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[DC] Bridging the Gap Between Real and Virtual Touch : Multisensory Avatars for Enhanced Training in Virtual Reality

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ABSTRACT

This position paper presents our ongoing PhD work exploring the integration of interpersonal haptic interactions into immersive VR training systems for first responders. The research focuses on enhancing user engagement, emotional resilience, and decision-making in high-stress scenarios by leveraging advanced haptic technologies, such as vibrotactile feedback and electromuscular stimulation. The primary goal is to model and simulate haptic interactions, such as touch sensations perceived by individuals in the real world, enhancing the realism of virtual training. This paper details the research objectives and the ongoing work and highlights the critical gaps this work aims to address in the current VR training landscape.

Index Terms: Haptic feedback, Multisensory interaction, Interpersonal touch, Human factors, Professional training.

1 INTRODUCTION

First responders—police officers, emergency personnel, and firefighters—regularly face life-threatening, high-stress situations where quick decision-making and physical action are critical. Traditional training methods, such as role-playing exercises and theoretical instruction, often fail to recreate real-world physical and emotional intensity. Immersive VR has emerged as a promising solution, offering the ability to simulate high-pressure environments in a safe and controlled setting [3]. However, many VR-based training systems lack sufficient realism regarding physical feedback, which is essential for preparing trainees to cope with the sensory challenges of their roles [10]. Recent advancements in multisensory feedback—particularly wearable haptic technologies, such as the Skinetic Vest and Teslasuit—offer the potential to bridge this gap by simulating physical sensations including touch. Integrating such haptic feedback into VR training enhances the realism of the experience and improves user engagement and emotional resilience, better preparing individuals for real-world scenarios [10].

By leveraging vibrotactile feedback and electromuscular stimulation, this work aims to replicate real touch sensations in immersive learning spaces where users interact with avatars and virtual characters. The main goal is to design haptic interactions as closely as possible to real-world physical experiences, enhancing the emotional and behavioral responses of users in high-stress scenarios.

By addressing critical gaps in existing training systems, this work contributes to developing adaptive, high-fidelity training environments that improve decision-making, emotional engagement, and collaborative behaviors in first responder teams.

2 RELATED WORK

Using VR for training first responders to cope with high-stress environments has garnered attention in recent years. VR can simulate

dangerous scenarios in safe, repeatable, and controlled settings, fostering emotional resilience and improving decision-making in critical situations [10]. Despite these advantages, existing VR systems heavily rely on visual and auditory cues, limiting their ability to replicate the full sensory intensity of real-world emergencies [5]. To bridge this gap, researchers have increasingly turned to multisensory feedback, particularly haptic technologies, to enhance the realism and effectiveness of VR training systems [10].

Haptic feedback, which enables the simulation of physical sensations, such as touch, has emerged as a key innovation in this domain. Technologies, such as vibrotactile feedback and electromuscular stimulation, offer distinct approaches to delivering these sensations. Vibrotactile feedback technologies (eg. the Skinetic Vest) employ localized vibrations to replicate tactile sensations on the skin. In contrast, electromuscular stimulation (implemented in systems like the Teslasuit), stimulates muscles directly to produce a realistic and nuanced sensation of physical force. By mimicking real-world physical interactions, these technologies provide a critical layer of sensory immersion for VR training applications [2].

The importance of being physically touched or impacted in VR has been well-documented, with research demonstrating its critical role in influencing both emotional engagement and behavioral responses. For instance, Fribourg et al.[4] found that virtual threats can elicit behavioral changes without significantly altering the sense of embodiment, emphasizing how tactile feedback reinforces behavioral realism. Building on this, research on multisensory avatars highlights the value of haptic feedback in enhancing the sense of presence and emotional connection with avatars in VR [9, 1]. Similarly, Sun et al. [11] observed that simulated touch significantly enhances emotional and behavioral responses, suggesting that accurately replicating the experience of being hit or touched in VR can substantially improve training effectiveness, particularly in scenarios requiring physical or emotional resilience.

