Modeling of Pedestrian's Unintentional Guide Using Vection and Body Sway

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ABSTRACT

In daily life, our behavior is guided by various visual stimuli such as the information on direction signs. However, our environmentally-based perceptual capacity is often challenged in crowded circumstances, or more so, in emergency evacuation circumstances. In those situations, we often fail to pay attention to important signs. In order to achieve more effective direction guidance, we considered the use of unconscious reflexes in human walking action. In this study, we experimented with vision-guided walking direction control by inducing subjects ' gaze direction shift using a vection stimulus combined with body sway. In this paper, we confirm a shift in subjects ' walking direction and body sway, and discuss a possible mechanism.

Keywords: Pedestrian Navigation, Gaze Control, Vection, Body Sway

1 INTRODUCTION

In the daily act of walking, we take in large amounts of sensory information through visual, auditory, tactile, and olfactory channels, (among others), and decide how to act. An important information source in these action decisions is explicit visual information such as signs or arrows. However, in crowded situations or when avoiding danger, it is difficult to recognize relevant signs, and it may become difficult to take appropriate action[2].

The situation is similar in the artificial environment of augmented reality (AR). Although the awareness of the environment ' s artificiality may tend to keep us from visual attention, this artificial environment nonetheless stresses proper attentional allocation to signs, as compared to the more routine environment of daily life. In order to more effectively guide ambulatory behavior using AR, we considered the use of an unconscious or reflex based guidance method in addition to usual visual action signs. Galvanic Vestibular Stimulation (GVS) is reported as a method of causing unconscious walking direction guidance[1][6][3]. GVS is a produces the illusion on the sense of equilibrium by throwing a slight current on the vestibular organ. When GVS is presented to a subjective pedestrian, the subject perceives that his or her own movement is different from that intended and tries to correct for the difference unconsciously and the reflexive correction produces a change in walking direction. However, the use of GVS in human behavior guidance requires continuous application of electrical current to the vestibular organ, and may not be entirely safe.

Thus, we experimented with body sway perception using a vibration device and vection, instead of GVS. When vibration is delivered to the leg, our sense of equilibrium transfers dependency on body sway to the available visual input. Accordingly, we should expect that the self-body motion illusion by vection to be sufficient to cause a reflexive change in gaze direction and an unconscious modification of body motion direction.

It is thought that these reflexes can safely deliver the level of sensation that can cause unconscious guidance of walking direction. In this study, we examine the behavioral dynamic in a case of walking direction guidance.

2 WALKING INDUCEMENT BY GAZE CONTROL

2.1 Self-motion Sensation

The self-motion sensation is an effective method to control a pedestrian's autonomous motion. The self-motion sensation combines information from multiple sensors such as the vestibular, visual, auditory and tactile systems, and yields perception of own ' s balance, direction and motion. The vestibular and visual senses are the most basic among all those of the sensory systems.

The vestibular system perceives gravity and acceleration, and influences the faculty of equilibrium. However, the sense of self-motion by the vestibular system is temporal, in that it responds to changes in speed and acceleration. Therefore, the perception of self motion due to the vestibular sense disappears when we move at a constant speed. However, the sense of constant speed is necessary for walking as is the sense of acceleration. The sense that plays the principal role in continuous self-motion perception is the vision.

The sensation of visual self-motion is referred to as vection[5]. Vection is the perception of self-motion without actual motion produced by optical flow. When vection occurs, we correct our posture to compensate for the perceived self-motion. Yoshida et al. reported that when a standing subject perceived vection, the center of gravity inclined unconsciously to the opposite side of the perceived self-motion[8]. However, visual information alone was not sufficient to change the walking orbit but at most allowed the body incline to change with respect to the center of gravity.

It was previously thought that information from other sensations such as somatic sensation was contradictory and thereby suppressed by reflexes, just as by vision.

