

Gravity Jockey: A Novel Music Experience with Galvanic Vestibular Stimulation

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ABSTRACT

In this paper, we propose a Gravity Jockey (GJ) system in “Electric Dance Revolution” that allows subjects to experience vestibular sensation by means of galvanic vestibular stimulation (GVS) synchronized with music rhythms. The Gravity Jockey system enables people using GVS to feel music rhythms not only by the sense of hearing but also by visual perception and balance sensation. And in order to evaluate the effects of this system on user’s perception, we conducted psychophysical experiments during GVS with alternating current (AC).

Categories and Subject Descriptors

H.5.3. **Information Interfaces and Presentation**: Group and Organization Interfaces – *Synchronous interaction*

General Terms

Experimentation, Human Factors

Keywords

Galvanic vestibular stimulation, alternating current, visual perception, entertainment, novel music appreciation

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1. INTRODUCTION

Most music impresses our mind. But we don’t experience music only with our ear. We can enhance the perception of an impression and the enjoyment that music has through more than just the hearing sense. In the past, the experimental methods of music appreciation other than listening are visual stimulation and vibrotactile sensation. For example, “Visual Jockey” creates visual stimulation that is able to adjust the image for the moment and atmosphere of the music [16]. “Bodysonic apparatus” presents vibrotactile sensations to people by mean of mechanical vibration synchronized with music rhythms [17].

“Electric Dance Revolution” (EDR), which was developed by the authors, is an application that allows subjects to experience vestibular sensations by means of Galvanic vestibular stimulation synchronized with music rhythms [11]. This was aided by the fact that the authors had noticed that GVS with alternating current can induce subjective tilt of the visual field for the user.

In this paper, we propose the Gravity jockey system in EDR. The Gravity Jockey system is the novel system that enables people using GVS to feel music by not only hearing it but also by visual perception and balance sensation.

Galvanic vestibular stimulation (GVS) induces a sensation of virtual acceleration as vestibular information when a small current (below 3 mA) is passed between the mastoid processes. GVS causes standing subjects to adapt to a new final tilted position relative to gravity after an initial sway response towards the anodal ear and to feel virtual acceleration [1], [2]. Furthermore, GVS has been shown to influence various functions such as posture control [3], [4], human walking [5], [6], and eye

movements. In particular, eye movement responses induced by GVS consist mainly of torsional and horizontal components [7]. The ocular torsion-related effects of constant GVS with tolerable currents are similar to an accelerated head rotation at small amplitudes, which stimulates all semicircular canal afferents [8]. The amount of the displacement of eye movement depends on the value of the stimulus current [7], [9].

GVS is expected to be used as a wearable interface because it does not need a large device such as a motion platform. There have also been many studies where GVS has been used as an acceleration interface. "Radio-controlled walking" is an attempt to mimic human walking using GVS-induced vestibular information [10]. "Motionware" [14] and "Virtual Acceleration on Race Game" [15] produce a sense of motion during video games such as car racing games.

2. Gravity Jockey system

As previously noted, it is known that galvanic stimulation to the mastoid processes causes a sway response towards the anodal ear, and galvanic stimulation with AC induces subjective visual motion [18]. Therefore, the Gravity Jockey (GJ) system enables a user to stimulate visual perception and balance sensation by GVS with AC.

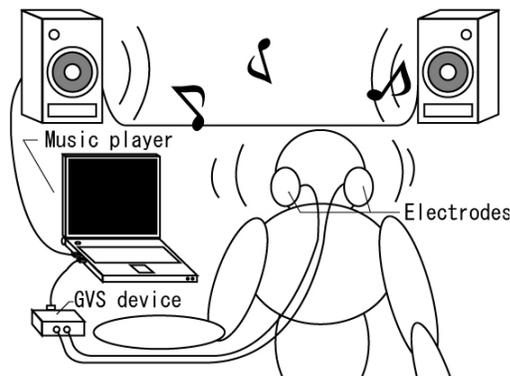


Figure 1. Gravity Jockey system

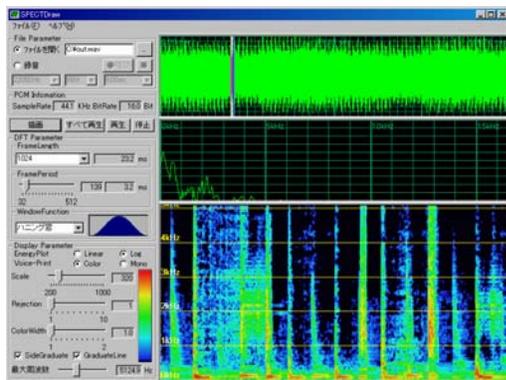


Figure 2. Sound wave pattern analysis screen

In GJ systems (see Figure 1), the user can control a stimulus current value through the GVS device, and a stimulus current

frequency is synchronized BPM (Beats per minute) of music by analyzing a wave pattern of a sound in real time. Figure 2. shows a sound wave pattern on an execution screen of the analysis software .

