# Highland VR: Exploring Virtual Reality for Collaborative Balance Training


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**Figure 1: Scene view of the different learning experiences in virtual reality, ranging from imitation learning (left) to gamified learning (middle and right).**


## ABSTRACT

Today virtual reality applications mainly allow consumers to engage in immersive alternative realities for fun and entertainment. However, researchers and therapists investigate their use for skill improvement and even fear prevention. In this work, we focus on balance training in virtual reality, which is directly linked to fear of heights. We first present a high definition virtual world supporting the training. Next, we highlight how different training attempts can support the learning process. Finally, we propose including the collaborative aspect into balance training, allowing for collaborative training and helping instructors to integrate and adapt to prior training sessions performed at home. Beyond balance training, the collaborative aspect will be helpful whenever feedback and performance review is required.



## CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**; • **Applied computing** → Computer-assisted instruction.

## KEYWORDS

virtual reality, user motion, balance, training, highlining, slacklining, full-body interaction, collaborative training

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## 1 INTRODUCTION

Balance training is an effective exercise to improve body control and posture [10], avoid injuries [4], and improve body coordination. Still, many people hesitate to start disciplines that specifically train the sense of balance (e.g., slacklining) out of fear of injuries or heights. Therefore, fear is highly researched, ranging from psychological [6] to computational analysis and therapy [8, 14]. Moreover, research on slackline balance training has shown positive effects on injury prevention [11, 12]. Virtual Reality (VR) is the ideal technology to introduce people with a fear of heights to these conditions in a safe and controlled environment. For instance, prior research successfully derived performance from tread pressure while balancing in VR [14]. In addition, providing feedback on the trainees' performance can further influence confidence. Kloiber et al. [7] presented a system for immersive analysis of user motion, which presents motion data in 3d space over several training sessions. Thus, we hypothesize that VR can positively impact users' balance and body coordination skills.

This work describes Highland VR, a virtual environment where we enable extensive research on computer-assisted balance and height tolerance training. Inspired by extreme slacklining at heights of several hundred meters, we created two learning approaches for height exposure and balance skill development: 1) imitation learning and 2) game design principles. Furthermore, we create user incentives, increase motivation, and therefore aim to distract from the fear of heights. In addition, multi-user collaboration boosts training performance and engagement, and the recorded session can be analyzed together with a trainer to support long-term skill improvement. Finally, we envision that such a VR system will be used in the future for many tasks involving motor skill learning, for instance, dancing (e.g., Villa et al. [13]) and industrial tasks such as welding.

## 2 HIGHLAND VR

*Highland VR* contains two remote islands amidst high seas, see Figure 1. We employed a beam that spans between the two islands' cliffs to create the experience of the feeling of height. We created the scene as realistically as possible using Unity's High Definition Rendering (HDRP) pipeline, directional lighting, sea movement, nature, and sound design.

### 2.1 System and Environment Description

While immersed in a high definition island scene using VR, the user balances on a solid physical structure for haptic perception, to which the VR scene is aligned. We calibrate and align the real and virtual environment using two VIVE Trackers 2.0 mounted at the two ends of the beam. The lighthouse tracking system provides position data of sufficient accuracy for this scene calibration. We further secured participants against falling with a harness attached to a ceiling-mounted rope slide.

In addition, we track the user by using different lighthouse-compatible trackers, including Valve Index controllers and VIVE Trackers 3.0, which are strapped to the user's hands, ankles, and back of the waistband. We projected the trackers' positions and rotations to the Unity 3D scene coordinates. With the Unity 3D Inverse Kinematics asset FinalIK[1], we can map a virtual avatar to the user's position. This solution provides a virtual representation of the user's own body and supports the feeling of embodiment, positively affecting immersion [3].

We worked with *Quixel Megascans*[2] and a *Book of the Dead* [5] environment to support scene realism, such as trees, mountain parts, and plank materials. Additionally, we used HDRP water shaders to animate sea waves and integrate ambient sea noises. Also, we set up birds that are either flying or sitting in trees.

### 2.2 Training Scenarios

We implemented two training scenarios in our current version: Learning through game design elements and learning by imitation. The two approaches aim to improve the posture of the user in order to walk more stably and safely on the beam, even in stressful situations, such as walking at heights. Initial test runs showed that non-slacklining subjects already had sufficient difficulties stabilizing on a stationary beam. Thus, we decided not to use a slackline for now. However, the task was the same for both conditions; the user had to balance from one island to the other.

In the gamified approach, the user's goal is to collect coins on the way while balancing. A sign positioned at the entrance and exit point displays the user's last run performance. During the balancing act, the "players" indirectly receive feedback on posture correction through the coins they have to collect with specific body parts (head and hip). For example, collecting with the head prevents the user from looking down. After reaching the opposing island, the system provides feedback by displaying the time needed and the number of items collected. The time and token count are implicit incentives to increase player engagement and deliver gamified feedback [2].

The imitation approach differs mainly in the level of difficulty. Before the user walks over the beam, a semi-transparent avatar appears in front of the user and presents a proper balance behavior. The user can then step on the beam and imitate the avatar while walking behind it. While balancing, the avatar is always visible in front of the user. Focusing on the avatar again helps the user concentrate on the task and not look down.

