Falling into Fears: Exploring Virtual Reality as a Fear-Reduction Training Tool for Climbers

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Figure 1: Climbing setup: (A) A participant, belayed by an experienced climber, is climbing up the wall with a headset, (B) A participant is falling from a 5-meter height while wearing a headset, (C) Participant's view to the virtual world during the fall.

Abstract

Fear of falling limits climbers' performance and progression, particularly for beginners who must develop trust in their safety equipment and falling techniques. Traditional methods of overcoming this fear through repeated practice are time-consuming and stressful. In this paper, we explore the potential of using Virtual Reality

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(VR) to assist climbers' training. We conducted an exploratory experiment in which 20 climbers performed multiple falls from a height of 5 meters both with and without a VR headset, experiencing 1-2 meters of free fall. We collected qualitative data through interviews conducted before, after, and following each fall. Our findings suggest that VR is a promising tool for reducing the fear of falling, though the exact mechanisms and effectiveness require further investigation through longitudinal studies. This study opens new possibilities for using VR as a training tool in climbing education, potentially accelerating the process of overcoming the fear of falling.

Keywords

VR, Climbing, Fear, Height, Fall, Mapping

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1 Introduction

Managing fear as a form of stress impacts athletic performance, particularly in high-risk sports where safety and success are intricately linked. Fear can impair cognitive processes, limit physical execution, and increase the risk of accidents, making it a significant concern for athletes in extreme sports contexts [6]. In climbing, the fear of falling poses a fundamental challenge, influencing climbers' movements, decision-making, and overall performance [11, 16, 36]. This fear often hinders progress, especially for beginners who need to develop confidence in their safety equipment while learning technical skills. Addressing this issue is essential for improving individual climbers' abilities and advancing the broader understanding of fear management in high-stakes athletic settings.

Traditional methods for overcoming the fear of falling in climbing emphasize gradual exposure through controlled practice [19]. These approaches involve repeated falling drills under safe and controlled conditions to build confidence and trust in climbing gear. A recent study from Garrido-Palomino [15] showed the efficiency of psychological training to improve self-confidence and climbing ability for women. While effective, these techniques are time-intensive and can be mentally taxing, limiting their scalability and accessibility [15]. Recent advancements in Virtual Reality Exposure Therapy (VRET) have opened new possibilities for fear management. VRET has been widely studied for treating various phobias, including acrophobia [38], with findings indicating its effectiveness on par with traditional exposure therapy [22, 26, 34]. As Diemer et al. [8] demonstrated, one of the main reasons for the effectiveness of VRET is that virtual environments can evoke physiological responses similar to those of anxiety-provoking situations in real life, emphasizing its potential as a tool for anxiety management. However, this principle may not directly translate to the fear of falling in climbing, where the experience is not exclusively visual or cognitive, but deeply physical and embodied. Unlike phobias, which are treated by passive simulation, the fear of falling arises during physical activity. It involves complex interactions between perception, movement, and body sensation that cannot be evoked by purely visual stimulation.

In this paper, we explore the conditions necessary for a successful VRET study targeting fear of falling. Building on prior research into fear management and VR technology, we conducted an exploratory study with 20 climbers, in which they had to fall 3 to 5 times (mixing VR/physical falls and falls without VR) from a height of 5 m. In addition, we implemented a dynamic movement scaling system in VR, allowing us to amplify the perceived fall distance from a 1:1 ratio (no scaling) to a 1:5 ratio, meaning a 1-meter fall in the physical world appeared as a 5-meter fall in the virtual environment. Unlike traditional VRET, which relies on simulated visual and cognitive stimuli, our approach integrates VR into actual falls. A fall while climbing is not only a visual experience, but is shaped by rich physical sensations and embodied responses. We hypothesized that combining (attenuated) real experience with VR-based perceptual modulation could provide a more effective training experience. The focus was not on collecting structured quantitative data but exploring the design space for an intervention with VR. Our findings indicate that while VR is a promising tool for reducing fear responses during climbing falls, scaling fall height to increase exposure is not necessarily a solution, as participants barely perceive it during the short fall time. We also found that individual responses vary based on experience level and psychological disposition. Finally, strong learning effects during each experiment point toward a longitudinal between-subjects design for studying the impact of VR.