2.1 GVS device

Gel-electrodes (National, Japan) were affixed over each mastoid process and stabilized with tape (Figure 3). The skin behind the ears was rubbed with alcohol to reduce impedance.



Figure 3. Electrodes applied to a subject.

A GVS device (Figure 4) used a current mirror circuit as a constant current circuit and realized a very safe and stable stimulation to the subject. It provided an output current of ± 2.5 mA and was equipped with a Micro-Processing Unit (MPU), a PIC18F252, Microchip Technology Inc, Arizona, USA, as the processing device for wave pattern control. The MPU had 256 phases of resolving power (the smallest resolving power was 0.025 mA) to send out the input value to a Digital-to-analog (DA) converter by serial communication of 8 bits. An H bridge circuit in an output edge was used to select the polarity of an electrode with a single power supply.

The size of the GVS device is 90 mm by 130 mm, height is 30 mm and weight is 240 g.



Figure 4. GVS device

2.2 Subjective visual motion induced by GVS

Subjective visual motion is perceived as a rotation movement that centers on the central point of the view of the subject, when GVS is used with an AC, and for whom the world was originally perceived as stable. This is shown in Figure 5. The frequency of rotation is synchronized to the stimulus frequencies. Furthermore, the amount of the displacement depends on the value of the stimulus current [18].



Figure 5. Example of a visual effect image

3. Stimulus frequency response

Most dance music tempo is 60-220 BPM. An AC stimulation frequency of 0.5-2.0 Hz was used in the GVS to synchronize with this BPM range.

We investigated the stimulus frequency response which influences vision during GVS in a wide stimulus frequency band up to 32 Hz from a low frequency of less than 1 Hz, and then quantitatively evaluated the effects of GVS on visual perception. Furthermore, we investigated the time delay between subjective visual motion perception and AC stimulation frequency of 0.5-2.0 Hz.

3.1 Stimulus frequency responses of the current threshold

Psychophysical experiments to measure the current threshold that produced subjective visual motion perception induced by GVS were performed with each subject in a darkroom. These thresholds were measured by the up-and-down method. Stimulations with different amounts of current were presented to the subject at each stimulation frequency, and the subject was required to advise which way they perceived the presentation image to have moved.

3.1.1 Subject preparation

Five healthy subjects (males aged 21-34 years) gave their informed consent to participate in the study after being briefed about the experiment. None of the subjects had any history of visual or vestibular disorders.

3.1.2 Experimental set-up

Subjects were instructed to sit on a chair 2.0 m from a wall surface in a darkroom and to look fixedly at the center of the line ahead. The stimulation time was set at 5 seconds and the

stimulation frequency adjusted each time. In this experiment, the stimulation frequencies were 0.10, 0.25, 0.50, 0.75, 1.0, 2.0, 4.0, 6.0, 8.0, 12, 16 and 32 Hz, and the stimulation current amplitudes were 0.02-2.0 mA.

The experimental set-up was as follows (Figure 6): the image presentation method used a red-laser pointer (RX-5, Sakuracraypas, Japan) which could display a line rather than a point, and the size of the image was calibrated with a 20° viewing angle (a length of about 0.70 m).

There were two head-fixation conditions (chin rest used or not used)

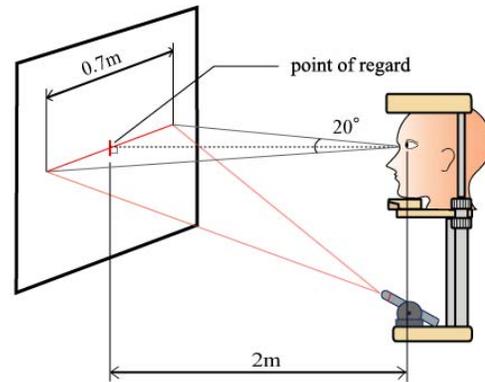


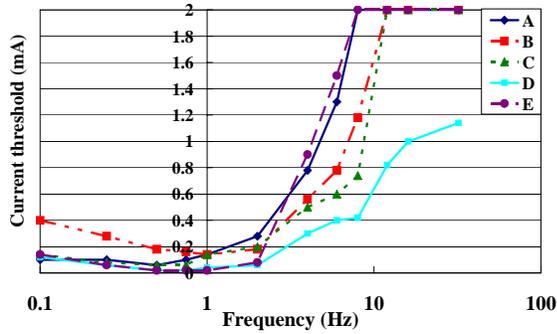
Figure 6. Stimulus Frequency Response Experimental set-up

