Safeguarding Sensations: Harm Prevention in Multisensory Distributed Mixed Reality

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Abstract

Haptic feedback devices bear great potential in multiuser Mixed Reality experiences, allowing for multisensory virtual experiences and facilitating interpersonal touch in distributed spaces. However, they also present significant ethical and safety concerns. In this paper, we describe three facets of a serious threat: the transmission of unwanted and harmful haptic stimulation, and propose strategies for developers and designers of Mixed Reality applications to reduce this risk.

Index Terms: Mixed Reality, haptic feedback, affective touch

1 Haptic Feedback and Affective Touch in Multiuser Mixed Reality

Multiuser Mixed Reality (MR) environments are continuously evolving, reflecting the potential of and increasing interest in a social Metaverse. Users can embody digital avatars that mimic the full range of human motion and audiovisual emotional expression, facilitating a feeling of co- and social presence [10, 8] even in distributed spaces [15]. Body-worn haptic feedback technology can stimulate another sensory channel by enabling physical sensations when interacting with virtual representations of people and objects. These wearables can transmit physical feedback through various means, such as vibrations, temperature, ultrasound or the movement of fluid [1], and facilitate the perception of somatosensory experiences among remote actors in distributed multiuser MR spaces [9]. This way, affective touch can function as an additional social communicative channel [6] to commonly transmitted nonverbal signals, such as gestures and facial expressions. It plays an integral part in establishing and maintaining trust in interpersonal communication [13] and could enhance social multiuser MR experiences [5]. However, every communication channel is potentially susceptible to manipulation and abuse. Thus, unlocking interpersonal touch in distributed MR environments comes with a unique set of ethical and safety concerns that must be carefully considered [11]. In this paper, we outline specific threats regarding haptic feedback and interpersonal touch in distributed MR environments, focusing on the topics of consent, physical safety, and emotional manipulation. We then propose several strategies for designers and developers of multiuser MR applications to mitigate these risks.

2 The Threat of Involuntary Sensory Stimulation

In the following, we focus on three manifestations of a multifaceted threat, which, in the MR context, is unique to the employment of body-worn haptic devices: The transmission of unwanted and harmful haptic stimulation with malicious intent.

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2.1 Non-Consensual Touch

The topic of non-consensual transmitted touch is especially complicated, as it is a form of abuse that can be performed without breaking or manipulating any components of a haptic feedback system, making it difficult to be filtered out by clear measures such as intensity. A consensual distributed MR meeting can be used to overstep personal boundaries, like touching someone's virtual body in unwanted places, a transgression amplified by the ability to perceive these touches. Even gentle, affectionate somatosensory experiences can cause emotional and psychological distress, if non-consensual [14], highlighting the need for systems that respect and support the user in upholding personal boundaries. Consent heavily depends on various contextual and personal factors and can be revoked at any time during an interpersonal interaction. These properties make non-consensual touch interactions hard to anticipate and prevention mechanisms hard to automate.

In this context, several questions arise: *How can the risk of this type of abuse be minimized? When does a non-consensual touch interaction start? Is it automatically anticipatable and preventable? If not, how can users be supported in preventing upcoming or stopping ongoing abuse themselves? If abuse has occurred, how can a system support reporting and prevent repeated offenses?*

2.2 Intentional Physical Harm

The widespread issue of online bullying and harassment shows that perpetrators are often unfazed by the perspective of real-world consequences for victims, such as public scrutiny, self-harm, or life-threatening situations like swatting. This issue becomes even more sensitive in the context of body-worn haptic devices, since they bear the potential of causing direct physical harm. It can be generally assumed that commercially available devices are safe if used as intended, and that immersive spaces are designed in a non-harmful way. However, malicious actors could exploit security gaps in device controls and known vulnerabilities to remotely manipulate device properties. This could lead to hardware malfunctions that can cause physical harm, such as electric shocks or burns from overheating. In a multiuser MR space, this type of abuse could be perpetrated either by fellow users or externally by hackers. Even if the devices are incapable of causing serious injuries during misuse or malfunctioning, conflicting or excessive sensory stimulation can still lead to physiological responses such as disorientation, nausea, or dizziness [2, 3]. Users with sensory sensitivities can suffer physiological and psychological consequences, such as anxiety, aggression, panic attacks, or seizures [4, 7, 12]. Maliciously suppressing haptic feedback can also lead to physical harm. In MR systems designed for users with vision impairments, or systems relying on haptic warnings for out-of-view hazards, such as approaching vehicles, tampering with these signals can result in severe injuries.

Thus, the following questions must lead the design of multisensory multiuser MR spaces: *How can the maximum amount of security and the least amount of exploitable vulnerabilities be ensured? If an attack has passed through the security mechanisms, how can it be stopped before causing harm? How can users be empowered to interrupt these attacks themselves if all else fails? How can users* *be supported in processing these attacks if they have occurred?*

2.3 Subliminal Influence and Emotional Manipulation

Another facet of intentionally transmitted non-consensual sensory experiences are sensations that are subtle enough to not be consciously perceived, such as small and gradual changes in temperature, soft pressure, or gentle vibrations. This form of stimulation could be employed by individuals or corporations to induce positive or negative emotions in users [16]. At the corporate level, this might be employed to advertise products or companies, or to impact endorsement for political parties. Individuals might influence the mood in interpersonal conversations for their personal gain. However, in MR spaces, users might welcome subtle sensory stimulation during selected experiences, like games, music, or movies, or to actively counteract negative emotions. For example, triggering a sense of comfort during public speaking could help calm the nerves.

