Vection can be induced without global-motion awareness

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Abstract

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Abstract. A new vection illusion is reported. Vection was induced even though there was no consciously perceived global display motion corresponding to the self-motion. The resulting experience can be summarised as: "I feel that I am moving but I do not know why".

Keywords: vection, motion perception, awareness, consciousness

Global patterns of optic flow are capable of inducing visual illusions of self-motion in physically stationary observers, known as vection. In previous vection studies, observers were always aware of the global motion which was present in their optic-flow displays (eg Brandt et al 1973; Seno et al 2011). In this experiment, we examined whether vection can be induced when observers are unaware of the global display motion. Previously, Maruya et al (2008) have shown that motion awareness can be inhibited by the continuous flash suppression (CFS) method. In a similar fashion, here we also plan to alter the visibility of the global motion in our displays, so that our observers are not always consciously aware of it.

Our computer-generated motion displays typically contained both local and global motion components. Subjects always looked at a fixation point located at the centre of the screen when viewing these 30 s motion displays.

The local motion was generated by 200 discrete grating patches (in many cases these grating patches overlapped—see figure 1). The sizes, as well as the mean luminance and contrast values, of these individual grating patches were all randomised (see the demo movie at http://dx.doi.org/10.1068/p7206). Each grating patch displayed either horizontal or vertical motion—moving in one direction (either up, down, left, or right) for 0.7 s at 6 deg s^{-1}. After each 0.7 s both the locations of these 200 patches and the directions of their motions were randomly altered. The spatial frequency of each of these local motion patches was always 1.0 cycle deg^{-1}. Henceforth, we will refer to this component of the stimulus as a Mondrian grating.

We superimposed global motion onto this Mondrian grating. Unlike the local motions in the Mondrian grating, the global-motion component moved in the one direction for the entire display (either up, down, left, or right). It only changed direction from one trial to the next. In order to generate this global motion, we multiplied each patch of the Mondrian grating by the luminance of a global sine-wave grating. This global motion was clearly visible if the contrast of this motion component was high. Thus, to produce our 'unaware' condition, we set the contrast of this global motion to 4% (Michelson contrast). We also tested two other contrast conditions: 'highly visible', where the contrast was set to 40%, and 'less visible' 8% conditions. In addition, we also tested a 'no global motion' control condition. The spatial frequency of the global motion was 0.3 cycle deg^{-1}. The velocity of this global motion was 45 deg s^{-1}. There was a fixation point in the centre of the screen.
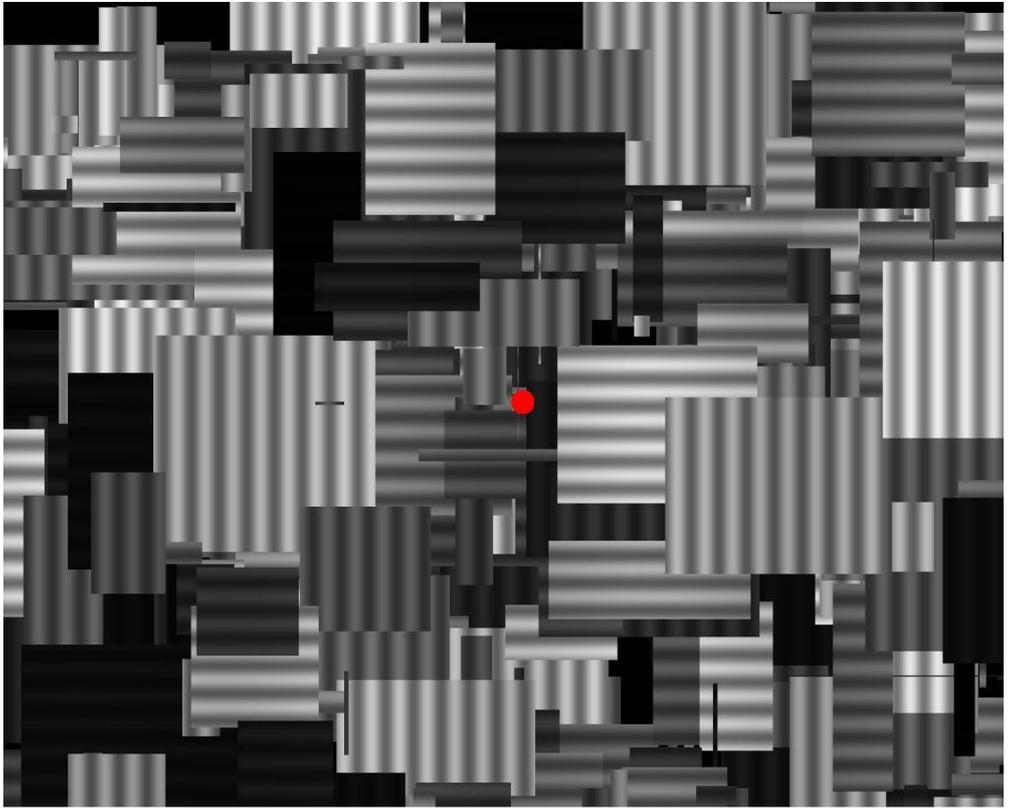
Figure 1. [In colour online, see http://dx.doi.org/10.1068/p7206] The Mondrian grating. Each local patch in this Mondrian display moved in a different (horizontal or vertical) direction. Vection was induced by superimposing a global-motion signal (luminance-defined global grating)—which was not always consciously perceptible—onto this Mondrian grating.