3.1.3 Results

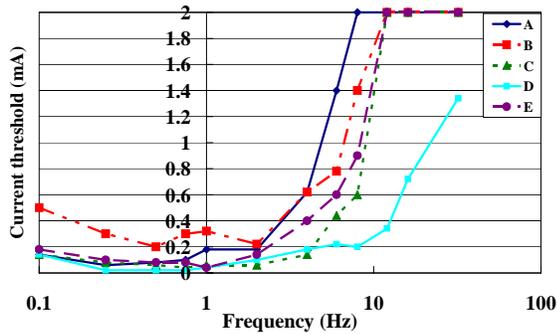
Figures 7 shows graphs of the frequency responses of the current threshold provided in each experiment (chin rest used or not used). The horizontal axis is the stimulation frequency and the vertical axis is the current threshold for motion perception for a line, to the stimulation frequency. A-E in each graph denotes the five subjects (subjects A-E: ages 21, 23, 23, 25, and 34 years old respectively).

When a subject reported that they could not perceive the image motion with the application of the maximum stimulus current (2 mA), we considered that effective data were not measurable and plotted to 2.0 mA in a graph.

These graphs show that there was frequency dependency in the subjective visual motion perception induced by GVS with AC. Sensitivity of what was perceived was highest at about 1.0Hz; visual motion was easily perceived, but sensitivity fell rapidly at frequencies higher than 1.0Hz, and the sensitivity decrease was less marked at frequencies lower than 1.0 Hz. As a result, it is thought that all the graphs of the obtained frequency responses showed a U-shaped character type for which the minimum value is the current threshold of 0.75-1.0Hz.



Horizontal visual line and Chin rest use



Horizontal visual line and no chin rest

Figure 7. Frequency response results

3.2 Time delay between subjective visual motion perception and current stimulation

In this experiment, we measured the size of the angle of subjective tilt of the visual field, and the delay between subjective visual motion perception and current stimulation during GVS. This experiment was performed with each subject in a darkroom.

In order to measure the angle and the time delay, we conducted the experimental procedure as following:

- (i) A rotational line with reciprocating rotational motion centered on the central point of the line was given to the subjects who could control the amplitude and phase.
- (ii) During GVS, the subjects regulated the amplitude and the phase to stabilize themselves as they perceived subjective visual motion.

We calculated the mean from these amplitude and phase data in each condition, which consists of the stimulus frequency and stimulus current amplitude, for four times provided in this experiment and made graphs: the rotation angle of subjective tilt of the visual field for the stimulation current value, relations of the delay of subjective visual motion perception for stimulation frequency and stimulation amplitude.

3.2.1 Subject preparation

Five healthy subjects (males aged 23-25 years) gave their informed consent to participate in the study after being briefed about the experiment. None of the subjects had any history of visual or vestibular disorders.

3.2.2 Experimental set-up

Subjects were instructed to sit on a chair 2.0 m from a wall surface in a darkroom and to look fixedly at the center of the line ahead. Their head were fixed by using chin-rest. The stimulation time was set at approximately 5 seconds and adjusted by the stimulation frequency. In this experiment, the stimulation frequencies were 0.50, 0.8, 1.0, 1.6 and 2.0 Hz, and the stimulation current amplitudes were 1.0, 1.5 and 2.0 mA.

The experimental set-up is shown in Figure 8 using a projector (V-1100, PLUS Vision Corp., Japan as the image presentation method. Table 1 shows the projector specifications. The size of the image was calibrated with a 20° viewing angle (a length of about 0.70 m).

Table 1. Specifications of projector

Projection System	DLP
Panel	DMD XGA × 1
Resolution	1024 pixels × 768 pixels
Brightness	1000 ANSI lumens
Horizontal Synch Range	15-85 kHz
Vertical Synch Range	50-120 Hz

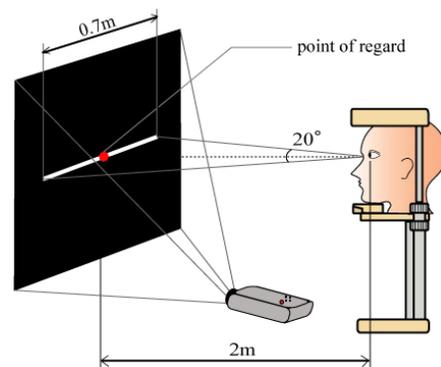
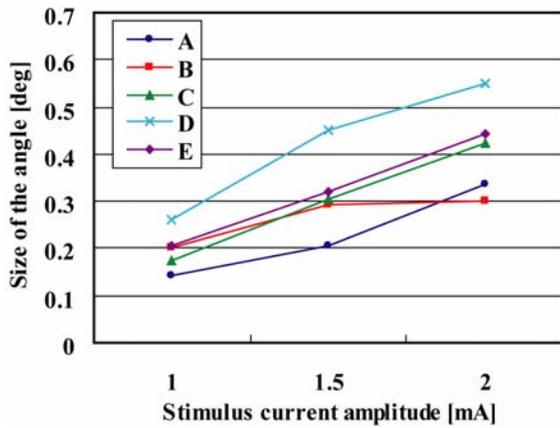


