SHORT AND SWEET

Vection induced by illusory motion in a stationary image

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Abstract. Ilusory self-motion (vection) can be induced by large areas of visual motion stimulation. Here we demonstrate for the first time that illusory expansion can induce vection in the absence of any physical display motion.

When stationary observers are exposed to a large visual motion field that simulates the retinal flow generated by self-translation or self-rotation, they often experience an illusory perception of self-motion, known as vection (Fischer and Kornmüller 1930). Stimulus attributes for effective vection induction have been extensively studied (Riecke 2010). In these studies explicit motion signals (eg moving luminance-defined dots or gratings) were used as stimuli to induce vection (Brandt et al 1973; Seno et al 2009). However, a number of recent studies suggest that vection induction does not require explicit motion.

In the first of these, Seno and Sato (2011) demonstrated that implicit motion stimuli can also induce modest vection. Vection was induced using animated movies consisting of four human walkers (viewed side-on in the context of a homogenous background). While their (independent) arm and leg movements were consistent with walking, their overall screen positions never changed (it was as if they were walking the wrong way on a moving walkway). However, vection was still induced, always in the direction suggested by the walkers' gaits, even though there was no motion energy in this direction (confirmed by Fujimoto and Sato 2006).

A subsequent study by Seno et al (2012a) suggested that vection can also be induced by implied motion. Directly after a brief explicit motion signal, they found that vection could be induced and maintained by displays consisting of only two static converging lines. By themselves these converging lines, representing the left and right edges of a road, produced little or no vection ('static line only' condition). However, vection was dramatically enhanced when a moving stop sign was briefly superimposed onto the display. The vection in this 'static line plus moving sign' condition was also superior to a 'moving sign only' control condition, and it persisted longer after the moving sign disappeared from view.

A recent study by Nakamura (2013) showed that vection can also be induced by two-stroke and four-stroke apparent motion displays. Nakamura concluded that the minimum stimulus requirement for inducing vection was the repeated presentation of a two-frame apparent motion sequence followed by a blank frame (assuming appropriate time intervals).

One common theme underlying all of the above studies is the idea that vection is determined by the perceived, rather than the physical, display motion. However, all of their displays contained some physical motion (either the independent arm and leg motions of the walkers, the moving sign in the otherwise static road scene, or the 2–4 apparent motion frames).

The current study shows for the first time that vection can be induced by perceived motion in the absence of any physical motion. We used a static visual stimulus designed by the second author called the 'Active Volcano'. As can be seen by figure 1a (left), this stimulus induces a powerful illusion of global expansion. On the basis of the 'color-dependent Fraser–Wilcox' illusion (Kitaoka, forthcoming), the direction of illusory motion is determined by the color arrangement. If color strips are repeatedly arranged in the following order—red, purple, red–purple, light red–purple, and back to red—perceived motion occurs in this direction. Owing to their radial arrangement in the Active Volcano, the image appears to expand. Yanaka and Hilano (2011) suggest the illusion is triggered by saccades, eye-blinks, or shaking the image. We also observed that the illusion could be strongly enhanced by repeatedly alternating the Active Volcano with a gray blank frame. This discovery was used to manipulate the strength of the illusory global expansion in the current study.
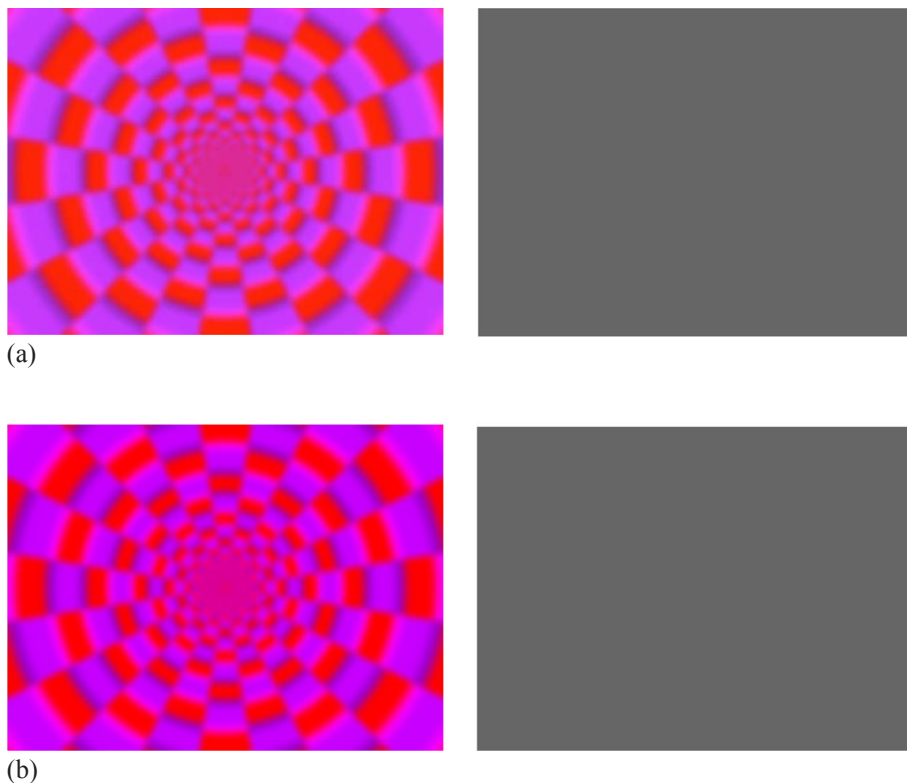

