Virtual Acceleration with Galvanic Vestibular Stimulation in A Virtual Reality Environment

Taro Maeda[*]

NTT Communication Science Laboratories

Hideyuki Ando[†]

NTT Communication Science Laboratories

Maki Sugimoto[‡]

The University of Electro-Communications

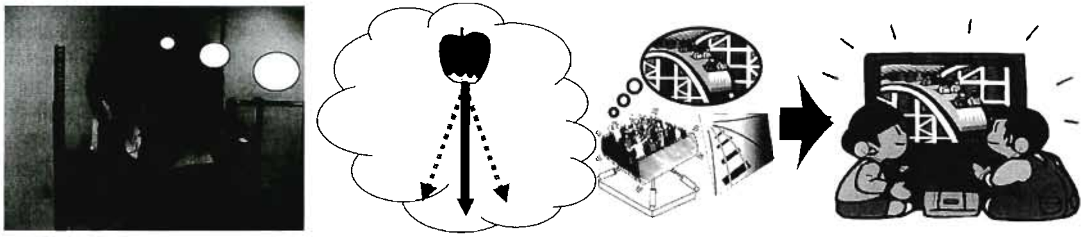

Figure 1· Galvanic vestibular stimulus (GVS) for producing vection

ABSTRACT

This study describes the relation between the vection produced by optical flow and that created by galvanic vestibular stimulation. Vection is the illusion of self motion and is most often experienced when an observer views a large screen display containing a translating pattern. This illusion has only limited fidelity and duration unless it is reinforced by confirming vestibular information. Galvanic vestibular stimulation (GVS) can directly produce the sensation of vection.

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Keywords: galvanic vestibular stimulus, vection, motion sickness

1 INTRODUCTION

The inner ear is closely involved in the VR experience, for it provides clues as to position and movement. Because many VR experiences are designed around the illusion of movement, a conflict will exist between the visual experience and the inner ear experience [1]. In the real world, this conflict is the basic source of motion sickness and loss of balance [2]. Motion sickness is commonly experienced in one form of virtual environment: the flight simulator. Take cabin rides in amusement parks as an example. While the jerking, shunting, and rolling motion of the cabin makes the experience seem much more real than the view from a passive seat at the movies, motion sickness (MS) may arise in viewers from the sensory conflict arising from inadequate visuo-vestibular agreement [3]. It suffices to say that motion sickness has occurred in VR and is a potential problem.

Galvanic vestibular stimulation (GVS) can induce vection (V-GVS hereafter) without an expensive motion platform [4]. Properly coordinated with the more common visually produced vection (VPV hereafter), V-GVS should be able to suppress MS and enhance the VR experience. Quantifying the interaction between VPV and V-GVS [5] should yield high-performance VR systems that do not use expensive mechanical motion platforms. To achieve this goal, we measure the lateral body sway generated by V-GVS and VPV.

2 MATERIALS AND METHODS

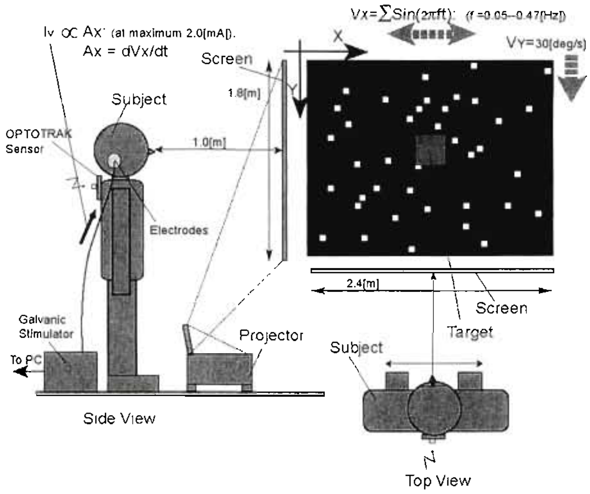

Figure 2: Apparatus for Experiments

A complex stimulus experiment of GVS and the visual stimulation is proposed in this chapter. It is designed to add GVS to an ordinary vection event created by optical flow stimulation using a wide field of view. The phenomena induced by lateral pseudo-random motion stimuli are evaluated by measuring body sway as the physical response and introspection reports of the polarity and strength of vection. Six human subjects (six men, aged 24-40) with no neuromuscular deficits participated in the experiment. Figure 2 shows the experimental apparatus. The visual stimulation was an optical flow of randomly scattered dots under constant downward velocity V_y : 30[deg/s] with lateral shift at multi-frequency sinusoidal velocity V_x from 0.29 to 0.44 Hz. GVS was delivered by current, Iv, was normalized at the maximum current, 2.0mA, and synchronized in-phase or anti-

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[*] e-mail: maeda@avg.brl.ntt.co.jp
[†] e-mail: hide@avg.brl.ntt.co.jp
[‡] e-mail: sugimoto@avg.brl.ntt.co.jp

