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Stay Safe! Safety Precautions for Walking on a Conventional Treadmill in VR

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Figure 1: Left: real world setup. Center: VR shoe store, the avatar follows user's movements. A virtual model of the treadmill is present. Right: safety belt.

ABSTRACT

Conventional treadmills are used in virtual reality (VR) applications, such as for rehabilitation training or gait studies. However, using the devices in VR poses risks of injury. Therefore, this study investigates safety precautions when using a conventional treadmill for a walking task. We designed a safety belt and displayed parts of the treadmill in VR. The safety belt was much appreciated by the participants and did not affect the walking behavior. However, the participants requested more visual cues in the user's field of view.

Index Terms: Human-centered computing—Human computer interaction (HCI)—HCI design and evaluation methods; Human-centered computing—Interaction paradigms—Virtual Reality;

1 INTRODUCTION

Locomotion in virtual reality (VR) applications has been a challenge for years. Omnidirectional treadmill devices have been developed that enable infinite walking in VR and can be integrated in entertainment applications. But commercial VR locomotion devices as the Virtuix Omni are expensive. Innovators have already developed low-cost alternatives [1], but they are not yet widespread.

Conventional treadmills are neither responsive nor omnidirectional and therefore cannot be used in all VR areas. However, they are suitable for monotonous walking tasks and are widely used in VR rehabilitation applications. The conventional treadmill exercises have been extended with VR environments, which leads to increased motivation and training outcome [3]. In addition, reasearch included conventional treadmills in VR studies where monotonic walking is essential, such as for analyzing gait variabilities [4].

However, using treadmills in VR raises challenges. There is a high risk of injury because the user could drift off the real unseen treadmill in 4 directions: left, right, forward, backward. To minimize the risk of injury, safety precautions must be taken when using treadmills in VR. Therefore, we developed a VR application with a walking task on a treadmill and took safety precautions to secure users in all four directions (Fig 1). We evaluated the use of the safety precautions in a user study.

2 RELATED WORK

To keep users centered when using the Omni, users are required to use an uncomfortable harness [2]. In contrast, users of conventional treadmills are less constricted and the safety precautions found in the literature are manifold. To prevent users from drifting off their path, Winter et al. [3] displayed a camera image of the real environment when looking towards the feet. This was supplemented by green and red arrows, which served as warning signals for estimating the forward/backward position on the device. Wirth et al. [4] fitted their study participants with a safety chest harness and a safety rope attached to the ceiling to avoid possible injuries. However, this solution is not mobile and requires appropriate constructional prerequisites.

3 IMPLEMENTATION

In this study, we aimed to investigated a simple, low-cost, and portable solution for securing subjects while walking on a treadmill in VR. The problem with using a treadmill in VR is that a user can drift off the device in 4 directions: left, right, forward, backward. Therefore, it is important to secure the user in all four directions.

For safety reasons, we displayed a virtual model of the treadmill in VR that matched the real treadmill in size and position. We removed the arm grips from the virtual model so that the avatar and the treadmill could be viewed head-on in a mirror. Users can thus check their own body position on the fitness device at any time using the mirror or by looking at the virtual treadmill.

We designed a safety belt consisting of a back part, two elastic bands and loops at the ends (Fig. 2). The belt was fastened to the treadmill and the subject's back using Velcro (Fig. 1). Tension on the slightly elastic belt made it possible to feel when one is positioned too far forward, backward, left or right on the device. This way the user can quickly correct this themself if necessary and prevent drifting off.

Furthermore, we started with a two minutes training walk without headset. During this, the user could get used to walking on the

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Figure 2: Attachement of the safety belt.



Figure 3: Box plots comparing the stride features in the beginning, middle and end of the walking interval.

treadmill and learn to associate the perception of the belt's tension with the body position on the treadmill.

4 Метнор

To test the proposed safety precautions, we developed a VR environment with walking task. Users were located in a VR shoe store and asked to try on a virtual pair of flat shoes using a female avatar. They then tested the shoes while walking two minutes with a speed of 3 km/h and 1 % incline on a treadmill. Meanwhile, we tracked their movements via OptiTrack motion capturing and analyzed them in the Unity application. The experiment consisted of several walking intervals on the treadmill. The user attached the safety belt and the treadmill's safety clip. Subsequently, the users practiced walking on the treadmill without headset before a VR training walk started. This was followed by the VR shoe testing. Before and after the experiment, participants had to complete questionnaires with demographic and open questions to evaluate the application.

5 RESULTS

We recruited 14 female students enrolled at the University of Würzburg as participants. They had a mean age of 20.50 years (SD = 1.45). For each participant, we averaged data from 5 consecutive strides at the beginning, middle, and end of the walking interval. Computing a repeated measures ANOVA revealed no significant difference between measurement time points considering stride duration ($F(2,26) = 1.07, p = 0.36, \eta^2 = 0.04$) and stride length ($F(2,26) = 0.54, p = 0.59, \eta^2 < 0.01$) (Fig. 3).

All participants felt safe walking on the treadmill in VR. 9 participants mentioned the safety belt as the reason, through which the correct position on the treadmill could be perceived, while others mentioned the presence of the experimenter. The spatial correspondence of the real and virtual treadmill, which was visible at all times in order to be able to check one's own position, also provided a good feeling of safety.

The subjects approved the idea to integrate conventional treadmills more often in VR applications, as it allows for locomotion in VR even in small spaces. In addition, the movement makes the experience feel more real, providing a high sense of presence, which was confirmed by the presence questionnaire [5] (M = 5.07 on average).

But all except two subjects found walking on the treadmill in VR more difficult than in real life. They mentioned the lack of usercentered visual feedback to easily estimate the exact body position, such as the real treadmill's arm grips. Displaying the arm grips and a bigger real treadmill for more freedom of movement would have simplified the situation.

6 **DISCUSSION**

The study revealed no significant difference in stride duration and stride length between the three measurement time points. This indicates a uniform walking behavior in the two minutes walking interval, as desired at a constant treadmill speed. The safety precautions, in particular the slightly tightened safety belt around the waist, do not appear to affect the walking behavior. The answers of the participants show that the belt contributed well to orientation and to a high feeling of safety.

In addition, the participants mentioned that the virtual model of the treadmill was important as visual cue for orientation during the walk. Virtual cues are crucial for estimating the position of the body on the fitness machine. We do not recommend a sole indication near the feet, as it requires extra lowering of the head. Other indicators in the user's field of vision are desired, such as the arm grips and display when using a real treadmill.

7 CONCLUSION

Using treadmills in VR poses risks of injury. As a safety precaution, the use of a slightly elastic safety belt has proven to be effective accompanied by a short training phase without headset. We also recommend providing visual cues to estimate the body position on the real treadmill, especially in the field of view.

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