(a)

(b)

Figure 1. [In color online, see http://dx.doi.org/10.1068/p7511] Sequences of the visual image in the two frames of vection stimulus. (a) The Active Volcano condition; (b) the control condition. Demo Gif-animations are provided as supplemental materials.

We measured the perceptions of illusory motion and vection induced by both the Active Volcano and a matched control stimulus (see figure 1b left). While the control was similar to the Active Volcano, it did not induce illusory global expansion (its color arrangement induced perceived local contractions as well as expansions). All stimuli examined subtended a visual area 100 deg × 80 deg, and were each presented for 30 s. There were two ways of presenting the Active Volcano and control stimuli: with and without an alternating gray blank frame, resulting in four different conditions (which were each tested twice). In flickering conditions, either the Active Volcano or the control was repeatedly alternated with the gray blank screen (see figures 1a and 1b right) at a rate of 5 Hz. In nonflickering conditions a static version of either the Active Volcano or the control was displayed throughout the entire 30 s

(ie 0 Hz conditions). Each of the above displays was viewed freely, as eye movements were required to induce their illusory motions.

Vection onset and total duration were calculated for each trial from button-press data. The 16 participants also rated vection strength using a 101-point rating scale ranging from 0 (no vection) to 100 (very strong vection) after each trial. In a different session we measured the duration of the perceived motion generated by each condition. The order of motion perception and vection testing sessions was counterbalanced across participants.

