Wheel-Based Attachable Footwear for VR: Challenges and Opportunities in Seated Walking-in-Place Locomotion

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ABSTRACT

This poster explores the potential of Cybershoes, a foot-based consumer input device, used with a swivel chair to enable seated walking-in-place (WIP) locomotion in virtual reality (VR). Through a qualitative study with 12 participants, we investigated the effects of Cybershoes on user comfort, presence, motion sickness, and overall experience during various sightseeing tasks. Our findings reveal both opportunities and challenges for Cybershoes as a seated-WIP solution. Participants perceived Cybershoes as more natural for navigation compared to handheld controllers, with most reporting reduced motion sickness. However, challenges included perceived slower movement speed, ergonomic issues, and limited action detection. Our work also highlights Cybershoes' potential beyond gaming, including applications in exercise, professional training, remote work, and accessibility.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**.

KEYWORDS

VR; seated walking, virtual travel, locomotion; shoes, wheel, input.

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1 INTRODUCTION

Virtual travel, the act of moving from point A to point B in Virtual Reality (VR), is one of the most common and universal forms of interaction in VR environments. While often secondary to tasks such as exploration, searching, and maneuvering, effective virtual travel is crucial for immersive VR experiences. Virtual travel techniques can be broadly categorized along three axes: *stationary* (e.g., sitting) or *mobile* (e.g., standing and walking-in-place); *vehicular* (e.g., a driving simulator) or *body-centric* (e.g., body leaning, foot stepping or sliding); and *magical* (i.e., techniques impossible in the real world, like teleportation) or *mundane* (i.e., techniques mimicking real travel) [1, 4, 5, 7]. Among these categories, prior work suggests that stationary, body-centric, and mundane travel techniques, such as **s**eated **w**alking-**i**n-**p**lace (sWIP), offer an optimal balance of user comfort, physical space efficiency, immersion, and practicality [1, 7]. However, traditional VR input devices, like handheld controllers with thumbsticks, cannot provide sWIP functionality, and most sWIP techniques [1] remain in the research prototype stage, thus limiting their access to a wider VR user base.

Figure 1: (Top-Left) Components of the Cybershoes (image from https://www.cybershoes.com/). (Top-Right) A participant wearing Cybershoes while navigating VR worlds for sightseeing tasks. Scenes from two VR worlds: (Bottom-Left) Eternal Ash [2] and (Bottom-Right) Eventide [3].

To address this gap, we investigate the potential of Cybershoes (https://www.cybershoes.com/), a commercial, low-cost (under $400 USD) off-the-shelf hardware solution for sWIP (see the left of Fig. 1). Cybershoes are shoesoles equipped with wheels that users strap to their own shoes while sitting on a swivel chair. This setup allows for comfortable posture and natural body rotation in VR. Users make treadmill-like movements with their feet lightly touching the floor. The wheels on the Cybershoes detect movement speed, which is then translated into locomotion within the VR environment. Cybershoes map forward-to-backward and backward-to-forward rolling movements to forward and backward locomotion in VR, respectively. Users can adjust their speed by changing their stride

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rate: increasing it transitions from walking (1 m/s maximum speed) to running mode, while decreasing it returns to walking mode.

2 PILOT STUDY

We conducted an IRB-approved study with 12 participants (8 men and 4 women, aged 25-30, mostly VR novices) to evaluate *Cybershoes* against a baseline of thumbsticks on the handheld *Controller* for *sightseeing* tasks in VR. Both conditions used Oculus Quest 2 HMDs in two distinct VR Chat (https://vrchat.com/) worlds. The first world (Fig.1, bottom left) featured an open area with small hills and ancient relics, while the second (Fig.1, bottom right) offered a compact space with indoor and outdoor areas, and architectural landmarks.

