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Abstract

Hunger was found to facilitate visually induced illusory upward and downward self-motions (vertical vection), but not illusory self-motion in depth (vection in depth). We propose that the origin of this hunger effect lies in the possibility that vertical self-motions (both real and illusory) are more likely to induce changes in visceral state.

Keywords

vertical, hunger, vection, enhances

Disciplines

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SHORT AND SWEET

Hunger enhances vertical vection

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Abstract. Hunger was found to facilitate visually induced illusory upward and downward self-motions (vertical vection), but not illusory self-motion in depth (vection in depth). We propose that the origin of this hunger effect lies in the possibility that vertical self-motions (both real and illusory) are more likely to induce changes in visceral state.

Keywords: vection, hunger

Visceral states (such as stress, hunger, thirst, and sexual desire) have been shown to play important roles in both cognition and behaviour. For example, studies have shown that bladder pressure increases our ability to resist impulsive choices during decision making (Tuk et al 2011). Other research has shown that our propensity towards risk taking and the value that we assign to goods both change as a function of our blood glucose levels (Briers et al 2006; Wang and Dvorak 2010). Here we examine whether visceral states also play an important role in perception. The particular focus of this study was on the effect of hunger on self-motion perception. Real-world self-motions are often accompanied by an increased awareness of our visceral states. It is also possible to generate compelling visual illusions of self-motion (known as vection) in physically stationary observers. Interestingly, these vection displays often generate simulator sickness (or cybersickness) symptoms that are remarkably similar to visceral experiences during real self-motions (eg increased stomach awareness—see Bonato et al 2009; Palmisano et al 2007). It has often been anecdotally reported, and has now been shown scientifically, that motion sickness severity increases with hunger (Uijtdehaage et al 1992) as well as being highly correlated with vection (Hettinger et al 1990). Furthermore, vection inhibits activity of the stomach and may delay gastric emptying (eg Faas et al 2001). These facts led us to hypothesise that hunger could enhance vection. We examined this possibility in this study.

Fourteen volunteers participated in this experiment. The different experimental conditions (hungry and normal) were tested on separate days. The testing order ('normal then hungry' or 'hungry then normal') was counterbalanced among all participants. Prior to testing in the hungry condition, the subjects were told not to eat anything (except for water) that day until they had finished their testing for the day (vection was tested at the same time of the day—12:00 PM—for all subjects). The normal condition was tested at the same time, but on a different day. Prior to testing in the normal condition, the subjects were instructed to eat as they normally would on any other day. During each trial, the seated subjects viewed displays which either simulated constant-velocity forwards and backwards self-motion or upwards and downwards self-motion. Vertical and in-depth vection trials were conducted on the same day. Each condition for four different directions of vection was conducted four times repeatedly. There were 32 trials in total. The vertical motion stimuli were grating stimuli (spatial frequency 0.1 cycle deg⁻¹; mean luminance 18 cd m⁻²; Michelson contrast of 10%), which simulated

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either upward or downward self-motion at a speed of approximately 15 deg s^{-1} . For vection-in-depth stimuli, we used either a radially expanding or contracting optic flow pattern, created by positioning 16 000 dots at random inside a simulated cube (length 20 m), which simulated forward or backward self-motion at 16 m s^{-1} respectively. These vection-in-depth stimuli were the same as those used in Seno et al (2011). These visual motion displays subtended a visual area of 72 deg (horizontal) \times 57 deg (vertical) when viewed from a distance of 57 cm in front of the screen. Subjects were asked to press a button when they perceived vection. We recorded the duration and latency of button-press of vection. At the end of each trial, the observers rated the subjective strength of their vection on a scale from 0 (no vection) to 100 (very strong vection).

Vertical vection was more compelling in the hungry (compared to the normal control) condition (figure 1). There were significant differences between all three vection measures (latency: $t_{13} = 2.84$, $p < 0.01$; duration: $t_{13} = 2.57$, $p < 0.05$; strength: $t_{13} = 3.76$, $p < 0.05$). Specifically, we found that vertical vection was induced earlier, lasted longer, and was rated as being stronger when our participants were hungry. Thus, it appears that we are more sensitive to our self-motion when we are hungry (even when this self-motion is illusory in origin). However, hunger appeared to have no significant effect on vection (compared to the normal control condition) when the displays simulated forward and backward self-motion (ie vection in depth) (latency: $t_{13} = 0.99$, $p > 0.05$; duration: $t_{13} = 0.89$, $p > 0.05$; strength: $t_{13} = 1.02$, $p > 0.05$).