Durations of perceived illusory motion in each of the four conditions are first shown in figure 2a. A two-way ANOVA revealed significant main effects of stimulus type (Active Volcano versus control) and flicker type (0 versus 5 Hz) and also an interaction ($F_{1,15} = 20.45$, $p < 0.01$; $F_{1,15} = 26.87$, $p < 0.01$; $F_{1,15} = 17.31$, $p < 0.01$). While Active Volcano stimuli produced longer durations of illusory motion than control stimuli, and flickering conditions produced longer durations of illusory motion than nonflickering conditions, the flickering Active Volcano produced much longer durations of illusory motion than the other three conditions. A follow-up test, conducted on 5 additional naive observers, indicated that the mean strength of illusory motion was 57 and 1.6 for flickering and nonflickering Active Volcano conditions, and 23.9 and 3.5 for flickering and nonflickering control conditions, respectively.
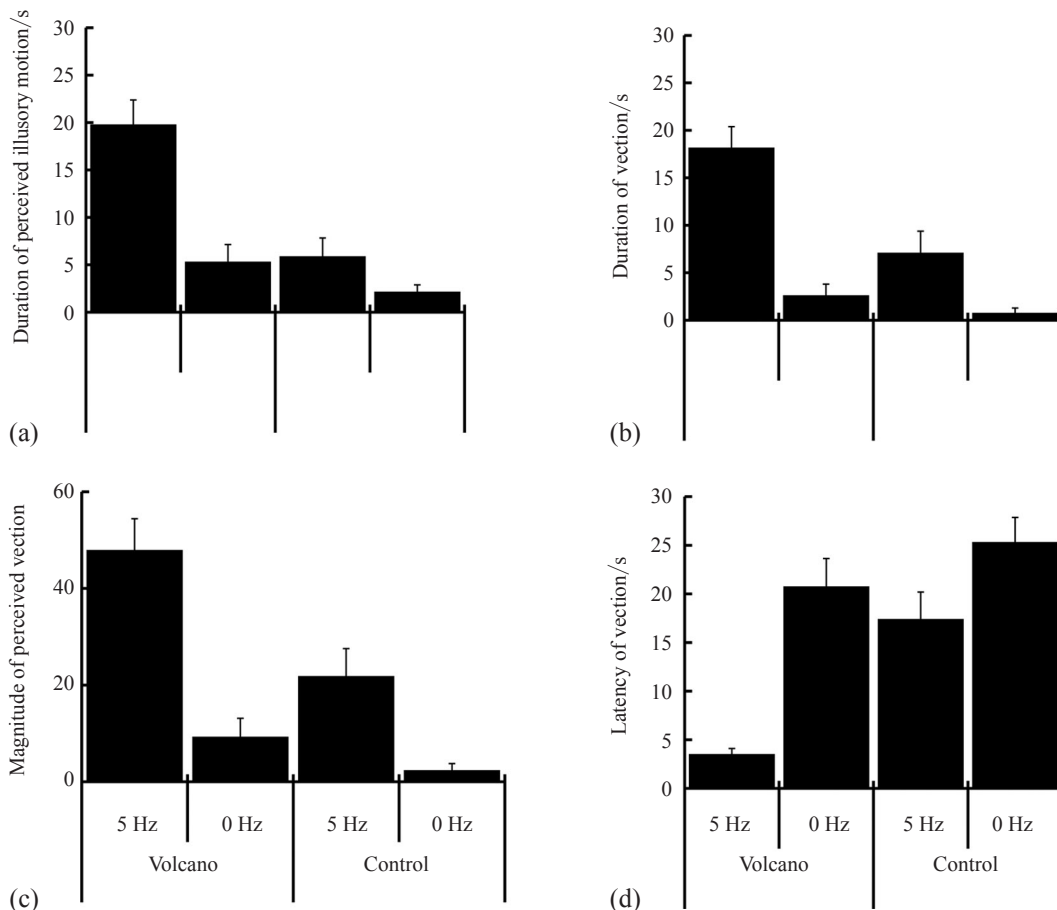

Figure 2. Illusory motion and vection generated by the four conditions. Error bars indicate standard errors.

Two-way ANOVAs revealed significant main effects of stimulus type (Active Volcano versus control) and flicker type (0 versus 5 Hz) for all three vection measures (latency $F_{1,15} = 23.40$, $p < 0.01$, $F_{1,15} = 16.08$, $p < 0.01$; duration $F_{1,15} = 21.52$, $p < 0.01$, $F_{1,15} = 25.11$, $p < 0.01$; magnitude $F_{1,15} = 16.20$, $p < 0.01$, $F_{1,15} = 24.72$, $p < 0.01$). Interactions between

stimulus type and flicker type were also significant for all three vection measures (latency $F_{1,15} = 6.74$, $p < 0.05$; duration $F_{1,15} = 15.51$, $p < 0.01$; magnitude $F_{1,15} = 7.77$, $p < 0.05$). These findings were interpreted as follows: while Active Volcano stimuli produced superior vection to control stimuli, and flicker produced superior vection to no flicker, flickering Active Volcano conditions produced markedly superior vection to the other conditions (see figures 2b–2d). Vection durations were also found to be highly correlated with the durations of illusory motion perception ($R_{63} = 0.74$, $p < 0.01$). The current findings are clearly consistent with the notion that vection was being induced by the illusory motion in these static stimuli.