2.2 Self-motion Sensation Using Vision and Body Sway

Suzuki et al. reported that they had achieved changes in body postural change toward the eye-movement direction by applying vection and body sway[7]. In their experiment, the body sway was produced by applying "neck dorsal muscle stimulation " (NS) using tibialis anterior stimulation, (called TAS), and "gastrocnemius stimulation, called " GAS", using a vibration device while a subject was standing. Applying a visual stimulus, they evaluated the amount of postural change quantitatively (See Fig.1). Experimental results with TAS, NS and GAS together were able to induce the postural change towards the gaze direction. But they only evaluated the effect for the standing state and did not try the walking state.

Then, in this paper, we examine a method for inducing a change in walking direction by showing an optic flow stimulus to control the gaze direction and self-motion sensation, together with a vibratory stimulus to the body. Specifically, the vibration device attached to a subject's leg destabilizes somatic sensation and causes the body to sway. The presentation of an optic-flow stimulus causes the illusion that the body is moving in a direction opposite to that of the

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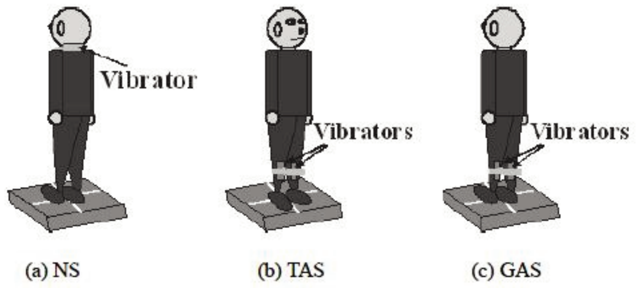

(a) NS (b) TAS (c) GAS

Figure 1: Vibration stimulation presentation part to induce body sway. ”NS: neck dorsal muscles stimulation”, ”TAS: tibialis anterior stimulation”, and ”GAS: gastrocnemius stimulation”. (Ueno, 2007[7])

flow, and the illusion induces the reflex of the subject’s body moving in the direction of the stimulus.

3 PEDESTRIAN INDUCEMENT EXPERIMENT USING SELF-MOTION SENSATION

To evaluate the effect of vection stimulation and body sway during walking, we used a motion capture system (Motion Analysis MAC3D). We used 12 cameras, and subjects wore 19 markers on their head (3 points), their shoulders (2 points), their elbows (2 points), their wrists (4 points), their waists (2 points), their knees (2 points), their ankles (2 points), and their large toes (2 points), as a means of measurement.

We used a handy massager ”Slive MD-01” as the vibration device and presented a high frequency (100Hz) and a low frequency (90Hz) vibration. The vibration was applied at left and right GAS, where it would not greatly affect their walking ability. (Fig.2).

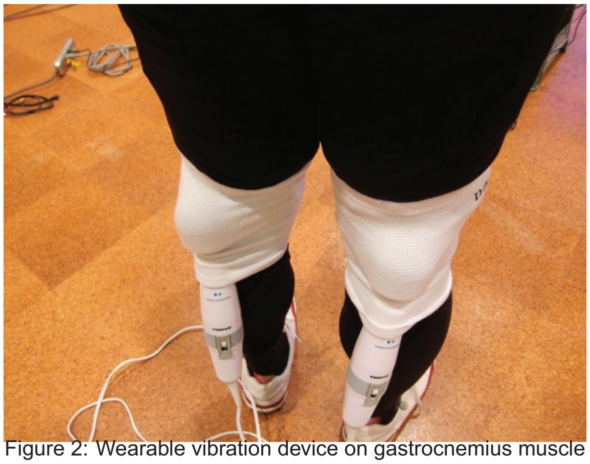

Figure 2: Wearable vibration device on gastrocnemius muscle

For the evaluation of gaze direction guidance by optical flow, we used an eye tracking system (NAC EMR-8B), and measured the subject’s gaze from the starting position of the walking task. We used a sequence of points aligned in the side and moved it to left or right by a speed of 160mm/sec as the optical flow stimulus. The size of one point is a circle 6 cm in radius, and all the points move at constant speed. The size of screen was 2m height by 3m width (Fig.3).

Six subjects participated in our experiment. In 10 trials of the high frequency (100Hz) and low frequency (90Hz) vibration conditions, 5 right- and 5 left-direction optical flow images were presented by a PC on a screen by a projector.