2 Related Work

2.1 Technological Assistance of Climbers

Technological assistance for climbers has evolved considerably over the last few decades. Typical examples include assistance wearables and Internet-of-Things (IoT) devices. For example, researchers have utilized direct on-foot vibrotactile feedback to remind climbers about using their leg power to climb [13]. Donavalli et al. [12] utilized IoT devices to explore safety problems in mountain climbing. Their system could monitor climbers' vital signs in real-time, follow their location, and understand the surrounding environment to speed emergency response in remote alpine areas. By placing Inertial Measurement Units (IMUs) on climbers' wrists, Kosmalla et al. [21] introduced a system to recognize climbed routes automatically as a solution to track climbers' progress. Logged ascents from climbers of different levels were used to train their recognition system. Pansiot et al. [31] also investigated general climbing performance during climbers' training and have shown how to quantify the overall level of the climber and the associated climbing styles by collecting data from a 3-axis accelerometer worn on the ear. Although these systems show advancements in methods for quantifying climbers' performance and providing additional assistance during climbing, there is a limited body of work focused on climbers' physiological state during climbing, understanding their fears, and their mitigation, which we explore in this work.

2.2 Anxiety and Performance in Climbing

Previous research explored the impact of anxiety on sports performance. Initial experimental studies suggest that a specific level of anxiety-induced activation leads to peak performance, which evolved into the theory of Individual Zones of Optimal Functioning (IZOF) [30]. Pijpers et al. [20] analyzed anxiety triggered by the fear of falling during climbing. Participants climbed identical routes at varying heights while secured by a top rope. The studies consistently demonstrated increased anxiety effects at greater heights and provided evidence of anxiety-related declines in performance [20, 32, 33]. Hardy and Hutchinson further observed that climbers with lower anxiety levels performed better than those with high anxiety and concluded that self-confident and skilled climbers are less affected by anxiety [16]. Climbers subject to fear of falling will find themselves way out of their IZOF and having trouble performing. By training themselves and keeping the anxiety related to the fear of falling at a reasonable level, climbers can improve their experience on the wall.

2.3 Virtual Reality and Fear of Falling

Investigating climbers' fear of falling in VR is valuable in understanding the broader context of its applicability to treat specific fears. Previous research refers to this as VRET [38], suggesting that it is as effective as traditional exposure therapy via a real-life exposure [22, 26, 28, 34]. The efficacy of VRET was demonstrated for fear of heights, which is highly relevant in this context. For instance, Diemer et al. compared height reactions in phobic and non-phobic participants and found that both groups exhibited similar physiological responses when exposed to height [9]. A variation of the VRGET protocol, in which individuals are gradually exposed to increasingly challenging scenarios, builds tolerance and reduces anxiety more effectively than through uniform exposure [40, 41]. Virtual exposure is valuable in climbing as participants can train in a safe environment and reap the benefits of exposure to more dangerous situations. Since we use falling as a stressor in VR, its perception becomes particularly crucial. The degree to which fear of simulated falls triggers fear depends largely on the effectiveness of the VR experience and the degree of presence it induces in users [24]. Previous research has shown that repeated exposure, passive haptics, and frame rate influence presence, e.g., a physical plywood ledge increased users' sense of presence as they walked towards a virtual cliff [25]. Gandy et al. reviewed several studies on how varying levels of detail affect presence and perception, with mixed results [14]. Zimmons and Panter exposed participants to two virtual rooms, a training room and a pit room featuring a 6-meter-deep hole in the ground to evaluate the impact of rendering quality. They found no significant differences in presence or subjective stress across different versions of the "pit" experiment, ranging from wireframe to high-detail renderings [42]. This aligns with Gandy et al.'s [14] conclusion that a virtual environment does not need to be visually perfect to make users feel present or capable of performing motor tasks. However, Slater et al. observed higher physiological responses, such as heart rate and skin conductivity, with increased realism, such as reflections and shadows [39].

