Poster: Do walking motions enhance visually induced self-motion illusions in virtual reality?

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Abstract

Locomotion interfaces that support physical self-motion in virtual reality facilitate spatial updating, but have relatively high cost and typically require large physical spaces. A better understanding of the illusion of self-motion, or vection, presents a potential solution to this problem. Though circular self-motion illusions induced using only visuals or only walking have been investigated previously, the interaction between these two types has not. We conducted an experiment to examine the additive effects of walking stimuli and visual motion cues on intensity and convincingness of circular vection. Our results indicate a trend towards decreased vection onset time when illusory rotation stimuli were combined. Measures of intensity and convincingness were also rated higher for the combined stimulus condition when compared with walking or visual stimuli separately. Consequently, lean and elegant virtual reality interface designs should include both walking and visual stimuli for a compelling experience of self-motion.

Keywords: Vection, biomechanically induced circular vection, visually induced circular vection, self motion illusions

Index Terms: I.3.7 [COMPUTER GRAPHICS]: Three-Dimensional Graphics and Realism—Virtual Reality;

1 Introduction

While virtual reality (VR) technology has made astonishing advances in recent decades, a convincing and inexpensive experience of virtual self-motion within a confined physical space has yet to be achieved. Several techniques attempt to enable exploration of large virtual spaces while walking in a smaller real-world space. The most promising approaches include redirected walking [5] and modifying the environment when the user is looking elsewhere [6]. Still, these approaches are environment dependent and require expensive motion-tracking technology.

Future VR interfaces might employ the perceptual illusions that result in a convincing experience of self-motion. A design framework [4, 1] that incorporates only the essential aspects of physical motion and relies on self-motion illusions to simulate the rest may lead to the design of low-cost and highly realistic methods of locomotion. We are particularly interested in understanding the perceptual mechanisms behind the illusion of rotational self-motion, as the rotational component of motion is important for maintaining spatial orientation and navigation [3].

The illusion of self-motion, also known as vection [7], is sometimes experienced in the real world. For example, an observer seated on a train or in a car starts to question their state of self-motion for a short period of time when an adjacent train or car begins moving forward. Though this example relates to linear vection, self-motion illusions are also found during rotation. Referred to as circular vection, this illusory sensation of rotation can be induced using auditory, biomechanical, vestibular, or visual stimuli [4].

Visually induced vection can be experienced by simply viewing a rotating scene with an adequate field of view. In contrast, biomechanically induced circular vection commonly occurs when a seated individual steps from side to side along a rotating floor while their body remains stationary [2]. This type of vection is important, as the lack of proprioceptive and somatosensory cues limits the believability of self-motion [2, 3].

Regardless of the stimuli inducing it, the process of vection follows a regular time course (Figure 1). In particular, the critical parameter that describes vection is the vection onset latency, defined as the time between the start of perceived self-motion and the start of the stimulus. Ideally vection onset latency should come as close to real world motion latency as possible.

While visual and biomechanical vection have been studied extensively in isolation, our goal here is to investigate if there might be benefits in combining both modalities. Such cross modal benefits have previously been observed between visually and auditorily induced vection[4]. Consequently, we hypothesized that combining visusal and biomechanical stimuli will enhance vection, resulting in increased intensity and convincingness and reduced vection onset latency.

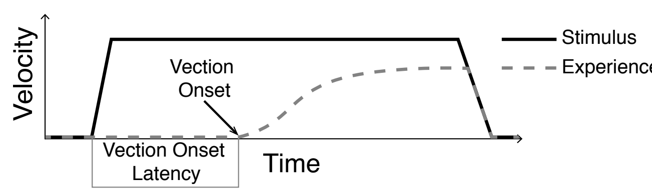

Figure 1: Idealized time course of vection stimulus and self-motion illusion.

2 Methods

2.1 Participants

A total of 6 participants (4 female) completed the experiment. Participants were recruited from an online research pool at a Canadian University and were compensated with research credit for use in their coursework. A 7th participant (male) was unable to complete the experiment due to motion sickness.

2.2 Procedure

Participants responded to three rotation conditions. These conditions consisted of either only rotating visual stimuli, only rotating biomechanical stimuli, or both rotating stimuli combined. The experiment used a between-subjects design of 12 trials with a factorial combination of 3 rotation conditions and 4 repetitions each. Each

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trial lasted 45 seconds, with a short break between rotation conditions to prevent motion sickness. The ordering of conditions was pseudo-balanced between participants, and each trial alternated between left and right rotation in an effort to reduce motion after effects and motion sickness.

