Circular vection is facilitated by a consistent photorealistic scene

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Abstract

This study investigated visual parameters that influence the onset time and convincingness of circular vection in a Virtual Reality setup. The visual stimuli consisted either of a photorealistic scene of a market place or a scrambled, mosaic-like version of the same scene in which all pictorial cues about depth and scene layout were eliminated. In a within-subject design, vection onset times and convincingness ratings of perceived ego-motion were compared for the two stimulus conditions. We found significantly shorter vection onset times and higher convincingness ratings of ego-motion for the consistent market scene. Our results indicate that a consistent photorealistic scene has a stronger vection-inducing potency than similar visual stimuli where scene layout is eliminated. We conclude that not only bottom-up processes, but also top-down processes can significantly influence ego-motion perception. Such top-down influences have been largely neglected so far in the vection literature.

1 Introduction

It is well known that large visual stimuli that move in a uniform manner can induce illusory sensations of self-motion in stationary observers. Observers perceive themselves moving in the opposite direction than the visual stimulus, and this perceptual phenomenon is commonly referred to as vection. Most of the psychophysical studies on vection that have been done so far have used simple, artificial visual stimuli like random-dot patterns or Mach-stripes. While this approach has the advantage of providing high stimulus control, it has the disadvantage of low ecological validity. In our study, we investigated whether a photorealistic image of a scene that contains consistent spatial information about pictorial depth and scene layout (e.g. linear perspective, relative size, texture gradients etc.) can induce vection more easily than a comparable stimulus with the same image statistics where information about relative depth and scene layout has been removed. The underlying idea is that the consistent photorealistic scene might facilitate vection by providing the observers with a convincing reference frame for the simulated environment so that they can feel “spatially present” in that scene. That is, the more observers accept this virtual scene instead of the physical surrounding - i.e., the simulation setup - as the primary reference frame, the more the conflict between the two competing reference frames should diminish and spatial presence and ego-motion perception in the virtual scene should be enhanced.

2 Hypotheses

If consistent photorealistic scenes have higher vection-inducing potency than similar images without pictorial depth information and consistent spatial layout, we would expect shorter vection onset times and higher

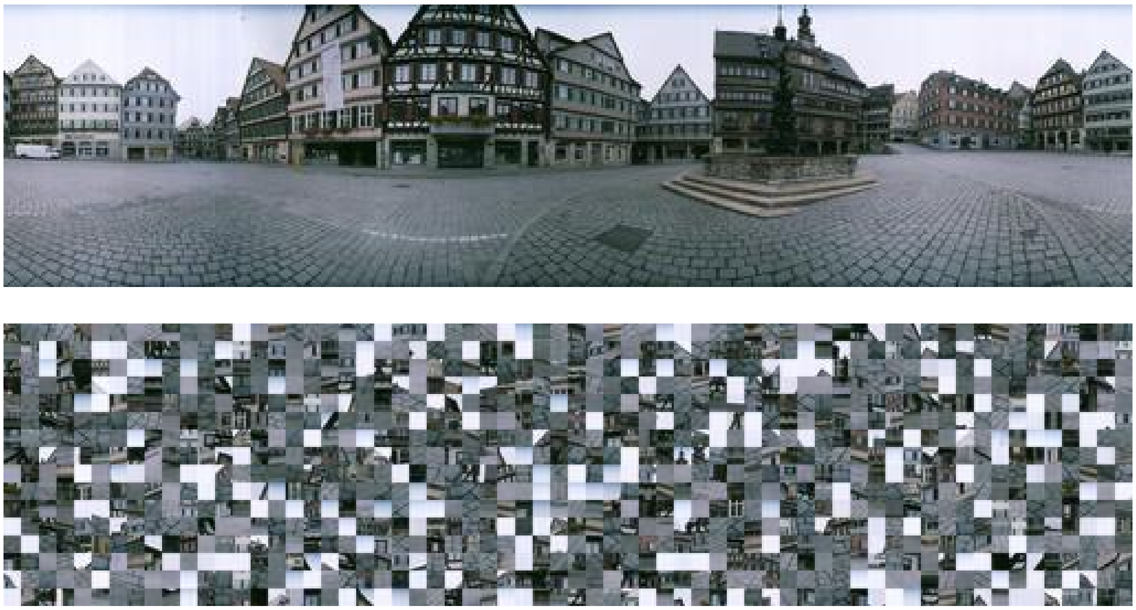


Figure 1: Top: 360 deg roundshot of the Tübingen Market Place. Bottom: Scrambled version of the same picture.