Participants completed sightseeing tasks in first-person view. They could see their avatar's arms and legs in standing position when looking down, facilitating a sense of body ownership essential for presence [5] and providing a static reference that could reduce motion sickness [6]. We asked them to approach target landmarks, walk up/downhill while enjoying the scene, or follow scenic trails.

We conducted the study in a quiet 20ft × 25ft room. Each session consisted of introduction, consent, training, and four counterbalanced tasks (two per world, two per condition). We used a think-aloud protocol to capture participants' real-time feedback, particularly regarding cybersickness, thus reducing reliance on post-task questionnaires like SSQ. Each hour-long session concluded with open questions about use cases, design improvements, and general feedback. Participants received a $20 Amazon gift card. All sessions were recorded post-consent and manually transcribed. We used iterative coding to develop our codebook with 3 major themes:

Challenge and Opportunity 1: Reduced Motion Sickness: The mismatch between expected and actual movement played a crucial role in the user experience. Most participants (N = 10) noticed slower speeds with Cybershoes compared to their normal stride pace. Nonetheless, participants reported more natural maneuvering by combining foot movements with head and body movements. For example, they rotated their body (via the swivel chair) for larger directional changes, used head movements for smaller directional adjustments, and applied real-life walking movements such as taking large steps, leaping, walking backward, and increasing stride pace. However, increasing stride pace was physically tiring. This limitation proved serendipitous: the normal pace of strides caused discrete movement, reducing optical flow during locomotion and potentially decreasing motion sickness. This corroborates prior work on sWIP [1] and stepping interfaces [7].

In contrast, participants could easily increase speed using the thumbstick, often moving faster than their normal pace. Without additional motion sickness reduction techniques (such as restricted field of view or reverse optical flow [6]), this condition led to more frequent motion sickness. Participants took intermittent breaks by removing the HMD to recover. Some participants quickly realized they could move their avatar at a constant speed with the handheld controller. Since movement and direction inputs were separate, they could maintain course as long as they did not change direction.

Challenge and Opportunity 2: Physical Fatigue and Simulating Remote Work: Physical fatigue was more pronounced with Cybershoes, as they engaged participants' lower extremities more intensively than thigh muscles, which are typically more involved in daily walking. On average, participants spent five minutes on each Cybershoes task and reported sore legs afterwards.

This challenge led to new design opportunities. The embedded IMU sensors in Cybershoes could provide detailed movement data, opening possibilities for various applications. Professional training scenarios, such as for firefighters, could benefit from realistic movement simulation. Exertainment (exercise + entertainment) apps could offer engaging experiences like virtual marathons, combining physical activity with immersive environments. Additionally, Cybershoes could facilitate the development of exercise routines that specifically target lower body parts.

Another promising application lies in telepresence work. For instance, a facility manager could remotely walk through a building using a telepresence interface with Cybershoes. Physical fatigue experienced during this virtual walk would more closely mimic the real-world exertion of on-site inspections, making remote work more equitable and authentic. This approach could bridge the gap between remote and on-site work experiences, potentially improving job satisfaction and performance for remote workers.

Challenge and Opportunity 3: Usability Enhancement: User experience varied based on prior gaming experience. Those familiar with video games appreciated the ergonomics and button mapping of handheld controllers but noted overly sensitive controls. Those who were VR novices found Cybershoes more intuitive – they could focus on tasks rather than searching for controller buttons. The gentle learning curve enhanced immersion.

However, participants noted that Cybershoes tended to loosen over time, requiring frequent adjustments for comfort. They expressed a desire for improved ergonomic design to ensure comfortable wear and a simpler way to put them on and take them off. They also reported that Cybershoes could only detect a limited number of actions, some of which felt unnatural (e.g., jumping).

Participants suggested several potential design improvements. These included adding force feedback, implementing adjustable wheel resistance based on terrain, and detecting airtime when feet do not touch the floor for a more natural walking experience. Lastly, participants expected better control and calibration to reduce the mismatch between their stride rate and the movement speed in VR.

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