Potential Risks of Ultra Realistic Haptic Devices in XR

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ABSTRACT

In the last years, there has been a strong push of the Human-Computer Interaction (HCI) community to create and develop highly realistic haptic devices to improve the Virtual Reality (VR) experience (e.g., by increasing presence). However, while these ultra realistic devices focus on positive experience, they also have the potential to simulate a plethora of negative physiological feelings (e.g., pain, anxiety). Our goal is to understand what psychological implications (e.g. discomfort, fear, pain) the experience of ultra realistic haptic devices could entail during a negative experience and how they impact more traditional Extended Reality (XR) metrics (e.g., presence, embodiment, enjoyment). To understand this potential safety concern of haptic devices, we implement a visual experience simulating the dislocation of a finger in VR. Additionally, we are building a haptic device that lifts a user's finger and triggers a solenoid to increase the realism of the virtual dislocation. We are planning to run an experiment comparing the impact of the haptic device in contrast to an isolated visual experience. We hypothesize that the haptic device would not only impact the traditional XR metrics (e.g., presence, embodiment and enjoyment) but also result in a larger degree of negative psychological effects. The goal of our research is to create a critical stand towards the ever improving realism in XR haptic devices and to reflect on potential limits that we as a community should not cross.

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1 INTRODUCTION

With the recent rise of Extended Reality (XR) in the field of Human-Computer Interaction (HCI), the creation and research of haptic devices rendering new forms of feedback became an important direction [5]. These haptic devices often strive either to create a set of new haptic perceptions [6, 10, 13] or aim to improve the realism and fidelity of existing haptic devices [8, 16]. The direction of realism can be distinguished into physical and psychological realism [14]. While physical realism aims to recreate the sensation of stimuli, psychological realism aims to result in realistic perception even without the use of similar stimuli [12].

While the development of these haptic devices often focuses on the increase of XR related positive metrics such as presence, immersion and embodiment, they also have the potential to create the perception of unpleasant experiences. This could occur either accidentally or even deliberately through a form of immersive attack on the user [3, 15]. This potential abuse of realism in XR was already mentioned by Slater et al., but mostly focused on the ethics or realism that are induced through visual realism [14]. In this paper, we want to focus on the potential ethical implications of perceptual realism in haptic devices in XR, and especially on psychological realism. Indeed, psychological realism would enable some already existing devices to be abused. A device, not originally made to generate a specific stimulus, could be used as a basis to induce the perception of a specific physiological harm. An example would be creating "virtual pain" that resembles the feeling upon the infliction of physiological harm, without physically hurting the user in any way.

Our research question is *"Are psychologically realistic haptic devices able to induce the perception of negative physiological feelings (e.g., discomfort, pain, fear) ?"*. To explore this research question, we focus on a well controlled and "simple" scenario: the dislocation of a user's finger. Our goal is to understand the ability of haptic devices to be misused. While prior work already started to explore the impact of potential painful events on the user's avatar in virtual environments on metrics such as embodiment and presence [4], our goal is to explore if a psychologically realistic haptic device might even impact physiological perception of discomfort or pain. The implications of such an ability would raise a question of whether there should be a limit to realism in haptic devices. Additionally, this would open the door for potential abuse where traumatic physiological experiences could be induced through haptic devices that might even lead to the creation of potential traumas.

At the current state we are implementing an application in VR which is able to render and induce the perception of the dislocation of a user's finger (Figure 2). The reason for choosing the finger, instead of another body part, is twofold. The finger is one of the most sensitive part of the human body, and it is also often targeted by haptic devices (e.g., haptic gloves). Our goal is to compare three modalities (visual stimuli, haptic stimuli, combined stimuli) and measure their impact on perceived negative feelings (discomfort, pain, fear) and the emotional state of the participant. This setup would enable us to compare the differences of each modality and in particular understand the impact that a combined visual-haptic experience can have on negative feelings. We deliberately selected this currently "simple" scenario to avoid substantial harm or the

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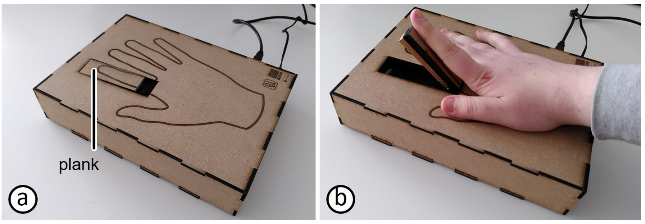

Figure 1: (a) FingerLifter is a haptic device that simulates the dislocation effect. A servomotor controlled by an Arduino is able to (b) lift the participant's index finger to 45°.

induction of pain to participants. We are currently in the process of getting approval from our local ethics committee to run the experiment.

2 IMPLEMENTATION

We are currently building a haptic device that allows us to understand the effects of simulating harm upon a user with a combination of VR visualization and realistic haptic feedback. The visualization must represent the bending and dislocating of a virtual finger, while the haptic device must be able to bend the actual user's finger, and simulate the dislocation in a painless but realistic way.

2.1 Hardware

We created a haptic device prototype. It takes the shape of a box made of laser-cut plywood. A small plank on the top surface of the box can move, and thus lift a user's finger (see Fig. 1). We use an Arduino UNO connected to a servomotor situated inside the box to control the angle of the plank (from 0°to a maximum of 75°).

We are currently working on adding a simulation of a dislocation to this haptic device. We plan on using a solenoid to trigger an impact on the base of the user's finger, at the moment we want to simulate a dislocation.