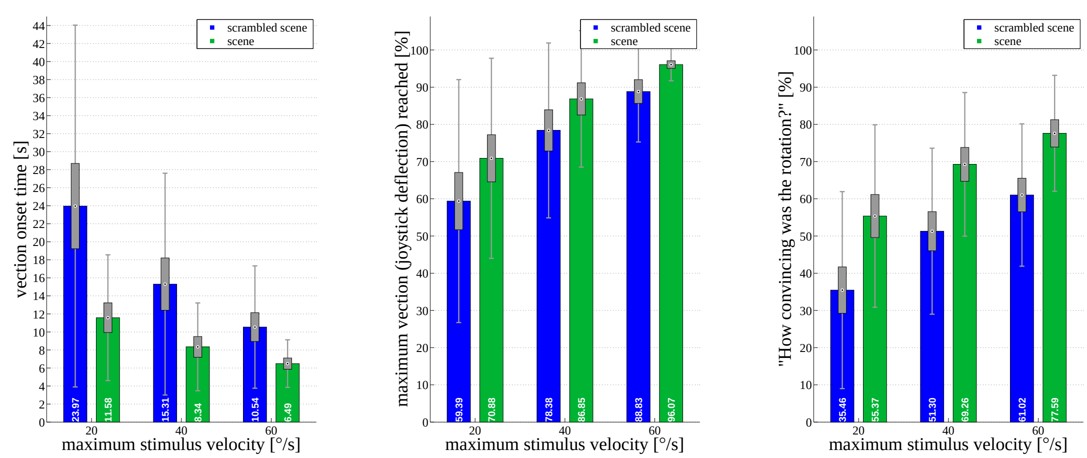
intensities of perceived vection for stimuli of the former kind. To test this hypothesis, we generated two kinds of visual stimuli: One was a photorealistic 360 deg roundshot of the Tübingen Market Place (see Fig. 1, top). The second stimulus was a mosaic-like scrambled version of the same picture, where all parts of the picture were shuffled and reassembled at random positions (see Fig. 1, bottom). This had the effect that all information about pictorial depth and scene layout was eliminated, even though individual small parts of the scene, e.g. a window, remained recognisable. Compared to the natural scene, this procedure added many high contrast edges to the scrambled picture, which is known to facilitate vection: Psychophysical studies have shown that increasing the contrast and spatial frequencies facilitates vection (see Dichgans and Brandt (1978), Palmisano and Gillam (1998)). This fact works against our hypothesis that eliminating scene layout and pictorial cues should impair vection. We decided to use this stimulus because it provides a harder test of our hypothesis.

3 Methods

The roundshots were mapped onto a virtual cylinder. Circular vection was induced by rotation of the virtual cylinder around the observer. Participants were seated in a darkened room and viewed the visual stimulus on a 84×63 deg projection screen at a distance of 106 cm. Physical and geometrical field of view (FOV) were matched, and care was taken to fade out the physical reference frame of the simulation setup as much as possible. Participants were instructed to watch the stimuli "as relaxed and naturally" as possible. They were also told not to suppress the optokinetic reflex (OKR), and neither to stare through the screen nor to fixate on a static point on the screen, but to concentrate on the image in the central part of the projection screen. We did not use a fixation point, even though it is known that a fixation point reduces vection onset times (Becker et al. (2002)). The main reason is that from an applied perspective for ego-motion simulation, it is important to investigate vection-inducing parameters under “natural” viewing conditions. Furthermore, this also reduced the perceived flicker and ghost images due to the 60 Hz projection. Participants started trials by a button press, upon which the static image started to rotate around the vertical axis. Maximum rotational velocities were 20, 40, and 60 deg/sec, and constant acceleration times of 3 seconds and deceleration times of 6 seconds were used. The duration of constant velocity rotation was 60 sec. As soon as participants felt themselves moving, they pulled the joystick in the direction of their perceived motion. The stronger the perceived vection, the more they pulled the joystick. With the joystick, vection onset times and the timecourse of vection intensity was measured. The rotation stopped automatically after 60 seconds. After each rotation, subjects additionally rated the "convincingness" of perceived self-motion using a 0 - 100 scale in steps of 10 (0 = "no perceived motion at all", 100 = "very convincing sense of vection": the image is perceived as static, all motion is perceived as ego-motion). 18 participants completed 36 experimental trials after a practice session. The market scene and scrambled image stimuli were run in two separate blocks with a 10 minutes break in between. This was done to avoid carryover-effects between two kinds of visual stimuli across trials, since it is known that after prolonged sensation of vection, aftereffects can last for several minutes. Within the blocks, the presentation order of stimuli was randomised. Presentation order of the market scene and scrambled image was balanced across participants and also across their gender.