Ten naive volunteers participated in this experiment. The vection testing session consisted of 12 trials (3 replications of each of the four stimulus conditions). In each of these trials, subjects reported both the presence of vection and its direction by pressing a corresponding button. In the perceived global-motion testing session, subjects reported the perceived direction of any global motion by pressing a corresponding button. The stimulus duration for trials in both testing sessions was 30 s.

We found that perceived motion was reported in the correct direction for the longest period of time for the high-contrast (ie 40%) global-motion displays (for, on average, 25 s out of the total 30 s). However, correct motion direction reporting declined as the contrast of the global motion was reduced (figure 2). The ratio between the durations of correct and incorrect motion direction reporting fell to ~1:3 when the contrast was reduced to 4%. Since this represents change performance (ie there were four possible global-motion directions), this finding confirms that observers were unaware of the hidden global motion in this particular condition.

Vection was expected to be induced by the display's global motion and occur in the opposite direction to this component of the display motion (at least in conditions where this global-motion component was visible). As with perceived motion, correct vection direction reporting was found to decline when the contrast of the global motion was reduced (figure 3). However, performance was still better than chance in both the 4% and the 8% contrast conditions. This finding suggests that vection direction can be altered by global motion even when we are not aware of this motion.
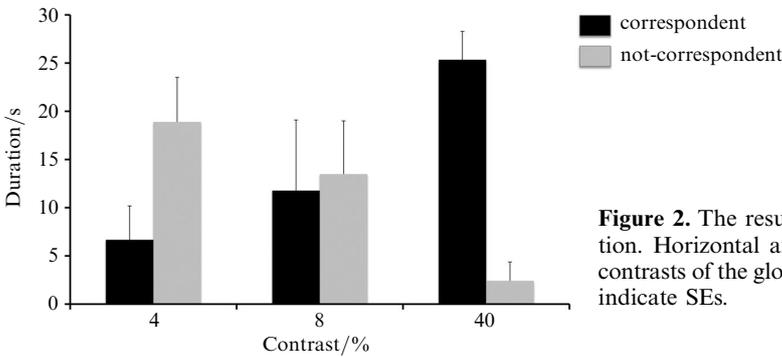
Figure 2. The results of motion perception. Horizontal axis indicates the three contrasts of the global motion. Error bars indicate SEs.
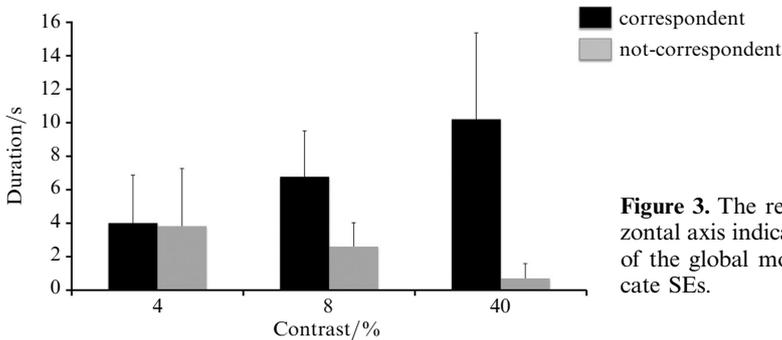

Figure 3. The results of vection. Horizontal axis indicates the three contrasts of the global motion. Error bars indicate SEs.

Interestingly, it did not appear to matter whether the observer was aware or not of the global display motion in terms of initially inducing vection. Vection onset latency was approximately 12 s for all three of the global-motion contrast conditions tested (ie 40%, 8%, and 4%). However, our Mondrian-based motion stimuli appeared to generate weaker vection (longer onsets and shorter durations) than the explicit motion stimuli we have tested previously (eg Seno et al 2011). In the 'no global motion' condition, the total vection duration was only 1.7 s on average. The rather short vection durations found in this condition suggest that the global motion is likely to be the main factor in inducing vection (even if it is not consciously visible to the observer).