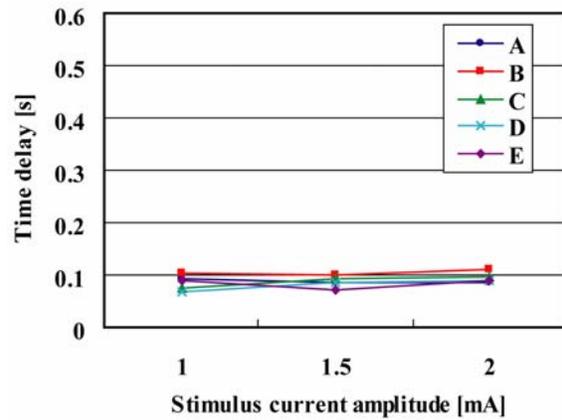
Figure 8. Time delay Experimental set-up

3.2.3 Results

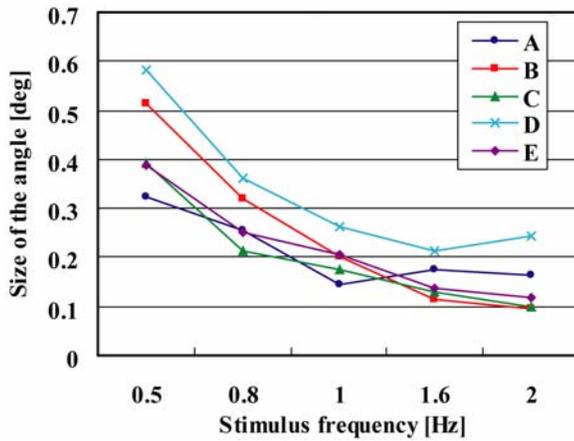
Figure 9. shows graph of the size of the angle. Figure 10. shows graphs of the time delay. A-E in each graph denotes the five subjects (subjects A-E: ages 24, 23, 24, 23, and 25 years old respectively).



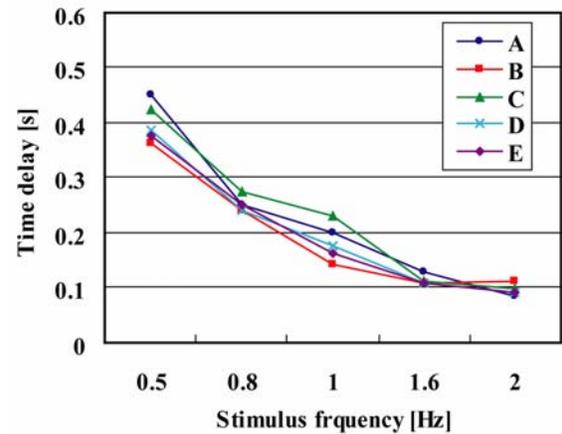
Size of the angle at 1Hz (stimulus frequency)



Delay between subjective visual motion perception and current stimulation amplitude (stimulus frequency: 2Hz)



Size of the angle at 1mA (stimulus amplitude)



Delay between subjective visual motion perception and current stimulation frequency (stimulus amplitude: 2mA)

Figure 9. Size of the angle graphs

Figure 10. Time delay results

These graphs shows that there was frequency dependency in the size of the angle of and time delay of visual motion perception induced by GVS with AC. Furthermore, the size of the angle has stimulus current amplitude dependency.

There was about 0.1-0.6s time delay for each current stimulation frequency (0.50, 0.8, 1.0, 1.6 and 2.0 Hz). This time delay has stimulus frequency dependency, but does not have stimulus current amplitude dependency. In other words, when stimulus frequency rises, the time delay shrinks.

4. Conclusions

With the Gravity Jockey system it is easy to obtain the visual motion of the rotation movement that synchronizes with music, because the stimulation frequency used is about 1.0Hz. That is, it can be said that the GJ system is a system that can experience music not only by the vestibular sensation induced by a GVS synchronized with music rhythms and the sense of hearing, but

also visually as experienced by the visual stimulation that synchronizes with the rhythm. But it is necessary to compensate for the time delay at the time of stimulation based on the stimulus frequency data.

In the future we want to investigate applications using GVS for portable music terminal units by improving the way music is experienced using visual and vestibular senses, and by making the best use of wearable units that are a feature of vestibular sense presentation devices with GVS.

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