4 Results & Discussion

Repeated-measures ANOVAs showed the following within-subject-effects: For vection onset time as the dependent variable, the effect of visualisation condition as well as rotation velocity was significant: $F(1,14) = 9.12$, $p < .01$ and $F(1.38,19.25) = 14.72$, $p < .001$, respectively. In a separate analysis, the same pattern of results was found for the convincingness ratings of felt ego-motion: $F(1,14) = 12.02$, $p < .01$ and $F(1.21,16.99) = 19.05$, $p < .001$, respectively. In both analyses, the F-values for the factor velocity were Greenhouse-Geisser-corrected to adjust for violated sphericity-assumptions. As can be seen in Fig. 2 (a), mean vection onset times were always longer for the scrambled image than for the market scene. This effect is especially pronounced for slower rotations. At all velocities, paired-samples t-tests showed significant differences between the two stimuli at least at $p<.01$. It can also be seen that vection onset time was shortened with higher velocities, and this effect was stronger for the scrambled image: The interaction between visualisation condition and velocity is significant at $F(1.42,19.92) = 4.30$, $p < .05$. The presentation order of the two visual conditions had no significant effect on any of the dependent variables: For example, for vection onset time, F-values were $F(1,17) = .30$, $p = .59$ and $F(1,17) = 1.53$, $p = .23$ for the market and the scrambled image, respectively. Results for convincingness ratings were similar.



(a) Vection onset times

(b) Vection ratings by joystick

(c) Convincingness-rating by magnitude estimation

Figure 2: Left: Mean vection onset times. Centre: Maximum perceived vection intensity, measured by % joystick deflection. Right: Mean convincingness-ratings for felt ego-motion. Boxes show standard error of the mean, whiskers depict one standard deviation.

It is notable that for the natural scene, vection onset times are relatively short compared to other studies that used artificial stimuli like Mach-stripes or random dots (Dichgans and Brandt (1978); Fushiki et al. (2000); Becker et al. (2002)). This is especially true for higher velocities, where we found a mean value of 6.5 seconds for rotations of 60 deg/sec. On the other hand, onset latencies for the scrambled image were in the range between 10 and 24 seconds, which is comparable to above mentioned studies. Furthermore, the onset latencies for the natural scene relate well to a comparable study by van der Steen and Brockhoff (2000), where mean latencies as short as 3 seconds were found. In that study, a realistic cockpit-replica with a spherical projection screen with a large FOV (142 $\times$ 110 deg) that showed a natural landscape was used. The enhanced foreground-background separation between the cockpit window and the projection screen might have facilitated vection (see Nakamura and Shimojo (1999)). Most importantly, the cockpit-replica provided a very convincing reference frame for the simulated visual environment. We suppose that these combined effects have contributed to the extremely short vection onset latencies.

Graphs (b) and (c) in Fig. 2 show data on perceived vection intensity and convincingness. Vection intensity was measured by the angle of joystick deflection (b), and convincingness ratings were based on a 0-100 scale (c). As can be seen, vection ratings and convincingness ratings were always higher for the market scene for both measurands. Paired-samples t-tests show significant differences for the convincingness ratings at all levels at least at $p<.01$.

Previous studies have reported gender differences in circular vection (see Darlington and Smith (1998)). However, in our study, we found no gender differences at all for any of the dependent variables.

5 Conclusions

We found a higher vection-inducing potency for a photorealistic scene with consistent information about pictorial depth and spatial layout. We conclude that not only bottom-up processes that depend mainly on physical image-properties like spatial frequency or contrast, but also top-down processes like reference frames and spatial presence can significantly influence vection. Such top-down influences have been largely neglected so far in the vection literature, and might have important implications for ego-motion simulation. Our study provides a first step to investigate this topic, and further experiments are in preparation to explore in more detail how spatial layout, spatial presence and reference frames can influence ego-motion perception in Virtual Reality setups.

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