In the experiment, subjects stood facing the screen, looked at a fixation point on the screen and start walking straight from a starting position. The optical flow stimulus was projected when the subject reached 1.8m from the starting position, and walked an additional 2.5m after the start of projection, while watching the screen (Fig.4). The vibration stimulus was presented simultaneously with the commencement of walking.

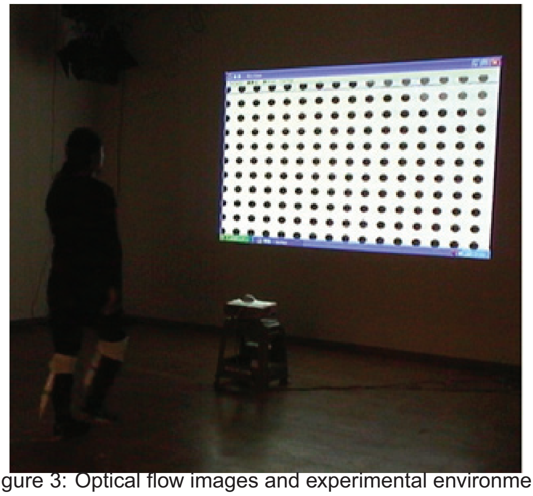

Figure 3: Optical flow images and experimental environment

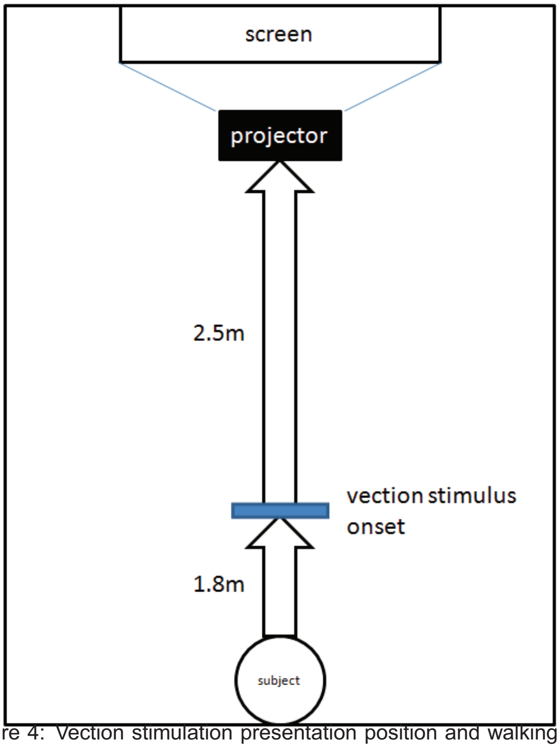

Figure 4: Vection stimulation presentation position and walking distance

3.1 Result

3.1.1 Eye Movement by Vection

Fig.5 shows the eye movement of a subject when they were presented the Optical-Flow stimulus. The X-axis shows the number of frames (30frame/sec) and the Y-axis shows the direction of the eye (upper is right direction in degrees). In the measurements taken, the eye moved to the right by right flowing stimulation and moved to the left by left-flowing stimulation. Namely, the gaze moved in the direction of the optical flow, and it was confirmed the results that the gaze movement was induced by the vection stimulation in our experiment.

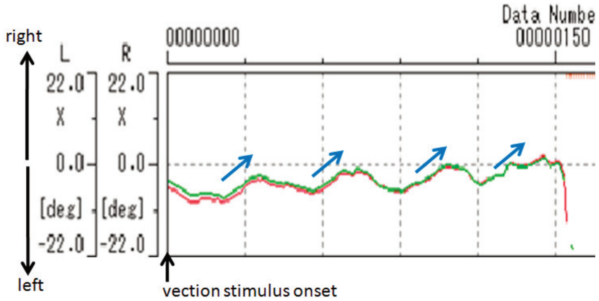

Figure 5: Gaze point measurement from vection stimulation onset to the right side of 5 second. X-axis shows the number of frames (30frame/sec) and Y-axis shows the gaze point movement (deg). Green line shows left eye trajectory and red line shows right eye trajectory.