3 Evaluation

3.1 Participants

We recruited 20 participants (11 F, 9 M) aged between 21 and 52 ($M = 29.8, SD = 6.9$.Their climbing experience spanned from <1 to 10 years ($M = 2.2, SD = 3.0$). All participants had previous climbing experience at least once in a gym. Participants were recruited through posters and email communications in the university, gym, and local climbing or outdoor communities. Participants' climbing ability ranged from being able to complete a beginner route graded 4C (5.7) to being able to train on a 7A (5.11d)[1].

3.2 Study Design

There are different styles of climbing which expose the practitioners to various heights and various risks, which include:

- **Bouldering:** The climber falls on a ground mattress that absorbs the impact (<5 m)
- **Top rope:** The climber is attached to a secure rope running through a fixed anchor on top of the wall (typically 15 m in gyms)
- **Lead:** The climber secures the rope from the ground with periodically spaced pre-installed bolts (same height as top rope)

Independently, the angle between the wall and the ground will also influence the technique and the risk of injuries:

- **Slab:** Less than vertical wall, slopes away from the climber
- **Overhang:** More than vertical wall, slopes towards the climber

To ensure the safety of the participants, we chose a top rope style on an overhanging wall. According to Schöffl et al. [37], most injuries happen on lead climbing, where falls are bigger, and in bouldering, injuries happen when landing on the protective pads. Neither of these styles is risk-free for participants who are blinded by the headset. On a slab wall, the climber has to land on their feet, which exposes a similar risk to bouldering, whereas the overhang allows for a fall in the air without contact with the wall. The study [37] also demonstrated that most injuries in top rope climbing are caused by belaying mistakes or incorrectly tied knots, which we mitigated with a partner check between the experimenter and the participant. This helped build trust and reduce anxiety related to equipment failure for the participant. The climbing ropes' elasticity and length on the top rope provide comfortable falls for the participant.

Before examining specific situations that trigger fear or anxiety during climbing activities, we used a semi-structured interview guide that covered climbing experience and regular practices. Participants were asked to reflect on their perceived causes of fear. Then, participants got to experience and react to four falls from a height of 5 m (spanning fall height between 1 m and 3 m, depending on the participant's weight) with a VR headset that occluded the gym around them. In addition, we introduced a scaling mechanism to amplify participants' movement in VR from a 1:1 (no scaling) to 1:5 (a 1 m movement in real life results in a 5 m movement in VR, in all directions) to facilitate bigger falls. We hypothesized that this scaling effect could be used in a VRGET experiment to grade the exposure, as bigger falls are generally considered scarier. The fall conditions were determined through agreement between the experimenter and the participant to ensure the latter was comfortable. Each participant was exposed to both VR and NoVR conditions to allow the participant to compare and report on the impact of wearing

[1]https://www.mountainproject.com/international-climbing-grades

the headset. The repetition of four falls helps mitigate the learning effect throughout the experiment (repeating the same fall is less scary). For each fall, participants were instructed to pay attention to their bodies and what they were thinking and to rate their fear at different stages: before letting go, while they free-fell, and after the rope caught them. We hypothesize that climbers experience more fear in the expectation before the fall in accordance with our own experience. In the VR conditions, participants were shown a virtual cliff environment made from low-poly assets on Unity. The environment features an overhanging cliff, trees on top of the cliff and the ground, and flowers on the cliff and the ground. The objects in the scene give the participant clues about the dimensions of the space. The participant starts the experience on the virtual cliff, around 12 meters above the virtual ground. With this environment being different from the gym in many aspects (greater height, rock, and non-realistic), we wanted to elicit comments from the participants on the intervention.