From the start of psychological experiments of vection (Brandt et al 1973) to the most recent studies, it has typically been assumed that object motion perception always precedes vection induction (ie the observer first perceives exclusive object motion, then later perceives object and self-motion combined; and eventually, if the conditions are favorable, exclusive vection). However, more recently it has been reported that vection can be induced without global motion awareness (Seno et al 2012b). In the data obtained in this current study the durations of vection and illusory motion perception were of very similar lengths. So we speculated that vection without motion awareness might have been obtained here as well. It was reported that a Healing Grid illusion (Kanai 2005) could be enhanced during vection (Fukuda and Seno 2012). We speculate that vection might have enhanced the illusory motion perception in the Active Volcano and vice versa.

Flicker clearly enhanced the illusory motion induced by our displays. We propose that flickering promoted the retinal slip of the stimulus, which in turn enhanced the illusory motion (and subsequently vection when this illusory motion was globally coherent).

Our Active Volcano stimuli provide a completely new way to induce vection, where just a single frame is required (ie no explicit motion signal). This one-frame method for creating vection stimuli has many practical advantages. No longer will vection experiences be restricted to virtual reality/simulation environments. For example, with suitable lighting conditions, a poster version of this Active Volcano stimulus could be used to induce vection.

Here we provide stronger evidence than any previous study that vection does not rely upon the presence of physical motion. Our findings clearly show that vection is determined by perceived, not physical, motion. To our knowledge, this is the first report that vection can be induced by a genuinely static image.

References
Brandt T, Dichgans J, Koenig E, 1973 "Differential effects of central versus peripheral vision on egocentric and exocentric motion perception" *Experimental Brain Research* **5** 476–491
Fischer M H, Kornmüller A E, 1930 "Optokinetisch ausgelöste Bewegungswahrnehmungen und optokinetischer Nystagmus" *Journal für Psychologie und Neurologie (Leipzig)* **41** 273–308
Fujimoto K, Sato T, 2006 "Backscroll illusion: Apparent motion in the background of locomotive objects" *Vision Research* **46** 14–25
Fukuda H, Seno T, 2012 "Healin' groovy—Movement affects the appearance of the healing grid illusion" *Perception* **41** 243–246
Kanai R, 2005 "Healing Grid", annual best illusion of the year contest 2005, Vision Sciences Society
Kitaoka A, 2012 "The Fraser–Wilcox illusion and its extension" *Perception* **41** ECVP Supplement, 91 (abstract)
Kitaoka A, forthcoming "The Fraser–Wilcox illusion and its extension", in *Oxford Compendium of Visual Illusions* Eds A Shapiro, D Todorović (Oxford: Oxford University Press)
Nakamura S, 2013 "The minimum stimulus conditions for vection—two- and four-stroke apparent motions can induce self-motion perception" *Perception* **42** 245–247

Riecke B E, 2010 "Compelling self-motion through virtual environments without actual self-motion—Using self-motion illusions ('vection') to improve user experience in VR", in *Virtual Reality* Ed. J-J Kim (Rijeka: InTech) pp 149–176

Seno T, Ito H, Sunaga S, 2009 "The object and background hypothesis for vection" *Vision Research* **49** 2973–2982

Seno T, Ito H, Sunaga S, 2012a "Vection can be induced in the absence of explicit motion stimuli" *Experimental Brain Research* **219** 235–244

Seno T, Palmisano S, Ito H, Sunaga S, 2012b "Vection can be induced without global-motion awareness" *Perception* **41** 493–497

Seno T, Sato T, 2011 "Vection can be induced without explicit motion signal using backscroll illusion" *Japanese Psychological Research* **54** 218–222

Yanaka K, Hilano T, 2011 "Mechanical shaking system to enhance 'Optimized Fraser–Wilcox Illusion Type V'" *Perception* **40** ECVP Supplement, 171 (abstract)