3.1.2 Body Movement by Vection

Fig.6 shows the probability of body movement when the vibration and the optical-flow stimuli are presented. The Y-axis represents the probability that either left or right movement have occurred. It shows that the body moved with high probability towards the vection stimulation direction, independent of the vibration frequency.

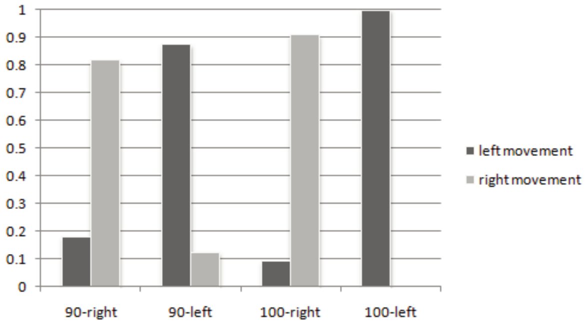

Figure 6: Body movement direction probability after vection stimulation. The X-axis shows vibration frequency and the vection stimulation direction. The Y-axis shows the ratio of left and right movement.

Fig.7 shows the trajectory of a left leg ankle for one step after vection stimulation to the left. The upper graph is a right or left shift of the ankle to forward direction and lower one shows height of the ankle. From this graph, it is confirmed that the inducement of leg movement by vection stimulation occurs at a phase of the leg lifted up in a walking cycle. A feature of the motion was that the ankle moved in a direction opposite to direction of stimulation at a first half of the leg lifting step and moved to the stimulus direction afterwards. It is thought that this opposite direction movement is a correction reaction for the illusion caused by this stimulation.

Next, figure8 shows latency in in the beginning of ankle motion from the vection stimulation onset. The X- axis shows the conditions of the vection direction and the foot from which movement first appeared. Average latency was 1.35sec, 1.4m distant from the stimulation where the walking speed was 1.05m/s. We can say that the inducement effect appeared about one step after the stimulation. There was no significant difference in the latency between the conditions of the vection direction or motion induction of the leg.

Fig.9 shows the duration of ankle movement to the opposite direction of a vection stimulus compared to the conditions of the vection direction and the foot with which movement first appeared. The average duration was 0.38 sec, and the average distance was 0.4m (half step). As a result, it was confirmed that the movement induced by vection stimulation is rather limited in time, when compared to walking behavior.

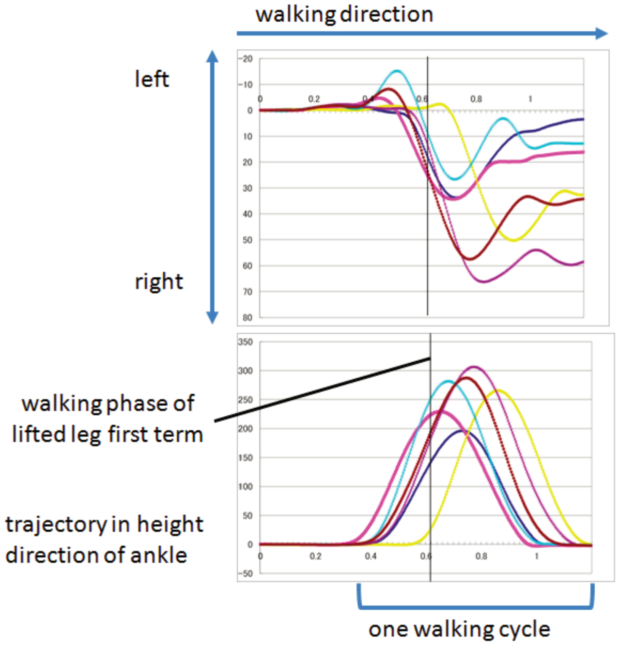

Figure 7: Trajectory of the left ankle for 1 step after vection stimulation. Above graph shows tracks of a right and left ankle to walking direction and below shows tracks in height direction.