2.2 Software

The visualization part of the experiment was implemented using Unity 3D. and deployed on an Oculus Quest 2. This Head-Mounted Display (HMD) provides native hand and finger tracking. By overriding the finger tracking of the index finger, we are able to bend the virtual finger, while maintaining a realistic representation of the rest of the hand in space. To simulate the dislocation, we abruptly increase the bending angle beyond 90°, so that the virtual index finger takes an unnatural position (see Fig. 2).

In the experiment we will run, the visualization and the haptic device will be synchronized. They will both be controlled by Unity 3D, using the Uduino plugin to control the Arduino UNO. This will ensure synchronization for both the bending and the dislocation.

3 EXPERIMENT STRUCTURE AND DESIGN

In this section, we introduce our tentative plan for the experiment.

Figure 2: The visual representations of progressive finger bending: (a) no effect, (b) mild effect, and (c) dislocation.

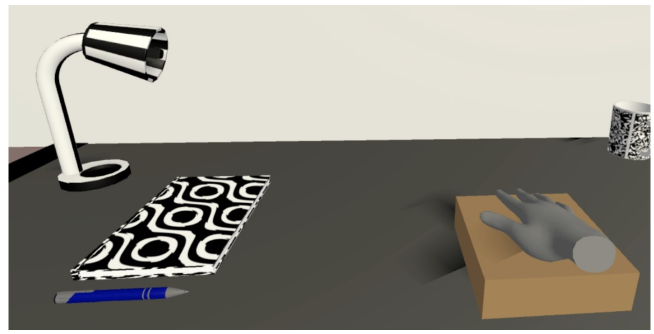

Figure 3: The first-person view in the virtual environment of the experiment.

3.1 Apparatus

The user will be sitting on a chair, in front of a desk, with the haptic device on top. They will put on the VR HMD. The virtual scene will contain a similar environment (see Fig. 3).

First, we will build ownership of the virtual hand. We will create agency by letting the user freely use the hand for 5 minutes, thanks to hand tracking. Then the user will be asked to put their right hand on the device, and an external person will trigger the start of the movement. At first, the visualization will bend the virtual finger, while the haptic device will gradually bend the user's real finger, Then, when a maximum angle is reached (chosen to stretch the user's finger without causing any pain), the visual dislocation will occur, abruptly pushing the bending angle to 120°. At the exact same time, the haptic device will generate a small impact at the base of the user's index finger.

3.2 Study design

The experiment has one between-subject variable (MODALITY) with three conditions, *visual-only*, *haptic-only*, and *combined*. The event of dislocating the virtual finger only happens once. Before the experiment, we inform participant that their index finger will be bent. The maximum angle of the haptic device is controlled within a safe range that they do not feel any pain.

- *haptic-only*: The participant will put their hand on the box, but will not wear a VR HMD. The haptic prototype will then bend to the maximum angle, and the solenoid will create an impact at the base of their finger.
- *visual-only*: The participant will wear a VR HMD. They will also put their hand on the box, but nothing will happen physically. They will just see the virtual bending and dislocation.

- *combined*: The participant will put their hand on the box and wear a VR HMD. Then, synchronously, the virtual and real finger will bend. At the maximum angle, the virtual finger will dislocate, and the solenoid will create an impact on the real finger.

During the experiment, we will measure biometric data of the participants that can be representative of the physiological feelings we might induce: heart rate and pupillometry, as they are both useful tools to assess pain and fear. [7, 11]. We will also watch the behavioral reactions of the participants, like pulling their hand back. After the experiment, the presence and embodiment of participants will be evaluated through questionnaires, as well as the level of discomfort and pain they felt, their level of fear and their global emotional state. Pain will be measured using the Borg pain scale [1]. Fear will be measured using a subjective scale [9], and the emotional state of the user will be measured using the Self-Assessment Manikin (SAM) questionnaire [2].

3.3 Expected Results

Through the *visual-only* modality, we expect the visual dominance to create discomfort in the participant. Through the additional use of the haptic device, we expect an improvement of the feeling of ownership over the virtual hand, and a increase of the discomfort generated. Thus, during the study, we will examine the following hypothesis:

- H1: Presence and embodiment are higher whenever haptics are used. Indeed, this is a result that has already been observed, and the reason why haptic devices tend to be used to enhance VR experiences.
- H2: There is more discomfort felt in the *visual-only* modality than during the free usage of the virtual hand.
- H3: The discomfort/pain level felt by the participant is stronger when using a combination of VR visualization and haptics, compared to haptics alone and VR visualization alone.

In the *combined* condition, if a participant answers that they felt pain, it will mean that it is possible to induce "virtual" pain (and thus potential trauma) to users of haptic devices, even though these devices are carefully calibrated not to inflict any physiological harm.

4 CONCLUSION

In this paper, we argue that ultra realistic haptic devices, used to enhance a VR experience, have the potential to be harmful to users. An example would be inducing negative physiological feelings like discomfort or pain, and thus potential trauma. We plan to test this hypothesis by combining two experiences that are designed to avoid inflicting any physiological harm. One purely visual, of a virtual finger bending then dislocating. The other through haptics, with the participant's finger safely bending, and feeling an impact at the end. If the combination of VR and the haptic device creates more discomfort, or even pain, to the participants, it will indicate that ultra realism through haptics can be dangerous, and we as a research community should think about the limits of realism when designing and implementing such haptic devices for XR.

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