:

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