GalVR: A Novel Collaboration Interface using GVS

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ABSTRACT

GalVR is a navigation interface that uses galvanic vestibular stimulation (GVS) during walking to cause users to turn from their planned trajectory. We explore GalVR for collaborative navigation in a two-player virtual reality (VR) game. The interface affords a novel game design that exploits the differences in first and third person perspectives, allowing VR and non-VR users to share a play experience. By introducing interdependence arising from dissimilar points of view, players can uniquely contribute to the shared experience based on their roles. We detail the design of our asymmetrical game, Dark Room and present some insights from a pilot study. Trust emerged as the defining factor for successful play.

CCS CONCEPTS

•**Computing methodologies** →*Virtual reality;* •**Human-centered computing** →**Collaborative interaction; Haptic devices;**

KEYWORDS

Virtual Reality, Collaboration, Galvanic Vestibular Stimulation

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1 INTRODUCTION

GVS is a technology that directly affects a user's vestibular system by altering their sense of balance and direction through electrical stimulation via electrodes placed on the mastoid bones behind each ear. In standing users, GVS evokes a prolonged 'galvanic body sway.' In walking users, it affects balance and produces anodal staggered foot placements (Fig 1a, b). However, in walking users, with their head pitched forward, it causes them to turn smoothly from their planned trajectory in the anodal direction (Fig 1c, d) [Fitzpatrick et al. 1999]. Prior research has used GVS to evoke balance responses in a two-player game [Byrne et al. 2016] or induce directional virtual head roll and pitch motions [Aoyama et al. 2015]. In GalVR, we present the use of GVS for smooth turning during walking which has not been readily explored in prior research. We demonstrate GalVR with an exemplar collaborative VR game. Our GVS prototype is small, portable, and can be digitally and remotely controlled (Fig. 2a).

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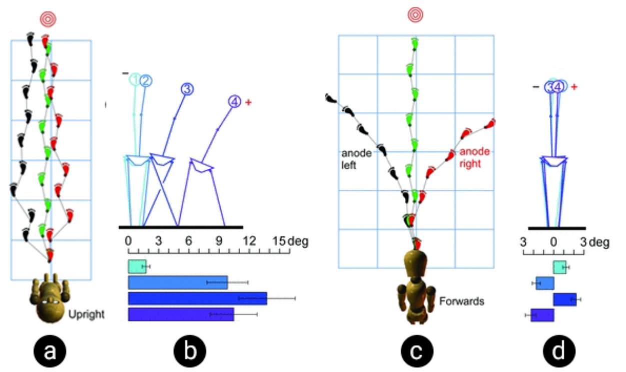

Figure 1: (a - b) With head upright, GVS produces anodal staggered foot placements because of a balance response. This results in large body tilt during the first few steps following which balance is regained. (c - d) With the head pitched forward, GVS turns a user smoothly in the anodal direction without staggering or body tilt [Fitzpatrick et al. 1999].

2 GALVR

Navigation is important for VR applications and real-walking locomotion interfaces are believed to produce a higher sense of presence than other locomotion interfaces [Usoh et al. 1999]. However, using a real-walking locomotion interface is a challenge because the virtual world is typically restricted to the size of the tracked space [Sra et al. 2016a]. Redirection techniques like rotating, scaling, skewing, or translating have been used to enable users to walk in virtual worlds (VWs) larger than the tracked space [Peck et al. 2012]. Resetting has been used to steer the user away from physical boundaries by stopping and reorienting them. We propose GalVR as a general purpose navigation interface that uses vestibular stimulation during walking to cause users to turn from their planned trajectory. We envision its use in redirection and resetting techniques as well as in HTC Vive chaperone like safety systems that can automatically steer users away from tracked space boundaries. In this paper we explore GalVR as a collaborative navigation interface in an asymmetrical VR game, **Dark Room**. A VR player (VP) equipped with the GVS device and a non-VR player (NVP), who can control the GVS stimulus (time, duration, direction) to steer the VP, work together in an 'escape the room' like game. With the high cost of VR devices, more asymmetrical experiences are beginning to emerge where each player has partial information about the game world and can participate with a VP through non-VR devices. SnowballVR presents an asymmetrical game where each user plays a different role that is defined by the size of their physical space [Sra et al. 2016b]. We believe our GVS-based navigation control interface can create unique shared experiences.

