Modulating effects of optic flow on brain and body

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Introduction

In the field of neuroergonomics there is currently great interest in how perceptual cognition operates during everyday life. Here we focus on one experimental paradigm in which some of the deepest issues remain enigmatic, despite having been the topic of substantial research for several decades. These are the effects of optic flow on the mind, brain and body. Optic flow in this context refers to the moving visual input that falls on our retina as we move through the world around us, or watch the world go by. Optic flow can have several striking effects. Large moving visual stimuli can be so distracting as to prevent us from being able to pay attention to anything else. Since the optic flow mimics an important aspect of what we see when we move through the world, many report an illusory sensation of self-motion ("vection") or even start to physically sway back and forth. Like all rich dynamic stimuli, optic flow produces prominent brain activity changes measurable with EEG, perhaps most evident as the event-related desynchronization in the alpha band. It remains unclear however precisely which effects of optic flow are immutable and what neural substrate may underlie how they interact with perceptual cognition. We explored which cognitive and neuromodulatory manipulations can modulate, or survive, the effects of optic flow. We looked at the effects of exogenous attentional cueing (Experiment 1) and endogenous self-initiated preparation (Experiment 2).

Experiment 1: Attentional orienting depends on what people are doing at the time (Spence, 2010). Exogenous spatial cueing effects are abolished if participants simultaneously monitor a rapidly changing central visual stimulus (Santangelo et al., 2007). Attentional effects are eliminated in a range of settings (Boot et al., 2005; Cosman & Vecera, 2009; Folk et al., 2009), even if the distracting central stimuli are task irrelevant and require no response (Visser et al., 2004), do not comprise any sudden onsets (Kellie & Shapiro, 2004) and bear only low perceptual load (Santangelo et al., 2007, 2008). Optic flow is presumably visually distracting: can this be measured, and what are we capable of doing despite this distraction?

Experiment 2: Self-initiated actions can have their own sensory consequences. These self-produced sensory stimuli need to be predicted, and compensated for, in order to allow both perceptual stability and efficient motor control (Rao RPN and Ballard DH, 1999;Von Helmholtz H, 1867;von Holst E and Mittelstaedt H, 1950). Optic flow suppresses neural oscillations, as measured by event-related desynchronization (ERD (Ehinger B et al., 2014;Palmisano S et al., 2016;Vilhelmsen K et al., 2015) and is associated with increased experience of presence in VR (Kober SE et al., 2012). Alpha-band ERD can be interpreted to reflect the end of the modulatory effect of alpha (Klimesch W,Sauseng P and Hanslmayr S, 2007), or disinhibition (Edwards AE et al., 2018). Which neural processes are sensitive to whether optic flow is self-initiated or externally generated?

Methods

Experiment 1: Can our attention still be drawn to flashed peripheral stimuli even while viewing optic flow? We investigated this by combining a cued visual motion discrimination task with optokinetic stimulation (OKS). Exogenous attention was modulated by peripheral stimuli, cues presented at the same (valid) or at the opposite (invalid) location of impending targets, while participants were looking passively at the middle of a moving background, in order to elicit a reflexive eye response, or while they were fixating on the moving background.

Experiment 2: Optic flow causes postural sway, and causes a strong alpha ERD in the EEG. What if we are expecting the optic flow: can we prepare ourselves for this input and can this affect our sway and brain responses? We measured behavioural, neurophysiological and head motion responses of 29 healthy participants to radially expanding, vection-inducing optic flow stimuli, simulating forward transitional motion, which were either initiated by the participant's own button-press ("self-initiated flow") or by the computer ("passive flow").

Results

Experiment 1: Exogenous attentional cueing modulated the behavioural response and brain activity both during ongoing reflexive eye movements and during fixation, shown by a facilitation in the reaction times in valid compared to invalid trials and a reduced P1 component.

Experiment 2: Self-initiation led to a prominent and left-lateralized inhibition of the flow-evoked posterior event-related alpha desynchronization (ERD), and a stabilisation of postural responses. Neither effect was present in control button-press-only trials, without optic flow. Additionally, self-initiation also produced a large event-related potential (ERP) negativity between 130-170 ms after optic flow onset.

Discussion

Experiment 1: Attentional cueing can modulate the perceptual judgment of stimuli presented during OKS, and the perceptual processing of those stimuli.

Experiment 2: The visual system is capable of predicting optic flow when self-initiated, and these predictions can affect behavior. The event-related desynchronization has multiple potential sources and we show it can be modulated by voluntary prediction during optic flow.

Optic flow has striking effects on brain and behavior. These data explore how it is that these effects are not fixed, but to some extent are under the participants' own control. These results bear impact on both basic and applied research questions. Recently it has been suggested at both the psychological and neural levels that the relationship between visual cognition and navigation might be fundamental (Wolfe 2021, Nau et al. 2018). Furthermore, the effects of optic flow on brain, mind and body have relevance to virtual reality applications and the changing demands of the workspace of the future. It is of particular interest in the fields of transport, VR and AR whether the automatic and reflexive responses to optic flow can be inhibited, because this can contribute to participants' reported subjective experience and objectively measured behavioural performance. Future work can explore how other factors may affect optic flow such as movement of the limbs and eyes, or non-invasive brain stimulation. Developments in mobile EEG must be exploited to extend this exploration of optic flow into the domain of real locomotion: stationary setups may be an inaccurate echo of what really occurs during genuine movement.

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