Experience of rotational self-motion was primarily assessed by the participants report of rotation onset. This measure was registered by a joystick button press. Following each trial participants used the joystick to adjust a slider to rate how intense and how convincing the rotation was.

2.3 Apparatus & Stimuli

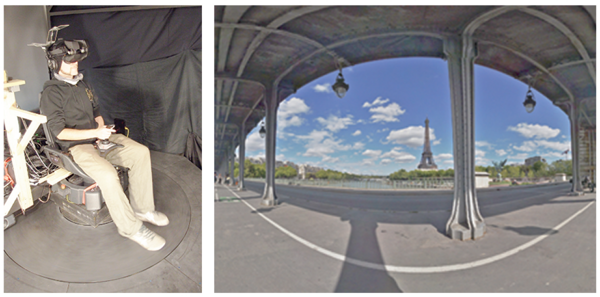

Figure 2: The rotational treadmil (left) and a section of the panorama image used as the visual stimuli (right).

The rotating visual scene was displayed on a position tracked NVIS SX111 head-mounted display. The HMD presented a 111 degree field of view with a frame rate of 60 fps. The panorama used is displayed above in Figure 2. Noise cancelling headphones with an ambient background noise were used to prevent any unwanted auditory cues. Biomechanical rotational cues were supplied using a circular treadmill in which a floor disc rotated independent of the seated stationary participant. The participant did not physically rotate, but was directed to step along as the floor disc rotated.

2.4 Results

Analyses were focused on comparing the measures of illusion convincingness, intensity, and vection onset times between each experimental condition. For each measure a one-way repeated measures ANOVA with a post-hoc Tukey HSD test was used.

On average, vection onset times were the highest for the treadmill only condition, followed by the visual only condition, with the combined condition lowest (Figure 3). However, the difference between conditions was only marginally significant, $F(2,69) = 2.52; p = 0.0883$. In particular, onset times for the visual with treadmill condition were marginally lower than for the treadmill only condition, $p = 0.07$.

Rotation convincingness reports differed significantly between conditions, $F(2,69) = 8.21; p < 0.001$. On average, the convincingness of the visual with treadmill condition was significantly higher than either the visual only ($p < 0.01$) or the treadmill only ($p = 0.02$) condition (Figure 3).

Ratings of vection intensity also differed significantly, $F(2,69) = 8.38; p = 0.001$. The ratings for intensity of the combined visual with treadmill condition were significantly higher than either the visual only ($p < 0.01$) or the treadmill only ($p = 0.01$) conditions.

3 Discussion & Conclusion

Our research examined the relationship between visually induced circular vection and biomechanically induced circular vection. The

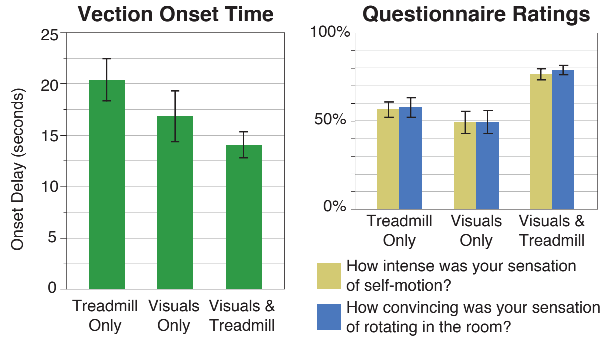

Figure 3: Average vection onset time (left), and average post-trial questionnaire ratings (right). Error bars represent standard error.

results indicate that a combination of biomechanically induced vection with visually induced vection improved the vection experience when compared with either individually. Ratings of vection intensity and convincingness were significantly higher for the combined rotation condition, indicating that the experience of rotation is much stronger when combining biomechanical and visual rotational cues.

Given the small sample size of this pilot study, the main limitation involved statistical power. Because of the low number of participants, vection onset time was found to be only marginally significant. However, our findings do point toward an additive relationship between biomechanical and visual components of circular vection. This certainly warrants further investigation within a larger study.

As we continue to investigate self-motion illusions and the interactions between vection induction stimuli, our understanding of how to design a realistic and compelling virtual reality locomotion interface expands. It is our hope that this research contributes to a more complete and comprehensive design framework [4, 1] capable of creating an affordable yet powerful virtual reality experience.

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