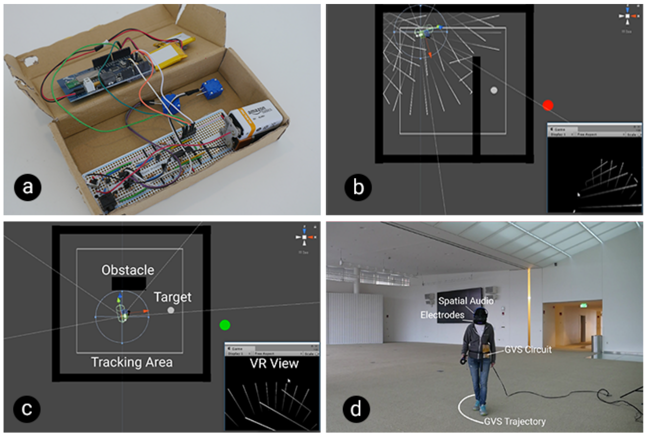

Figure 2: a) GVS circuit fitted inside a box for portability. b) A top-down view of the VW. c) The NVP's view of the virtual world. Inset shows the VP's point of view with lines reflected off obstacles. d) VP being turned right with GVS stimulus sent by the NVP.

2.1 Dark Room

Dark Room is a two-player asymmetrical VR game, inspired by the singleplayer game Dark Echo. We use GVS' ability to turn a user smoothly from their planned trajectory as the gameplay mechanic between two players. A VP "sees" the VW by the reflected sound of their footsteps and claps, represented visually by lines on the floor (Fig. 2b), and an NVP sees a bird's eye view of the VW (Fig. 2c). The VP can only echolocate obstacles resting on the floor while the NVP can only see those above shoulder height. The target, visible in the bird's eye view as the green dot (Fig. 2c), periodically emanates a spatialized audio ping to guide the VP to its location. The goal is for players to work together to reach the target without colliding with any obstacles. Since the VP needs to look at the reflected lines on the floor while walking, they are automatically in the correct starting position of head pitched forwards for eliciting the GVS turning response. The NVP observes the walking path of the VP to infer possible obstacle locations invisible to them. Based on inference and partial world knowledge, the NVP plans the appropriate timing, duration and direction for applying GVS. The VP uses the received stimulus to update their mental map of the virtual world obstacle layout. The NVP uses arrow keys (left or right) on the PC keyboard to trigger the GVS circuit to current through the electrodes in the chosen direction (anode to cathode or vice versa) causing the VP to turn right or left (Fig. 2d). Holding down an arrow key results in longer stimulus that stops when the key is released.

2.2 Pilot Study

We invited 6 participants (2 females) with an average age of 23.5 ($SD = 3.5$) to our pilot study using an HTC Vive headset and a Windows PC. The Vive tracked space was set as $4 \times 4m$. Each participant experienced two sessions, one as VP and one as NVP. Before starting the VP session, calibration was done to determine the appropriate amount of current needed to generate an adequate turning response from each participant. This was important given the small tracked space. The amount of current in the GVS circuit was controlled via potentiometers and was set to a safe range ($0.1-1.0mA$) [Fitzpatrick et al. 1999]. After calibration, the current value was set and remained unchanged during that participant's session, which lasted 5-7 minutes. The study started with two practice sessions so users could learn the game mechanics and establish an appropriate walking speed in the small traced space. After practice, actual gameplay began with more challenging obstacle placements. Our pilot shows that our interface worked successfully and participants were able to cooperate using GVS and arrive at the target each time. Participants walked to the target with an average of 2.5 GVS turning events. The momentary tingling sensation from the stimulus was not found to impact the experience. In the study, trust emerged as a important constituent of gameplay. The VP had to occasionally give up control over where they wanted to walk, and trust that the NVP was steering them correctly. When asked, players unequivocally expressed a preference for GVS over verbal turning directions. *"Verbal would be boring and make the game too easy"* (P3). Since the GVS turning response only works when a user is walking, we recommend having a larger tracked space to allow for more walking and turning opportunities.

3 CONCLUSION AND FUTURE WORK

Vestibular stimulation is a simple technique that can evoke controlled sensations of self-motion and altered orientation when delivered appropriately. While prior research has used the balance reflex and ocular responses for creating playful interfaces, in GalVR we take advantage of the orientation response to control a user's walking trajectory. We demonstrate GalVR through an asymmetrical cooperative VR game. We argue that by embracing novel technologies, VR designers can create uniquely immersive social experiences. In order to establish superiority of GVS, we plan to formally compare our GalVR interface with direct verbal commands and with haptic devices for turning and indicating direction respectively. We also plan to explore GalVR as a redirected walking technique. A larger goal going forward is how to best integrate research from areas such as collaborative work and learning, non-verbal communication, and user satisfaction into the GalVR experiences.

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