3.3 Apparatus

We conducted the experiment in a local gym featuring 15 m high climbing walls. For the VR experience, participants wore a Meta Quest 3 equipped with a Meta Quest Elite Headstrap. A sling was attached between the harness and the headstrap to prevent any hardware from falling to the ground. Participants were equipped with their own climbing gear (harness and shoes) or rented gear if unavailable. The participants were belayed with modern sport climbing gear (harness, assisted belay device, rope, rated carabiners). We used the fixed climbing top rope setup in the gym. To facilitate a consistent falling experience, the experimenter set the slack to be exactly one meter and used a self-locking belay device that prevents the rope from sliding during the catch.

3.4 Procedure

After welcoming our participants, we explained the experimental procedure and asked for explicit consent and demographic data. The experimenter presented themselves as an experienced climber to enable trust from the participant. First, we conducted a semi-structured interview to understand participants' background with climbing and their relationship with fear of falling. Then the participants could use the headset while standing on the ground to get used to the environment. They were asked to look around and down, and to describe the environment. The experiment consisted of four controlled falling trials per participant, including at least one NoVR condition. For each trial, participants climbed a beginner-level route (5B or 5.9) to a height of 5 meters while belayed by the experimenter. Then the experimenter added one meter of slack in the system (allowing a 1 m fall before the rope catches) and informed the participant they could fall when ready. In VR trials, participants climbed with the headset on their forehead, lowering it on their eyes upon reaching the target height of 5 m. They then gestured to calibrate the VR tracking before initiating the fall. Participants rated their fear relative to the previous falls after each fall and safe return to the ground. They described their emotional and physical responses across different phases of a fall, from the anticipatory moment before letting go through the falling experience and landing. They reported physical markers of anxiety such as a racing heartbeat, tightness in the chest, difficulty breathing, gripping the holds, and a sinking stomach. Participants were also invited to express themselves on what they felt, and in the VR conditions on the change it provided. The full experiment required 45-60 minutes per participant. Fifteen participants completed the four trials, but a few (P1, P8, P16, P18, P19) did less due to fatigue (average 3.6 falls). In NoVR, the number of falls was 30, in 1:1 − 9, 1:3 − 27, and 1:5 − 6. Five participants also preferred falling without the headset for the first fall (P1, P8, P9, P18, and P19). All 20 participants experienced at least one VR fall and one NoVR fall, and their comments were included in the analysis.

3.5 Data Analysis

The quantitative data collected regarding self-reported fear did not exhibit a clear pattern, so we focused on the qualitative observations from the interviews. We analyzed the semi-structured interviews using an inductive thematic analysis approach [2] and an open coding process to identify key themes. Each data unit was a single coded quote, following the practice from previous research [1, 27, 29]. In total, we collected 207 data units and grouped them into high-level codes to derive themes.

4 Results

4.1 Fear in the Climbing Practice

Two main observations can be made consistently throughout the trials: the first fall in a given situation is consistently scarier than repeated falls in the same situation, and the scariest part of falling is letting go of the wall before the fall. There are a few exceptions, as for some participants, the first VR fall would be perceived as a new situation and scarier than the previous NoVR fall. Another exception is the simulated ground fall, where a couple of participants in the 1:5 condition went through the virtual grass. The event was the scariest trial for those participants and scarier during the fall than before, as they were not expecting it. On the body, the most common somatic reaction among participants was heart racing ($N = 17$), followed by tightness in the body ($N = 14$). There is no clear relation between experiencing those symptoms and the level of climbing experience of participants.

Furthermore, participants evoked two distinct types of fear: a rational fear of getting minor injuries that comes from previous experience of injuries and an irrational fear of catastrophic events or failures. The first type is not necessarily problematic for performance and might be needed to keep the practice safe. For example, a climber might recall spraining an ankle when belayed by a heavier partner, which led them to be more careful about falling position in certain climbs or communicate more explicitly with their partner. Some experienced participants also feel safer at greater heights, where the risk of hitting the ground is lower, while that rationalization is counterintuitive when scared of heights.