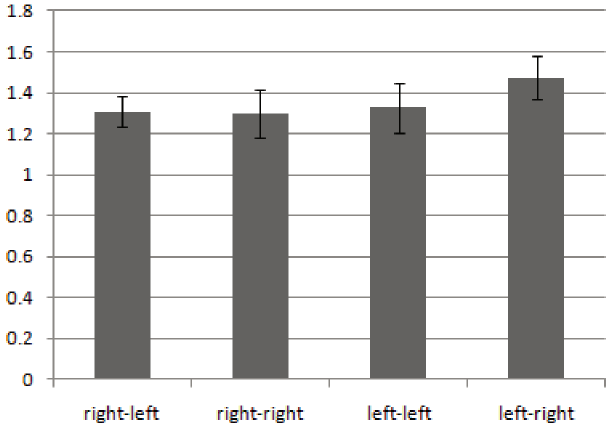

Figure 8: Latency from vection stimulation onset to inducement timing. X axis shows [vection stimulation direction] - [first movement appeared feet], and Y axis is latency time [sec]

4 CONCLUSION

Based on our experiments, we conclude that gaze-point movement and changes in walking direction are caused by optical-flow stimulation under the body sway proprioceptive sensed, and in this case, produced by a vibratory device. It was also confirmed that the reflexive leg movement by the vection stimulation first occurred in the walking phase of leg lifting, and next, the change in walking direction was induced.

Given these results, we consider the following mechanism for the walking guidance phenomenon that we found: Due to the vi-

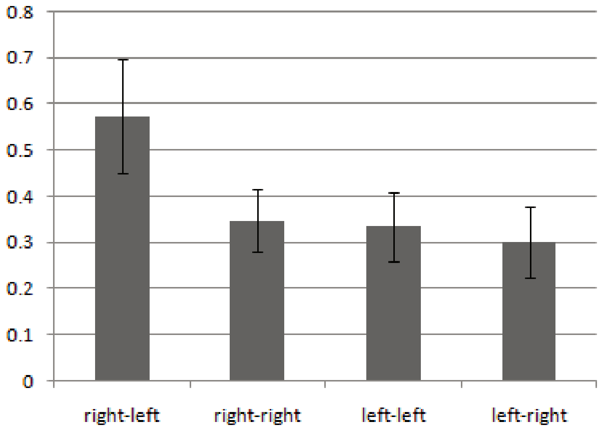

Figure 9: Inducement time to right and left of ankle. X axis shows [vection stimulation direction] - [first movement appeared feet], and Y axis is inducement time [sec]

bration stimulus given to the gastrocnemius, the signal gain within somatosensory the somatosensory channel, (namely, the vestibular system), is lowered. Yet, when an optic-flow stimulus is is visually delivered, the subject perceives his or her body as being shifted in a direction opposite to that of the flow, and thereby generates a correction reflex towards the vection direction.

In an AR environment, it was known that one feels acceleration when watching a moving object in a wide angle of view. On the other hand, this feeling produced a discrepancy between vision and the vestibular senses, and that incongruence consequently induced the what has been called VR sickness[4]. Although devices that display visual and vestibular stimuli simultaneously have been developed to relieve this conflict of inputs, they have until now been large and complicated systems which were inappropriate for daily use. Since the vection stimulus and the body sway in our study are easier to present using an HMD device and a vibration device, we can envision it as a practical inducement device in an actual AR environment.

While GVS was known as a method for inducing unconscious body movement using visual illusion, here in this paper, we demonstrate another method that does not require GVS. And, although we presented a vibratory stimulus continuously within this study, we do not believe it is essential. In the future, we plan to analyze the dynamics of sensory signal usage in the walking phase, and obtain effective walking action induced by only brief vibration during the walking cycle.

Although GVS was thought to be an attractive method for inducing the unconscious body movement using visual stimuli, it eventually did not become popular due to the possible side effect of dizziness when it is applied at length, or continuously. In summary, we here present a method that does not require GVS in order to generate adequate vection by further analyzing the dynamics of sensory signal usage during the walking phase, and inducing effective walking using only minimal vibratory stimulation during the walking cycle.

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