Alice in Gravityland: Augmenting Gravity Experiences with Around-the-Head Vibrotactile Feedback and Illusory Tactile Motion

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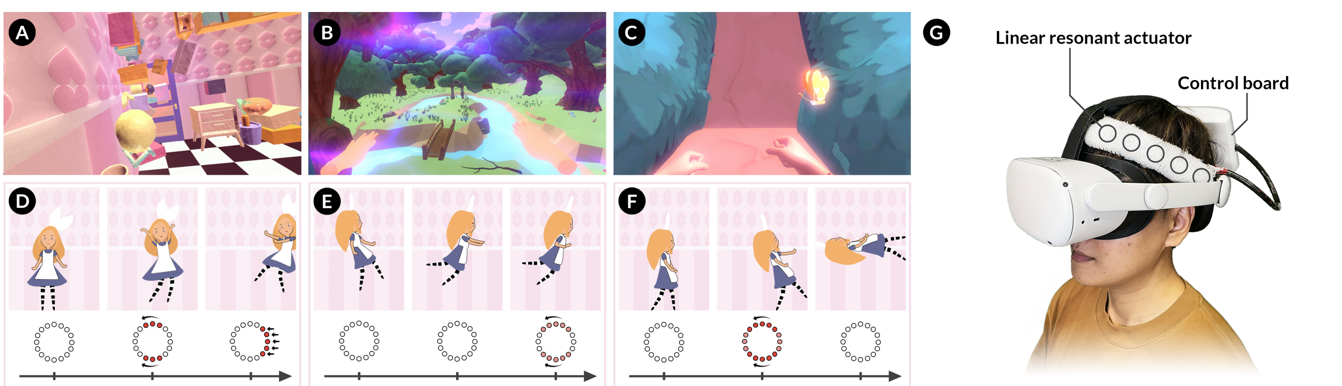

Figure 1: Different gravity experiences and vibrotactile patterns: (A,D) changing the direction of gravity, (B,E) floating through zero gravity, and (C,F) defying gravity. (G) Haptic feedback patterns are delivered to the head via a wearable headband.

ABSTRACT

Alice in Gravityland is a VR adventure exploring three gravity experiences with novel, around-the-head vibrotactile feedback using illusory tactile motion. Players are able to 1) change the direction of gravity, 2) navigate through zero gravity, and 3) defy gravity as they walk on walls. The haptic feedback helps improve players' sense of directionality to improve immersion when experiencing gravity events. Inspired by Lewis Carroll's *Alice's Adventures in Wonderland* (1865), the game invites players to alter gravity to solve puzzles and experience gravity in a unique way through this multi-sensory VR adventure.

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CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**; **Haptic devices**.

KEYWORDS

virtual reality, haptic feedback, gravity

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1 INTRODUCTION

The idea of being able to manipulate gravity, or exist in a world without it, remains a captivating thought. Consider for example notable movies like Inception (2010), Gravity (2013) and Interstellar (2014). Despite significant advancements in immersive audio and visual experiences through virtual reality (VR), the absence of complementary haptic feedback for virtual gravity experiences often prevents players from achieving a convincing level of immersion.

2 DESIGN AND IMPLEMENTATION

As players of Alice in Gravityland traverse down the rabbit hole, they will find themselves immersed in an alternate reality. In order to return back to the 'real' world, players must puzzle their way through three scenes, each presenting a distinct type of altered gravity experience, complemented by unique vibrotactile patterns.

Haptic Feedback. The vibrotactile patterns are applied to the players' heads via a wearable haptic headband, designed after MotionRing [Chu et al. 2021]. The headband contains 16, equally spaced, Vybronics VL91022-170H linear resonant actuators (LRAs), each individually controlled by a DRV2605L driver and connected to a central NodeMCU-32S. By modulating the timing, duration and amplitude of the actuators, it is possible to induce illusory tactile motion on the players' heads, where discrete stimuli are perceived as continuous motion [Sherrick and Rogers 1966]. The intensity and velocity of the illusory tactile motion can be manipulated by adjusting the amplitude of the actuators and the interstimulus onset interval (ISOI), which is the delay between the activations of adjacent actuators.