These aspects warrant a differentiated discussion about subliminal sensory stimulation, framed by the following questions: *Which laws and regulations are needed to prevent corporate and individual abuse of influence through subtle sensory experiences? Do the positive effects of subliminal stimulation outweigh the negative ones? Should users be empowered to enable consensual subliminal influence through sensory stimulation, and if yes, how?*

3 Risk Mitigation through User Empowerment

Misuse of haptic feedback in multiuser MR spaces must be addressed from multiple angles: Existing laws and regulations must be extended to include the nuances of virtually transmitted touch sensations; Underlying reliable user authentication and identification mechanisms must be paired with secure data transmission, encryption, and storage; Haptic feedback hardware must be of high quality and ensure a low risk of malfunctions and injury.

In terms of protection strategies, there are many more opportunities and obligations for legislators, manufacturers, network providers, and software architects. In the following, we will focus on what designers and developers of MR applications can do to directly empower users in the context of abuse protection by zooming into three aspects that we recognize as especially crucial.

3.1 Awareness and Transparency

The first step in fostering a safe haptic multiuser MR experience is to raise awareness about the risks associated with haptic feedback technologies. This information must be easily accessible and ideally integrated into the virtual environment, such as through in-app tooltips or in a mandatory tutorial walkthrough. This encourages a more cautious approach to using haptic feedback technologies in MR and supports users in making informed decisions about their interactions. Haptic feedback can also be used to heighten awareness through alerts about incoming security threats or unwanted interactions, e.g., someone approaching from out of sight triggers a sensory sensation that communicates their relative direction and proximity. Naturally, these sensations, in turn, must not feel invasive or uncomfortable. Applications must also be transparent about their own capabilities and protection mechanisms, including clear documentation and keeping users informed about security patches and changes through in-app notifications. Compared to smartphone apps, haptic-feedback enabled applications require even more fine-grained permissions and controls. They must clearly outline what types of feedback they can initiate and under what conditions. Users need to be provided with the ability to grant, customize, and revoke these permissions at any time, based on their comfort levels and changing circumstances.

3.2 Agency in Harm Prevention

While automated prevention mechanisms can be employed to reduce risks of unwanted sensory experiences, they cannot entirely address the nuances of individual boundaries, due to the subjective nature of consent and comfort. Thus, it is essential to empower users to make their own decisions. Modular, removable haptic feedback patches could enable users to decide beforehand where and if incoming touch should be felt. For example, in a MR job interview, a user might only put on a sensory glove for an expected handshake. Applications can further offer a calibration step to communicate an individual's threshold for the intensity and type of feedback they consent to receive. Applications should offer the opportunity to dynamically opt out of an incoming or ongoing sensory experience by allowing users to quickly disable either specific parts or the entirety of the haptic feedback system. For instance, users could choose not to feel interactions by turning off the sensor of a body part which is about to be touched in an undesirable way. Conversely, users might prefer to keep all sensory inputs disabled by default, and enable them selectively when they desire specific interactions. An alternative way to realize this opt-in and opt-out concept would be physical safety zones that users can step into and out of, which can not be penetrated by other user's touch transmissions. Users might choose to only extend body parts out of these zones for consensual touch experiences. Users should further be either able to exclude specific other users from transmitting touches to one's system, or by default only receive touches from a selected number of trusted users.

3.3 Reporting Mechanisms

It is necessary to consider the consequences of when implemented security and prevention measures fail or are successfully circumvented. Users must have access to immediate, easily accessible and user-friendly in-application reporting tools in the case of abuse. These forms must allow users to provide detailed descriptions of the incident, paired with relevant data automatically collected by the system, such as timestamps, activity logs, and interaction histories, lending validity to a user's claims and providing a clear picture of the incident. Simplifying the process might encourage more users to report incidents. All reports and related data must be transmitted and handled with strict confidentiality and protect user privacy. Being able to directly export relevant data to collect evidence can enable users to directly involve law enforcement. Beyond individual applications, a centralized infrastructure must be able to offer immediate support, investigate claims, and draw consequences. In the real world, information can be forwarded to law enforcement, and in the virtual world, users can be temporarily or permanently suspended or banned from entering virtual spaces with selective users. Misusing or abusing these tools must have clearly communicated consequences, and since reports would be combined with data and incident logs, untruthful reports should be mostly identifiable.

4 Conclusion

Though we believe that haptic feedback and affective touch bear great potential in distributed MR spaces, we want to emphasize the associated risks. While infrastructural and automated safety measures play an important role in mitigating these risks, we advocate for a mindset that centers on user empowerment when designing these applications. Users should be in control before, during, and after critical situations, supported by applications that facilitate informed decisions in alignment with one's individual boundaries.

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