The stimulus we used in this experiment was designed on the basis of the findings of a series of pilot experiments. In the first of these pilot experiments we examined a luminance-defined moving grating (identical to the hidden global-motion stimulus used in the main experiment but without the many small masks). We reduced the contrast of this grating display until the direction of its global motion could no longer be detected. However, the contrast of this display was then too low (0.05%) to induce any vection. In another pilot experiment we varied the strength of the global-motion signal provided by a vertically moving dot pattern (by replacing dots moving in the same direction with randomly moving dots). However, again, when the global-motion direction could no longer be detected, the display was not able to induce any vection. By contrast, in our Mondrian-based motion displays, vection could be still induced even when the global-motion direction was no longer consciously detected (ie when the contrast was 4%). The global motion we used would normally be (i) consciously perceived and (ii) serve as a strong vection stimulus. Even though subjects were unaware of this global motion when it was superimposed on strong local masking motions, this 'hidden' global motion was still able to induce vection. This is the reason why we succeeded in inducing vection without global-motion awareness.

We additionally measured the horizontal eye positions of two head-fixed observers as they viewed these stimuli. We found that eye position was biased by approximately 2.5 deg on average (over the first 10 s exposure to the motion display) in the direction of the global motion for both 4% and 40% contrast displays). This bias in eye position was absent in the no-global-motion condition (0%) (figure 4). These findings suggest that even though the observer was not aware of the 4% contrast global motion, it was detected correctly by his/her oculomotor systems and could still modulate vection.
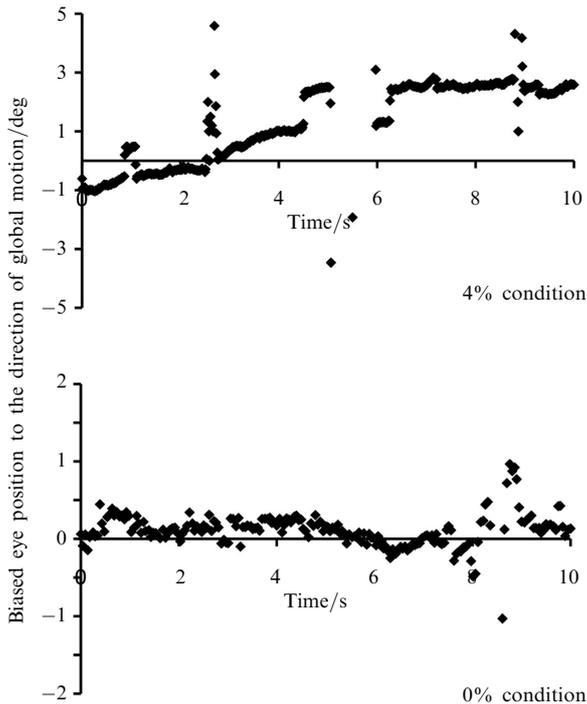

Figure 4. Typical examples of time course of the eye positions.

We propose that vection is supported by at least two pathways: a conscious pathway based on global-motion perception and a subconscious pathway which involves oculo-motor modulation (figure 5). Optic-flow-based self-motion displays not only generate conscious perceptions of motion and self-motion, but they also provide important information for the control of self-motion. When viewing such a display, conscious perceptions of motion, vection, and control based effects (optokinetic eye movements,
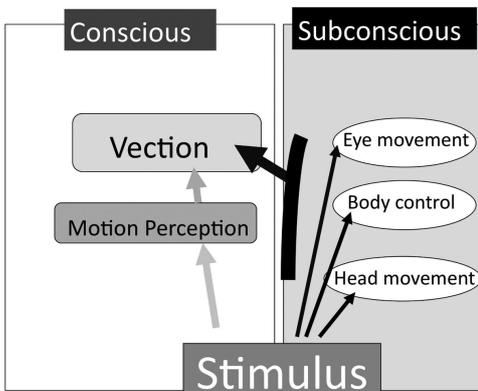

Figure 5. A schematic illustration of the two pathways for vection induction.

visually induced postural sway) all normally co-occur. However, here we present a special case where vection occurs in the absence of any conscious global-motion perception. In addition, Brandt et al (1974) previously showed that vection can persist even after the visual motion stimulus has ceased because of oculomotor modulation (it appeared to be based on optokinetic nystagmus and afternystagmus). Thus, not only by the conscious motion perception pathway, vection was instead induced via the other motor control pathway. This proposal is compatible with recent findings that second-order oscillatory motion does not enhance vection strength even when it is fully perceived (Seno and Palmisano, in press). We can say that the perceived motion does not always determine vection strength. In future studies, the modulation of subconscious pathway should be further examined.

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