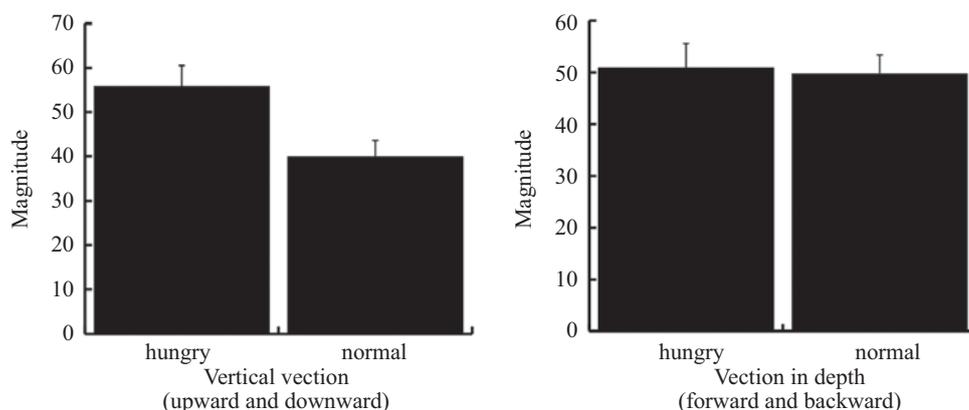


Figure 1. The results of vection. The error bars represent 1 SE.

We also carried out an informal observation with four naive volunteers, where we presented them with leftward/rightward display motion (vertical grating) and examined the horizontal vection induced. We found no difference in the vection induced by this stimulus when participants were hungry compared to when they were not. Since the vertical display motion in the main experiment should have induced a similar type of eye movement (optokinetic nystagmus, OKN) to the horizontal display motion in this control experiment (albeit along a different axis), these findings suggest that eye movements were not the dominant factor in the observed hunger-based enhancement of vertical vection.

It has been reported that gravireceptors are located in the trunk in addition to inner ear (Mittelstaedt 1992; Mittelstaedt and Fricke 1988). These trunk gravireceptors are thought to be related to motion sickness and self-motion (von Gierke and Parker 1994). We speculate that when one is very hungry, the reliability of these trunk-based gravireceptors is reduced by the altered visceral state. In principle, physical self-motions could be detected nonvisually, based on the inertia of the participant's stomach (ie a low-pass phase-delayed visceral perception). However, fasting will reduce the mass of the participant's stomach contents, ie inertia.

This may also reduce the likelihood of intermodal sensory conflict occurring when physically stationary observers view self-motion displays (von Gierke and Parker 1994).

If the above account is correct, this raises the question why a link was only found between hunger and simulated vertical self-motion? Reports suggest that our abdominal visceral receptors are specialised for detecting gravity (Mittelstaedt 1992). We speculate that, if signals from these abdominal graviceptors are less reliable due to fasting (ie the physical weight reduction), then the expected change in viscerally detected gravito-inertial force during vertical vection should be weaker. According to this notion, viewing vertical self-motion displays when hungry should result in less intermodal conflict (compared to normal conditions), which in turn would enhance the visually induced perception of vertical self-motion. However, since the intermodal conflict produced by horizontal vection displays was not as great as that produced by vertical vection (during normal conditions), the occurrence of horizontal vection was relatively unaffected by fasting.

It should be noted that most natural self-motions, such as walking, tend to generate oscillatory head motions along all three axes (horizontal, vertical, and depth), across a wide range of frequencies (0.1–10 Hz)—eg Palmisano et al 2011. The current study only examined the effects of hunger on the visual perceptions of constant velocity self-motions along a single axis. Thus, it is uncertain how the current findings will extend to accelerating self-motions or to simulated self-motions along multiple axes. These will both be the topics of future research.

Angelaki and Cullen (2008) reviewed the interaction of vestibular system and vision. Self-motion is mediated by multiple modalities. One of those is the vestibular input. Vestibular and visual inputs are integrated in medial superior temporal area (MST) (Gu et al 2008). In addition, it was reported repeatedly that, during vection experience, MST is activated (eg Brandt et al 1998). Thus, one possible locus of interaction of vision and vestibular information of self-motion should be MST. MST might be involved in the results obtained in this study. In future studies, we will focus on the activation of MST during vection with hunger.

Our results might be related to orthostatic hypotension, dizziness, or low blood glucose. However, the modulation of vection by hunger was not obtained in depth and horizontal vection. This might indicate that our results should be related to graviceptors in trunk rather than to simple dizziness. This is an important future topic to be examined.

In conclusion, we found that vertical vection was more compelling when subjects were hungry (compared to normal conditions). However, hunger did not appear to alter their experience of vection in depth. We propose that this discrepancy arose because visceral states are more tightly related to vertical self-motions than to self-motion in depth.

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