Advancements in haptic feedback have also demonstrated broader benefits for stress management and emotional regulation in VR training. Research showed that haptic feedback improves situational awareness and emotional resilience in high-stress police training scenarios [14, 12]. Kent et al. [8] explored how integrating pain stimuli can enhance realism and user engagement in VR training. Collectively, these findings highlight the importance of simulating physical impacts accurately, as this contributes to creating more immersive and emotionally engaging training environments.

Beyond physical impacts, interpersonal touch is an area requiring further exploration. The sensations of being touched by avatars or virtual characters in VR environments introduce new opportunities to improve the training dynamics [6]. Social touch, including user-avatar interactions, has been shown to regulate emotional responses, foster collaboration, and build trust [6, 13]. For instance, mediated touch can amplify social and emotional connections, as highlighted by Huisman and others, demonstrating its potential to enhance trust and cooperation in team settings [7]. While physical impacts primarily influence behavioral realism [10], social touch adds a layer of interpersonal engagement, making training scenarios more effective [1]. Integrating this into VR training systems can create environments that prepare individuals for physical challenges

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and enhance team-based learning outcomes.

3 RESEARCH GAPS

While existing research demonstrates the potential of haptic feedback in enhancing VR training, several gaps remain:

- **Comparison between real and virtual touch experiences:** Understanding how virtual touch replicates or diverges from real-world sensory, emotional, and behavioral effects is crucial for evaluating VR training effectiveness.

- **Effectiveness of haptic technologies for simulating physical impacts:** The ability of vibrotactile feedback and electromuscular stimulation to simulate physical impacts remains underexplored. A comparative analysis is needed to assess their realism and influence on user behavior.

- **Interpersonal dynamics of real and virtual touch in collaborative VR training:** The impact of real and virtual touch on collaboration, trust, and team-based responses in VR training is insufficiently studied. It is important to clarify how virtual touch replicates real-world interpersonal dynamics.

- **Impact of real and virtual touch on emotional and behavioral outcomes:** How real and virtual touch affect emotional resilience, stress, situational awareness, and decision-making in VR training remains unclear. Further research is needed to determine their roles in immersive training.

By addressing these gaps, this research explores how touch sensations in VR affect performance, evaluating haptic technologies to develop high-fidelity multisensory training systems that better prepare first responders for real-world challenges.

4 ONGOING WORK

Our current research investigates how vibrotactile feedback and electromuscular stimulation affect touch perception in virtual environments simulating physical impacts. Specifically, we compare the sensation of being hit in real and virtual contexts using a ball-launching system, focusing on behavioral and physiological responses.

Before initiating this study, we are conducting pilot tests to identify the technical limitations of the haptic devices and determine optimal calibration strategies. These tests are essential for ensuring reliable data collection and precise synchronization of haptic feedback with visual and auditory cues.

Based on pilot test insights, we are developing an experimental protocol combining psychophysiological measurements (e.g., heart rate) with user experience assessments during object impact scenarios. A ball-launching system simulates real impacts, while haptic feedback, generated using commercial off-the-shelf wearable devices, replicates virtual impacts. Early calibration efforts focus on synchronizing haptic feedback parameters with visual and auditory cues to reduce immersion breakdown and replicate real-world physical sensations in high-stress environments.

5 CONCLUSIONS AND PERSPECTIVES

This research explores the potential of advanced haptic technologies, such as vibrotactile feedback and electromuscular stimulation, in enhancing the realism and effectiveness of VR training systems for first responders. Preliminary insights suggest that precise calibration of haptic devices is crucial for delivering synchronized feedback, highlighting the importance of addressing technical challenges early on.

While conclusive results are still pending, we anticipate that haptic feedback will enhance sensory realism and improve emotional resilience and decision-making under stress. Our work aims to bridge the gap between real and virtual touch by effectively replicating physical sensations in VR.

Future research will focus on refining these systems and exploring the social aspects of haptic interactions, especially in fostering

collaboration and trust in team-based training, enhancing the utility of VR training systems for preparing first responders for real-world challenges.

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