A Demonstration of VRSpinning: Exploring the Design Space of a 1D Rotation Platform to Increase the Perception of Self-Motion in VR

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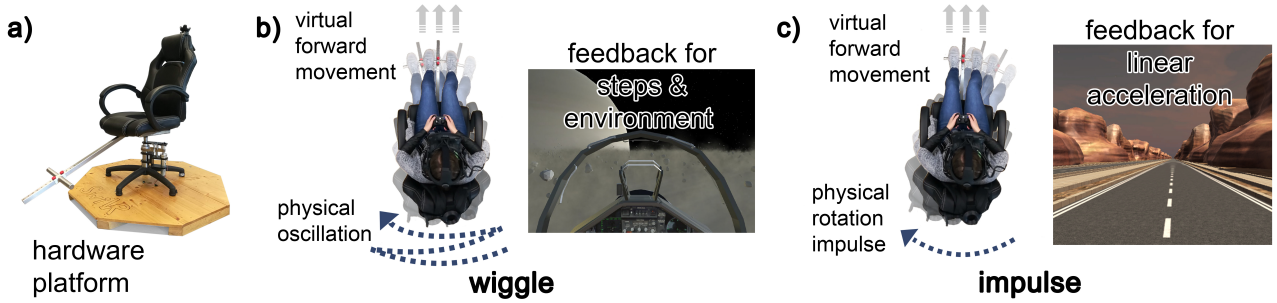

Figure 1. a) *VRSpinning* hardware platform consisting of a motorized swivel chair, a footrest and HTC Vive based orientation tracking. b) The forward motion approaches of *VRSpinning* to increase vection and reduce simulator sickness: *wiggle* movement to simulate steps or environmental events in VR. c) Alternative: *impulse* movement to simulate forward acceleration in VR by applying a short rotational impulse.

ABSTRACT

In this demonstration we introduce *VRSpinning*, a seated locomotion approach based around stimulating the user's vestibular system using a rotational impulse to induce the perception of linear self-motion. Currently, most approaches for locomotion in VR use either concepts like teleportation for traveling longer distances or present a virtual motion that creates a visual-vestibular conflict, which is assumed to cause simulator sickness. With our platform we evaluated two designs for using the rotation of a motorized swivel chair to alleviate this, *wiggle* and *impulse*. Our evaluation showed that *impulse*, using short rotation bursts matched with the visual acceleration, can significantly reduce simulator sickness and increase the perception of self-motion compared to no physical motion.

Author Keywords

virtual reality; simulator sickness; vection; seated navigation.

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INTRODUCTION

When looking at locomotion in current virtual reality experiences, most employ one of two common paradigms. The first option simply presents virtual movement via the head mounted display (HMD) to the seated users. The second option combines tracked walking in a confined real space with teleportation for larger distances, the so-called room-scale approach seen in both HTC Vive or Oculus Rift. Both are however not without caveats, as the room-scale approach can cause user fatigue over longer sessions and is not applicable for all types of experiences, e.g. excluding driving or flight simulations. Simulator sickness, a common problem for the virtual motion approach, is largely avoided due to the real motion though.

This simulator sickness, widely considered to be a subset of motion sickness[6], can cause symptoms like eye strain, headache, nausea, sweating, vertigo and more[7]. As expected with such symptoms, current VR designs try to avoid it as much as possible. The actual cause of simulator sickness is believed to be polygenic in nature[10], with the most accepted explanation being the conflict between the visual and vestibular senses[11]. This conflict might also have a connection to vection, as current consent points towards vection as a possible cause of simulator sickness[4]. Vection can be defined as a *conscious subjective experience of self-motion*[1, 9] and is induced by optokinectic stimulation with influence from other senses, including the vestibular system. With the cur-

rent approaches and the possible problems in mind, this work aims to provide a platform that allows for improved seated virtual motion experiences by including vestibular senstions to the visual ones. This approach is based on the idea of a motion platform, as seen in [8] and [5], though instead of a large, highly actuated 6-DOF design, we wanted to minimize the design of the platform to reduce space requirements and hardware costs, while still retaining a positive effect.