The second type is more impactful on climbing performance as most participants reported avoiding certain hard moves or harder climbs where the possibility of falling was present, or even quit climbing entirely (P19). Some participants are scared of equipment failures despite the safety regulations and standards in place: *"[the anchors] break and we are both out, me and my partner"* (P11). Others might imagine severe injuries like *"have my face cheese grated"* (P2, P6), which is an expression used by climbers to evoke the unlikely outcome that the head would be pressed against the abrasive texture of the wall during the fall. Finally, some participants did not express a specific reason, but confirmed that *"[they] would avoid falling"* (P6) nonetheless.

One dimension of the fear found in a few participants is the aversion to losing control. Being in control has been associated with performance: *"I have control because I'm the one holding the wall"* (P9), but also as a mitigation strategy: *"when I follow the plan [to fall at an agreed point] I feel secure because that's the plan."* (P4). This could be linked to the idea that an uncontrolled fall during climbing would lead to injuries, whereas in training falls, the risk is mitigated by the readiness of the climber. Despite the differences in climbing ability, all participants confirmed that certain situations could be scary for them, and that they are limiting their climbing well below their physical capabilities.

4.2 Impact of the VR on the Falls

The reception of the VR was varied among participants. Most negative reactions came from the fear of hitting the wall during or after the fall, despite the precautions taken to avoid it. One participant reported that the headset could throw them off balance while climbing. Finally one participant reported *"[VR] comes at a cost [. . .] of feeling in control, of being present."*, which can be a reaction to an unknown element brought into an otherwise familiar situation.

Although we did not design the VR world to be distracting to participants, the passive distraction it provided was received positively among most of them ($N = 13$). A part of the comment mentioned a loss of reference, like P16 *"I could not see the height."*, or P9 *"The expectation of the fall had less impact because I lost my reference in the environment"*. Many participants (N=11) evoked similarity to a less serious context that relieved them from the apprehension, such as a video game, a rollercoaster, and a cartoon. A participant (P15) explains *"Feeling that this is a game and maybe I should enjoy"*, which could mean that a sense of safety emerged from the playful aspect. One striking reaction came from P19, who felt calm despite their anxiety with heights during the first VR fall.

Due to the shortness of the fall time, the movement scaling we introduced was barely noticed by the participants, probably due to the lack of reference in the virtual environment that made distance evaluation difficult. Only in a pilot experiment where we tested a 5 m fall with a 1:5 scaling, an experienced participant reported that the fall felt physically inaccurate. The movement scaling can therefore be used to simulate situations that are difficult to replicate safely in real life. Otherwise, it is not suitable for graded exposure to falling. Overall, there seems to exist a subset of climbers who respond positively to VR. However, in the short time spent with the participants, we could not demonstrate any improvement in their anxiety related to falling or climbing.

5 Discussion

Our results suggest that VR could be a tool for climbing practitioners to integrate into their mental training. Here we present potential study designs that follow the best practices in climbing training and some practical considerations learned in this experiment.

5.1 Exploring VRET for Mental Training

The climbing journey practitioners undertake has very well-defined steps that must be mastered. For example, Hodgson et al. [18] noticed the influence of changing from top rope to lead climbing (where the climber risks bigger falls and harder collisions with the wall) in the anxiety markers, both physiological and self-reported. The other opportunities are when the climber transitions from the gym to rock climbing outdoors and starts multi-pitch climbing, which can expose them to greater heights than before (reaching heights in the 100 m to 1000 m range). We suggest designing a study around one of those steps, as they clearly define a goal and obstacles for the climbers. From this observation, we derive four opportunities for VR interventions:

- Experiencing a virtual lead fall while sitting on a chair (no physical fall)
- Experiencing a virtual lead fall while the climber falls on top rope in the real world
- Experiencing a fall on a virtual cliff while training in the gym
- Experience a fall on a very tall (>100 m) virtual cliff while training in the gym

This will help the climber get more exposure to the new environment or condition while staying at a more comfortable safety level, such as the one we used in our trials. Those options can be parameterized —for example, by varying fall heights—enabling graded exposure. The climbers could also be exposed to a gradation of realism in the VR environments, from a cartoonish cliff displaying no apparent dangers, to a fully fledged rock with more menacing features. Since some participants felt more secure in a playful environment, such progression could help them become comfortable outdoors.