As a result, the adaptation of the avatar's behavior led to a more stable posture which improved overall performance. The elapsed time is displayed in the scene after each run. Compared to the gaming approach, users overall reported an easy-to-follow approach that helped improve stability while walking. Our initial tests support this statement.

Besides these two training forms, the level of difficulty could be increased even further in several ways: 1) by Lowering the sea level and thereby increasing the height to overcome, 2) different token placements to influence the players' walking behavior and posture, 3) going backward, 4) performing jumps, or 5) setting a time limit to reach the other end. Time measurement starts when stepping on the beam and stops after stepping down either on the other side, in which case the run was successful, or sideways off the beam, in which case it was not.

Our system also records different body data in order to provide versatile feedback. For example, we collect motion data of the hands, feet, hip, and head to tell especially about the balance performance and physiological data such as an electrocardiogram (ECG) and electrodermal activity (EDA) for measuring excitement during the walk.

### 2.3 Collaborative learning

In our application, we see the advantage of collaborative working in especially two different aspects:

*Social Interaction.* In this scenario, people can join their friends in the virtual environment while competing against each other. Whether users play together in the same physical place or separately over a distance, the system allows a collective gaming experience. People are represented with their avatars in the scene, competing against each other based on values such as falls detected, the time needed, or coins collected. Moreover, the gaming approach could create new challenges and explore the limitations of balance skills.

*Balance Training Analysis and Progress.* Our second approach aims at athletes, therapists, and trainees who want to improve their balance skills professionally. Here we want to highlight the option of feedback after a training session. Therefore, we are considering implementing a virtual review room separated from the training area. In this room, trainees can meet their trainer/therapist and discuss previous sessions. To increase collaboration, even more, both parties appear with an avatar. The avatars allow to act out specific movements and demonstrate the proper execution. The previous session can be reviewed by looking through a window into the training area. On the window board, there will be different options for manipulating the scene and previous session, such as: Rotating the scene, zooming the scene, changing from third-person to first-person view, displaying the motion data of the run in the scene, and having a slider for rewind or fast forward within the tracked session. In addition, further analysis of the tracked data

[1] https://assetstore.unity.com/packages/tools/animation/final-ik-14290
[2] https://quixel.com/megascans

will be presented next to the window on additional billboards, such as the ECG and EDA data over time.

## 3 DISCUSSION

*Highland VR* provides the basis for exploring balance training at height. Overall, we received positive feedback on the scene's immersion and stimulation in a pilot study. We can also confirm that a sinking sea level had an apparent adverse effect on participants' balance skills without previous training. These observations are in line with the findings by Peterson et al. [9]. However, we can also report that learning by imitation positively affects height balance behavior. We offer real-time *in-situ* feedback while walking across the beam by posing a transparent avatar in front of the user. This keeps the focus on the avatar instead of focusing on the heights. On the other hand, one of the following steps will be to evaluate the effect of *Highland VR* on the user's ability to balance. To provide a skill-appropriate difficulty level, we plan user studies to determine the right trade-off between performance, height, and secondary task difficulty to achieve the best possible training effect. Further, we argue that the applicability to acrophobia treatment researchers hat to evaluate in the long run. Offering a Leaderboard can further encourage the users' competitiveness, as they will be allowed to enter their name and performance in a ranking table to compete with each other. While multiple users are in the environment, they can also learn through the observation of others. Our collaborative feedback room offers a platform to discuss the training progress. By rewinding the scene, the trainer can steer the focus for the trainee, which also affects the shared attention. In this room, the analysis aspect is in focus. For example, expert slackliners perform counterweighting mainly with their arms and non-standing leg. Hence, we want to evaluate balance performance by analyzing orthogonal pelvis movement, particularly the amplitude and the acceleration. This can be done with our system. Visualizing and understanding such feedback for sports training has not been done in VR yet. We saw such a mechanism in a mixed reality context, where Büschel et al. [1] showcased multi-user movements and provided spatial interaction to understand the data. In their scenario, the interaction was perceived with the help of a Hololens and a projector. This idea still leaves room for exploring the influence of an avatar representation in the context of feedback presentation and interaction. Furthermore, we could add further analysis and gamification options by utilizing eye-tracking. It could help present user feedback about the regions where participants look during the walk for analysis. Here, understanding the user's focus can be used to shift it. We can use eye-tracking to give bonus rewards if the user can focus a target on the destination island while walking across the beam for the gamified aspect.

## 4 CONCLUSION

In this work, we present Virtual Reality as a tool for virtual training and as a platform for collaborative training and feedback. We demonstrated an essential advantage of our virtual scenario: the possibility of training balance under circumstances that would be dangerous or even unrealistic to try in the real world. For this purpose, we described *Highland VR*, a photo-realistic virtual balance training environment with adaptable sea level, two training modes, and body data collection. We also envision multi-user collaboration to boost training performance and support the trainee. In the future, we envision our VR system to support many tasks involving motor skill learning and its analysis. We see our system as an opportunity to reshape how we perceive feedback on training. By using the capabilities of VR, we enrich the feedback and provide more details on the performance.

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