Changing Directions of Gravity. In the first scene, players yield the ability to manipulate the direction of gravity. Players sense the new direction of gravity through fast and intense illusory tactile motion to induce a sense of acceleration. Collisions with a surface are coupled with a brief vibrotactile impulse, emphasizing the impact of the collision.

Zero Gravity. In the following scene, players are encapsulated within a floating bubble, suspended in mid-air as they experience zero gravity. With swimming gestures, players navigate through the scene as gentle illusory tactile motion mimics the subtle drag of movement through the weightless atmosphere.

Defying Gravity. In the final scene, players brace themselves to escape the Queen of Hearts' 3-dimensional maze. Defying the very laws of physics, players tread upon the walls and ceilings in search of an exit to their original world. Transitions onto a new surface trigger double-layered vibrotactile feedback, where illusory tactile motion aligns with the direction of transition, while vibrotactile rumbling echoes the world rotating around the player.

3 DISCUSSION AND IMPLICATIONS FOR FUTURE WORK

This work has explored virtual gravity experiences, providing a heightened sense of presence and engagement through the integration of a wearable vibrotactile headband, using illusory tactile motion which has been shown to enhance players' perception of directionality [Chu et al. 2021]. Through our design iterations and feedback from pilot users, we have found that illusory tactile motion is better suited for transient events, rather than persistent, continuous feedback which may lead to overstimulation. Therefore, we have focused on applying such feedback during the transition of gravity direction and body orientation.

Moreover, prior haptics research has shown the possibility of reducing VR sickness while enhancing immersion by matching haptic feedback to visual experience to reduce sensory conflict. For example, WalkingVibe [Peng et al. 2020] showed that head-based vibrotactile feedback can enhance the immersion of walking experiences in VR and can also mitigate symptoms of VR sickness when the feedback is synchronized with users' footsteps. Changing the direction of gravity direction and body orientation are inherently disorientating, which is somewhat mitigated by our haptic design that improves spatial orientation. In future work, we plan to further explore its effectiveness in reducing VR sickness.

In conclusion, Alice in Gravityland is an immersive VR adventure enriched by novel, around-the-head vibrotactile feedback designed to enhance virtual gravity experiences such as altering gravitational direction, maneuvering through zero-gravity environments, and traversing walls. Drawing inspiration from Alice's Adventures in Wonderland, we aim to inspire further exploration of gravity experiences in virtual reality, while encouraging researchers to consider the role of haptic feedback in unlocking new experiences and elevating existing ones.

REFERENCES

Shao-Yu Chu, Yun-Ting Cheng, Shih Chin Lin, Yung-Wen Huang, Yi Chen, and Mike Y. Chen. 2021. MotionRing: Creating Illusory Tactile Motion around the Head Using 360° Vibrotactile Headbands. In *The 34th Annual ACM Symposium on User Interface Software and Technology* (Virtual Event, USA) *(UIST '21)*. Association for Computing Machinery, New York, NY, USA, 724–731. https://doi.org/10.1145/3472749.3474781

Yi-Hao Peng, Carolyn Yu, Shi-Hong Liu, Chung-Wei Wang, Paul Taele, Neng-Hao Yu, and Mike Y. Chen. 2020. WalkingVibe: Reducing Virtual Reality Sickness and Improving Realism While Walking in VR Using Unobtrusive Head-Mounted Vibrotactile Feedback. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI '20)*. Association for Computing Machinery, New York, NY, USA, 1–12. https://doi.org/10.1145/3313831.3376847

Carl E. Sherrick and Ronald Rogers. 1966. Apparent haptic movement. *Perception & Psychophysics* 1 (1966), 175–180. https://doi.org/10.3758/BF03215780