5.2 Quantitative Measures for Climbing

During the pilot and the experiments, we tried different measures and questionnaires on acrophobia, anxiety, and body responses; however, both the extremely short fall time and the one-hour format rendered our attempts unsuccessful. Very early on, we realized it would be hard to find significant differences between the VR and NoVR conditions or between the scaling conditions in this setup. For future studies, we recommend a longitudinal between-subject study design (similar to [15]), and a climbing trial to evaluate properly the effect of an intervention.

The CSAI-2 [5] questionnaire we tested in our pilot is ill-suited for evaluating falls, as some questions are focused on performance. However, it would fit nicely with a climbing trial involving a concrete achievement. Since fear of falling is perceived even without a fall, a challenging route could be used to evaluate participants before and after training. A trial lasting between 5 and 10 minutes would also allow for recording robust peripheral physiological signals such as heart rate [17, 23] or electro-dermal activity [7]. Practically, this also gives more time to calibrate the measuring devices at rest, and in a physically demanding yet mentally comfortable exercise. This would yield evidence to measure the efficacy of the proposed method and evaluate potential adaptive applications [3, 4].

As we have seen, participants get more comfortable with each subsequent fall, which strongly impacts the measurements. We want to limit the impact of this learning effect by evaluating the fear of falling separately from the training time. For example, the trial could occur a week after the training session. A longitudinal study would also better mimic real conditions, as practitioners typically train over multiple weeks to see the full benefits. This would highlight the long-lasting effects we are seeking.

5.3 Practical and Safety Considerations

Our experiment revealed several methodological challenges. Firstly, it is important to consider the physical fitness of participants. While safer for VR-blinded participants, the overhanging route proved physically demanding to climb repeatedly. The participants also had a hard time resting and preparing themselves for the fall, especially in the VR conditions. To alleviate those hurdles, one could set up a falling station where the participant climbs a ladder up to a platform so they can rest and equip the VR headset. Another solution would be to implement screening questions to evaluate the fitness of applicants, as climbing the wall and not a ladder could be key in the training.

Secondly, the VR posed several technical limitations. The tracking capabilities of the Quest 3 are sufficient to offer a good falling experience, but sometimes the reference would change mid-experiment and require recalibrating the application. It would be helpful to have the experimenter on the wall next to the participant to solve technical issues and quickly mitigate the participant's fatigue.

Thirdly, increasing the immersion by allowing participants to climb in the virtual environment before falling is quite complex. Several technical issues beyond the scope of this work need to be solved: consistently tracking the position over the whole wall, including hands and feet, reproducing the wall and grips with fidelity, and updating them when the gym changes. Currently, there is no experiment on VR climbing beyond a few meters of vertical progression.

6 Conclusion and Future Work

Our study explored the potential of VR as a tool for managing climbers' fear of falling through an exploratory experiment with 20 participants. The result suggests that virtually scaling fall heights is not promising for VRGET to help in training. However, VR proved to have a strong effect on the participants' perception of their environment, and we identified key progression steps for experimentation: top rope to lead climbing, indoors to outdoors, and single pitch to multi-pitch climbing. We also outlined practical recommendations to mitigate the challenges in maintaining consistent fall experiences across participants and the introduction of VR in that practice.

Future work should incorporate physiological measurements to quantify fear responses [10] and explore how different VR environments might affect falling experiences [35]. Additionally, longitudinal studies could help understand VR's long-term impact on climbers' confidence and performance. This research opens new possibilities for integrating VR technology into climbing training, offering a novel approach to building self-confidence and improving climbing ability while maintaining safety.

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