For the design of *VRSpinning* we used a motorized swivel chair, a idea already presented in the SwiVR project[3], and explored and published the possible options for generating motion feedback[12]. Two approaches were developed and tested, *wiggle* and *impulse*. *Wiggle* changes the rotation direction quickly and causes the chair to oscillate back and forth. Users associated this feedback with impacts from either the environment or steps of the virtual avatar. The second approach, *impulse*, was created as a response to this, to directly provide feedback for linear motions. For this we present the user with a visual linear acceleration, while also turning the chair during the this phase. In our evaluation we found that users can combine these sensations and feel increased vection with decreased simulator sickness. For the demonstration of *VRSpinning* we will present visitors both a short instance of *wiggle* and *impulse* with and without the chair's motion feedback, to allow them to experience and confirm our results for themselves.

DESIGN PRINCIPLES

Our aim with *VRSpinning* was to represent both, forward and rotational motion in VR based on a swivel chair as our motion platform. For our design approach, the fact that the vestibular system can only detect accelerations not constant motions, allowed us to focus on only generating feedback for rotational and linear accelerations. Rotation feedback was easy to achieve with the swivel chair and is not part of this project, instead forward motion was the main goal, as the chair cannot directly portray such motions.

We tested two approaches, the first one called *wiggle*. Here we quickly accelerate the chair and switch directions multiple times per second, creating a oscillating motion back and forth. When evaluating the wiggle prototype, we found that depending on the frequency of the wiggle, users mentally connected this motion with either steps or object impacts from the virtual environment but never with the virtual motion itself.

Therefore we implemented a second approach, *impulse*, where we take advantage of the inaccuracy of the human perception and present different visual and vestibular stimuli simultaneously. With the dominance of the visual system, as tested by Berthoz et. al.[2], we were able to use the non-matching vestibular sensation of turning to enhance the motion perception for the visual linear acceleration. For more details on both approaches and our design decisions, please refer to our main publication[12].

TECHNICAL SETUP

The basis for this project is a swivel chair equipped with a clutch, gearbox and a motor to allow for automatic rotation. This hardware was first used in the SwiVR project and was expanded with a footrest to allow for unhindered rotations. The HTC Vive serves as a head-mounted display (HMD) and a head position tracker, additionally the chair itself has a Vive tracker attached to it. With the tracked information from both sensors, a full manipulation of the virtual view is possible, e.g. removing any rotation of the chair from the users view, allowing the *impulse* prototype to function.

The software was designed in Unity3d and communicates with the Arduino motor controller of the chair via a USB serial connection. Coupled with the sensor input of the Vive tracker it can interact with the chair in different ways. Firstly the power levels of clutch and motor and the rotation direction can be adjusted directly, providing the fast paced switching necessary for the *wiggle* prototype. Alternatively the software can also track and adjust the angular velocity of the chair, allowing for precise angular accelerations and constant turns, as used in the *impulse* prototype. The platform can also handle direct user input and provide matching feedback or simply display pre-programmed scenarios.

For this demonstration, only pre-programmed sequences for *wiggle* and *impulse* will be used, to limit the amount of turns during a session and keep the HMD wire from twisting or breaking. Usually a wireless adapter for the Vive HMD would be used, but due to the critical timings necessary to adjust the virtual image, any delays caused by potential interference with other wireless equipment on-site could break the feedback illusion.

FINDINGS

With our two prototypes we conducted two studies. The first one was a user elicited study to explore the effects of *wiggle* on the perceived motion, leading us towards the step or environment based mappings instead of a direct connection to the displayed motion. The second study evaluated the *impulse* prototype in terms of Vection and Simulator Sickness, using self-reported measurements both during and after the exposure. Here we found a significant increase in the perceived Vection while simultaneously decreasing the simulator sickness. Further questions showed that despite not portraying the presented motion accurately, our impulse prototype also increased the overall feeling of acceleration and even the perceived realism of the motion.

CONCLUSION

We have presented VRSpinning, a seated 1D rotation platform used for motion feedback to increase the perception of self-motion in virtual reality. Our platform uses rotation to portray linear accelerations and can increase not only the perceived realism of motions, but also decrease the occurrence of simulator sickness in seated VR scenarios. In our demonstration we will present visitors with our two prototype *wiggle* and *impulse* to showcase both the environment and the acceleration feedback.

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