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phase to the lateral shift acceleration, A_x (=dV_x /dt), applied through electrodes (15cm^2) across the mastoids. The movements of subject's body were measured by OPTOTRAK synchronized to the visual display at 60 [samples/s]. Four conditions were set with regard to lateral shift as follows. **[V-S]**: Visual stimulation only, **[GVS]**:GVS only (downward visual flow continued), **[in-phase]**: Visual stimulation and GVS in phase, **[anti-phase]**: Visual stimulation and GVS in opposite phase. Ten trials were done under each condition and the visual stimulation was the same in the three conditions in which it was present; that is, the phase of GVS was reversed to create the in-phase and anti-phase conditions. Subjects were asked to provide the following information after each trial: **The polarity of lateral vection** (= Induced perception of X-axis self-motion against the lateral shift of the flow. Normal vection : -, Inverse vection +), **The intensity of lateral vection** (Three steps for each polarity: ---, --, -, No Movement, +, ++, +++), **The intensity of the incongruity** (conflict) between the senses (can cause motion sickness). (Three steps: Strong, Moderate, Weak)

Table 1: Responses by Each Subject

Inverse Vection

Conditions of Experiments: Stimulus Visual	Stimulus GVS	Subject IT		SS		HA		TM		TA		JW	
+	No	+	M	+	M	-	M	-	M	-	M	-	M
[V-S]		+20.2		+9.94		-5.86		-2.51		-4.56		-1.66	
No	+	+	M	+	M	+	M	+	M	+	M	+	M
[GVS]		+18.5		+5.76		+6.06		+14.8		+4.46		+6.12	
+	+	+++	W	+++	W	-	S	-	S	-	S	++	W
[In-Ph]		+44.0		+8.04		-8.47		+4.37		-3.48		+4.97	
+	-	No	S	+	S	—	W	—	W	—	W	—	W
[Anti-Ph]		-40.5		+10.0		-22.2		-20.0		-8.17		-3.37	

+/- : The intensity of lateral vection

Strong, **M**oderate, **W**eak : The intensity of incongruity

Std(Vs) [m/s] : The standard deviations of Vs with polarity defined from cross correlation

Conflicted Vection

Enhanced Vection

3 RESULTS AND CONSIDERATION

The polarity and strength of body sway and the introspection report of the six subjects under each condition are listed in Table1. In addition to the subjective responses, objective responses were generated from the standard deviations of Vs with polarity defined from the cross correlation to the input signal's velocity, Vx. The responses of the six subjects are shown in Table 1. Observations are shown as follows, to summarize the results according to the viewpoint of the relation between stimulations and responses: **1.**All subjects perceived correctly controlled vection induced by GVS, **2.** IT and SS perceived inverted vection (+) induced visually. **3.** The others perceived normal vection (-) induced visually. **4.** Visually inverted vection was fascilitated by in-phase GVS, and suppressed by anti-phase GVS. **5.**Visually normal vection was fascilitated by anti-phase GVS, and suppressed by in-phase GVS. **6.** The perception of incongruity (conflict) was strong under those conditions of suppressed vection mentioned in 4,5. Body sway velocity was suppressed exclusively by the conflict.

The responses shown in Table1 can be classified into two groups, normal vection (perception induced has opposite phase to the optical flow) and inverted vection [6] (perception induced is in phase to the optical flow), as shown in observation 2 and observation 3 under V-S condition. Subjects IT and SS form the latter group; the others lie in the former group. On the other hand, as shown by observation 1, all subjects perceived correctly controlled vection induced by GVS. Therefore, just contrary responses are obtained between the two groups in the complex stimulus conditions, [in-Phase] and [anti-Phase]. That is, when VPV and V-GVS have matching polarity, the feeling of conflict is suppressed and the amplitude of body sway and vection itself are reinforced. When they have incongruous polarities, the feeling of conflict is boosted while the amplitude of body sway and vection itself are suppressed. The only exception to the grouping is the response of Subject JW under in-phase condition. It was noteworthy that JW stated in the introspection report that he had experienced no conflict in any condition.

It suggested that JW could invert the polarity of VPV to match V-GVS. JW's response is feasible because humans can "refocus" their visual field to create either normal vection or inverse vection. This is possible by reassigning the figure-ground [7] to the visually relative-motion stimulus. JW appears have inverted the figure-ground assignment in order to avoid the incongruity.

All subjects except HA were also capable of figure-ground reassignment and could observe for a short time VPV inversion after they were told of JW's strategy. They reported that the incongruity was weakened when the inversion lead to matching polarities and enhanced when the inversion lead to conflicting polarities..

4 CONCLUSION

A virtual reality experiment that combined vection produced by GVS with that by visual stimulation was introduced in this paper. The phenomenon induced by a lateral pseudo-random motion stimulus was evaluated by measuring body sway as a physical response and introspection reports of the polarity and strength of overall vection. The design principles extracted from the results of this experiment are as follows.

- Conflict (incongruity) between V-GVS and VPV suppressed the intensity of vection and body sway.
- When the incongruity was suppressed, the intensity of vection and body sway were enhanced and a stronger level of reality was reported.
- GVS can reduce incongruity on intermodality (= origin of VR motion sickness by visually induced vection) and can facilitate the perception of self-motion.
- V-GVS can provide the stable reference needed to permit the inversion of visually induced vection under well-controlled conditions.

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